Establishing modified Canadian Aerobic Fitness Test (mCAFT) cut-points to detect clustered cardiometabolic risk among Canadian children and youth aged 9 to 17 years

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Establishing modified Canadian Aerobic Fitness Test (mCAFT) cut-points to detect clustered cardiometabolic risk among Canadian children and youth aged 9 to 17 years

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ABSTRACT

The objective of this study was to establish cut-points to help identify potential clustered cardiometabolic risk among children (9–13 years) and youth (14–17 years) using the modified Canadian Aerobic Fitness Test (mCAFT). Nationally representative cross-sectional data were obtained from cycles 1 and 2 (2007–11) of the Canadian Health Measures Survey. Cardiorespiratory fitness (CRF) was measured using the mCAFT, which was used to estimate maximal oxygen uptake (V̇O2peak). Clustered cardiometabolic health was identified as the mean of four standardized variables: sum of four skinfolds; total cholesterol-to-HDL ratio; systolic and diastolic blood pressure. In total, 2106 (49% female) participants were retained for this analysis. The optimal mCAFT cut-point for males was 49 and 46 mL•kg\(^{-1}•min\(^{-1}\) among children and youth, respectively. Among females, the mCAFT cut-point was 46 and 37 mL•kg\(^{-1}•min\(^{-1}\) among children and youth, respectively. In 2016–17 83% of females and 71% of males met the new mCAFT cut-points. The mCAFT cut-points can help identify children and youth at risk of poor cardiometabolic health in public health surveillance, clinical and school-based settings.

- We developed new mCAFT cut-points to identify potential clustered cardiometabolic risk among Canadian children and youth.
- These mCAFT cut-points can be used to inform national surveillance efforts.

Keywords: aerobic evaluation, child, adolescent, health, fitness, surveillance
INTRODUCTION

Cardiorespiratory fitness (CRF) is a physical trait that represents an individual’s ability to deliver oxygen to the muscles to produce energy during physical activity and exercise (Institute of Medicine 2012; Lang et al. 2018). Although related, CRF is conceptualized as a mediating variable between physical activity and health, with higher intensity physical activity often leading to greater improvements in CRF (Lang et al. 2018). CRF levels among children and youth are meaningfully associated with health markers (Lang et al. 2019), and these associations are often maintained when controlling for physical activity (Eklund et al. 2007). This suggests that CRF provides information on health beyond what can be obtained by physical activity levels alone. Furthermore, low CRF levels in late adolescence may be predictive of future cardiovascular disease outcomes in adulthood (Högström et al. 2014; Ruiz et al. 2009).

CRF can be measured using lab- or field-based assessments. Directly measured oxygen consumption ($\dot{V}O_{2\text{peak}}$) during maximal lab-based assessments remain the gold standard for CRF measurement. These types of measures are expensive and time consuming to conduct thereby limiting their use in public health surveillance. In Canada, the modified Canadian Aerobic Fitness Test (mCAFT) is a field-based measure of CRF used for national surveillance, collected as part of the Canadian Health Measures Survey (CHMS). The mCAFT is also endorsed by the Canadian Society for Exercise Physiology (CSEP), and recommended as a measure of CRF in the CSEP-Physical Activity Training for Health (PATH) (Canadian Society for Exercise Physiology, 2013).

The use of normative-referenced standards to aid in the interpretation of mCAFT results is common practice in Canada. For example, the CSEP-PATH uses data from the Canadian
population as a reference to help identify how an individual’s performance compares with other Canadians (Canadian Society for Exercise Physiology, 2013). These standards are, however, limited as they were not linked to a health-related outcome. To overcome this limitation, criterion-referenced cut-points have been developed to determine age- and sex-specific levels that discriminate individuals with or without a health outcome (Lang et al. 2017). In 2016, Silva et al. published criterion-referenced cut-points for the mCAFT in a small sample of Brazilian youth aged 14–19 years. More recently, criterion-referenced cut-points for CRF using the 20 m shuttle run test were developed in a larger sample of Canadian children aged 8–12 years (Silva et al. 2018). Comprehensive Canadian criterion-referenced cut-points for the mCAFT do not currently exist.

Thus, the primary objective of this paper was to develop age- and sex-specific criterion-referenced cut-points for the mCAFT using a nationally representative sample of children and youth aged 9–17 years. The secondary objective was to determine the prevalence of children and youth that met the new Canadian criterion-referenced mCAFT cut-points using data from 2016-2017.

**METHODS**

*Participants*

The mCAFT was included as a measure in the CHMS during cycles 1 (2007–09), 2 (2009–11), and 5 (2016–17). Thus, to calculate the mCAFT cut-points we used a subsample of participants aged 9–17 years from cycles 1 (2007–09) and 2 (2009–11) of the CHMS. To determine the prevalence of Canadian children and youth (9–17 years) that met the mCAFT cut-points we used
data from cycle 5 (2016–17) of the CHMS. The CHMS is a repeated cross-sectional survey used to obtain nationally representative health measure estimates for Canadians aged 3–79 years (Tremblay and Connor Gorber 2007). The survey represents approximately 96% of Canadians living in private homes. Those living in the three territories, members of the Canadian Forces, Aboriginal settlements, institutionalized individuals, and those from certain remote areas are not represented in the CHMS (Statistics Canada 2013a, 2013b). Data collection procedures and inclusion/exclusion criteria for the survey are described in detail elsewhere (Statistics Canada 2013a, 2013b; Tremblay and Connor Gorber 2007). Briefly, an interviewer-administered questionnaire was conducted at the participant’s home, followed by a visit within six subsequent weeks, to the mobile examination centre for physical measurements. The overall response rate for cycles 1 and 2 was 54% (Statistics Canada, 2013c), and for cycle 5 a combined response rate of 49% was observed (Statistics Canada 2019). Survey and bootstrap weights were included to adjust for non-response bias and the complex survey design.

In total, 2835 (49% female) individuals aged 9–17 years participated in cycles 1 and 2 (2007–11) of the CHMS. Of those who participated, we retained 2106 (49% female) participants in our analytical sample after excluding those without a valid mCAFT score (n=480) or missing criterion measures (n = 249). We retained 1084 (50% female) participants from cycle 5 (2016–17) for our prevalence sample after excluding those without a valid mCAFT score (n = 288).

Ethics approval was obtained by Statistics Canada from Health Canada’s Research Ethics Board. Written informed consent was obtained from youth aged 14–17 years. Written informed assent
was obtained from children aged 9–13 years, and their parent/guardian also provided written informed consent (Day et al. 2007).

**Modified Canadian Aerobic Fitness Test (mCAFT) protocol**

The mCAFT is a progressive submaximal step test used to estimate $\dot{V}O_{2\text{peak}}$ (i.e., CRF). The test was first developed in 1976 by Jetté et al. and later modified by increasing the number of possible stages to better accommodate fitter and older participants who often obtained underestimated CRF values using the original protocol (Craig et al. 2012; Weller et al. 1993). Details on the mCAFT protocol have been published elsewhere (Craig et al. 2012; Weller et al. 1993). Briefly, participants were asked to complete one or more, three-minute stepping stages on two 20.3 cm steps. The last stage for females and the last two stages for males are performed on one 40.6 cm step to allow for an increased stepping intensity. The stepping cadence for each stage was standardized based on age and sex. Following each three-minute stage, heart rate was measured using a heart rate monitor (Polar Electro Canada Inc., Lachine, Québec, Canada). Participants were able to progress to the following stage if their post-exercise heart rate was below 85% of their age predicted maximal heart rate ($220 – \text{age in years}$). If a participant only partially completed a stepping stage their final score reflected the last completed stage. Participants who did not complete a full stage were categorized as incomplete. The mCAFT has been validated for individuals aged 15–69 years (Weller et al. 1993), although it was used regularly in individuals as young as six years in cycle 1, and eight years in cycle 2 of the CHMS. We used the CSEP-PATH equation to predict $\dot{V}O_{2\text{peak}}$ (Canadian Society for Exercise Physiology, 2013), which was originally published by Weller in 1989.
Estimated $\dot{V}O_{2\text{peak}}$ (mL/kg•min$^{-1}$) = [17.2 + (1.29 x $O_2$ cost*) – (0.09 x body weight in kg) – (0.18 x age in years)], where * represents the oxygen cost of stepping during the final stage.

**Criterion measures**

The criterion measures for this study included four directly measured health indicators. These measures were selected due to the strength of their association with mCAFT scores (Lang et al. 2019), and the availability of international reference values (Stavnsbo et al. 2018). The *sum of four skinfolds* was assessed using the Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA) protocol (Canadian Society for Exercise Physiology, 2003). Skinfolds were measured from subcutaneous fat measurements at four sites (biceps, triceps, subscapular, and suprailliac) to the nearest millimetre using Harpenden skinfold calipers (Baty International, UK). *Systolic and diastolic blood pressure* were measured following a rigorous protocol that included a five-minute rest period, followed by six blood pressure measurements at every one-minute interval using an automated oscillometer (BpTRU$^{TM}$ BPM-300, BpTRU$^{TM}$ Medical Devices Ltd., Coquitlam, British Columbia). The final systolic and diastolic measurements were calculated as the mean from the last five measurements (Bryan et al. 2010; Campbell et al. 2005). *Total cholesterol-to-HDL ratio* was calculated using serum measures from non-fasted blood samples taken by a certified phlebotomist (Bryan et al. 2007). All blood samples were obtained at the mobile examination centre and analyzed at the Health Canada laboratory following standardized procedures. Details on the bio-specimen sampling, storage, and analyses have been published elsewhere (Bryan et al. 2007).
Cardiometabolic risk score

Each criterion measure (i.e., sum of four skinfolds, systolic and diastolic blood pressure, and total cholesterol-to-HDL ratio) was standardized as a z-score using international age- and sex-specific mean and standard deviation reference values (Stavnsbo et al. 2018). The cardiometabolic risk score was calculated as the mean from the four standardized criterion measures. Participants were considered ‘at-risk’ if their cardiometabolic risk score was greater than one standard deviation above the age- and sex-specific mean value. Using one standard deviation above the mean to describe ‘at-risk’ in paediatric populations has been described in detail elsewhere (Andersen et al. 2006), and used in several similar studies (Adegboye et al. 2011; Lobelo et al. 2009; Ruiz et al. 2007).

Statistical analysis

Analyses were conducted using SAS Enterprise Guide 5.1 (SAS Institute Inc., Cary, NC, USA). Descriptive analyses incorporated survey weights to account for the complex survey design. Bootstrap weights were used to calculate 95% confidence intervals using the balanced repeated replication method, with the degrees of freedom set to 24 for the combined cycle 1 and 2 dataset and 11 degrees of freedom for cycle 5 of the CHMS. Data are reported as means or frequencies with 95% confidence intervals, when applicable.
We used receiver operating characteristic (ROC) curves to identify age- and sex-specific mCAFT cut-points to discriminate between high or low cardiometabolic risks. ROC curve methods for complex survey designs were applied by following the SAS404-2014 paper (Agnelli 2014). First, PROC SURVEYLOGISTIC with survey and bootstrap weights were used to calculate the predicted probability, which was then used to calculate ROC curves using the PROC LOGISTIC command with the ROC function. Next, the SAS ROCPLOT macro (http://support.sas.com/kb/25/018.html) was used to obtain the sensitivity and specificity values for each mCAFT cut-point along the ROC curve. We selected the mCAFT cut-points for each age by sex group that maximized both sensitivity and specificity, otherwise known as Youden’s J statistic (Fluss et al. 2005). Sensitivity is the proportion of individuals who are correctly classified as having high cardiometabolic risk. Specificity is the proportion of individuals who are correctly classified as having low cardiometabolic risk. We used the area under the curve (AUC) value to determine the mCAFT discriminating power for each cardiometabolic variable, and for the combined cardiometabolic risk score. AUC values range from 1 (perfect discriminating power) to 0.5 (no discriminating power). We did not report 95% confidence intervals for any of the ROC curve results because it is not possible to appropriately incorporate bootstrap weights within the ROC function in PROC LOGISTIC. We also calculated the prevalence of Canadian children and youth in 2016–17 meeting the mCAFT cut-points using PROC SURVEYFREQ with survey and bootstrap weights.

RESULTS
Descriptive statistics for the sample by age and sex are provided in Table 1. Among females, the predicted $\dot{V}O_{2\text{peak}}$ score was lower in youth (aged 14–17 years) when compared with children (aged 9–13 years). When comparing 2007–11 to 2016–17 values there were small reductions in predicted $\dot{V}O_{2\text{peak}}$ values across all sex and age groups. The sum of four skinfolds score was significantly higher in male children (9–13 years) in comparison with male youth (14–17 years). This resulted in a lower percentage of male youth being categorised as high risk based on the sum of four skinfolds variable. Among females, the average sum of four skinfolds was higher in youth (14–17 years) compared to children (9–13 years), although these differences were not apparent in the percentages categorised as at-risk. The percentages categorised as at-risk for systolic and diastolic blood pressure variables were very low across all age and sex groups.

Tables 2 and 3 display the ROC curve analysis results for males and females, respectively. The mCAFT cut-points for male children (aged 9–13 years) and youth (aged 14–17 years) were 49 and 46 mL•kg$^{-1}$•min$^{-1}$, respectively. The AUC for both standards were greater than 0.80 (Table 2). Among females, the mCAFT cut-points were 46 mL•kg$^{-1}$•min$^{-1}$ for children aged 9–13 years, and 37 mL•kg$^{-1}$•min$^{-1}$ for youth aged 14–17 years (Table 2). The AUC values were greater than 0.65 for females (Table 2), which was slightly lower than the values for males. Figure 1 illustrates the ROC curve plot of sensitivity and specificity for each mCAFT cut-point, representing each cut-point’s ability to discriminate those with and without cardiometabolic risk.

Figure 2 illustrates the percentage of males and females meeting the new mCAFT cut-points for cardiometabolic risk. In total, more females (all-age mean: 83%) met the mCAFT cut-points than
males (all-age mean: 71%). Between 10 and 12 years of age, the percentages of male (62–75%) and female (65–68%) children meeting the mCAFT cut-points were similar. At 14 years of age there was a large increase in the percentage meeting the mCAFT cut-points for females (+21%), compared with only small increases for males (+6%).

DISCUSSION

In this study we developed nationally representative age- and sex-specific mCAFT cut-points for Canadian children and youth to help screen those at potential clustered cardiometabolic risk. We identified mCAFT cut-points of 49 and 46 mL•kg\(^{-1}\)•min\(^{-1}\) for male children and youth, respectively. In females, we identified mCAFT cut-points of 46 and 37 mL•kg\(^{-1}\)•min\(^{-1}\) for children and youth, respectively. Using the 2016-17 CHMS data, a large proportion (> 60%) of Canadian children and youth fell above these cut-points and would be considered at low clustered cardiometabolic risk. However, declining temporal trends in CRF have been observed in Canadians (and internationally) (Tomkinson et al. 2019), suggesting that the percentage of children and youth meeting these cut-points could decline over time, especially given the majority of Canadian children and youth are physically inactive (Public Health Agency of Canada 2018).

Among males we identified AUC values greater than 0.80, representing a strong discriminatory ability for the mCAFT to detect male children and youth at potential risk of poor cardiometabolic health. These AUC values are high in comparison to similar studies, with the majority of studies reporting AUC values between 0.65 and 0.75 (Lang et al. 2017). Two previous studies reported
AUC values greater than 0.80 (Ruiz et al. 2015; Welk et al. 2011). These studies also reported lower AUC values for females compared to males, consistent with the findings of our study. Although the observed ROC curve statistics were good, our mCAFT cut-points were high in compared to those reported in other studies. A meta-analysis of CRF cut-points in children and youth (8-19 years) found values of 42 to 47 mL•kg⁻¹•min⁻¹ and 35 to 40 mL•kg⁻¹•min⁻¹ in males and females, respectively (Ruiz et al. 2016). The mCAFT cut-point in female children (46.4 mL•kg⁻¹•min⁻¹) is 15% greater than the upper range limit found in the meta-analysis (Ruiz et al. 2016), whereas the mCAFT cut-point values for males fall within the upper limit. Important to note, the meta-analysis did not include Canadian data and none of the included studies used the mCAFT to assess CRF (Ruiz et al. 2016). One other study in Brazilian youth (14–19 years) reported mCAFT cut-points of 40 mL•kg⁻¹•min⁻¹ (AUC: 0.70) in males and 32 mL•kg⁻¹•min⁻¹ (AUC: 0.63) in females to identify high blood pressure (Silva et al. 2016). While these cut-points are also well below the values that we present in our study, their AUC and resulting sensitivity and specificity values are lower than those reported in the present study.

More recently, there have been efforts to identify where a CRF cut-point falls within a normative-referenced distribution. Buchan et al. (2019) developed 20 m shuttle run test cut-points to identify youth living in the United Kingdom at increased cardiometabolic risk. The cut-points they identified were at the 60th percentile for males and the 55th percentile for females when using international normative-referenced centile values (Buchan et al. 2019; Tomkinson et al. 2017). Using a slightly different approach, a study in Norwegian youth using directly measured \(\dot{V}O_{2}\text{peak} \) testing identified CRF cut-points that fell within the 2nd, 5th, and 10th percentile for male and female children and youth to help identify those with 6, \(\geq 5\), and \(\geq 4\)
cardiometabolic risk factors, respectively (Aadland et al. 2019). In using the CSEP-PATH normative-referenced centile values our youth mCAFT cut-points fell within the fair ($\leq 40^{th}$ percentile) and poor ($\leq 20^{th}$ percentile) quintiles for males and females, respectively (Canadian Society for Exercise Physiology, 2013); reflected in our prevalence estimates in Figure 2. Despite the mCAFT cut-points reported in our study being higher than CRF cut-points reported in the literature, they fall within a similar normative-referenced range when compared with studies that have used this approach. The cut-point values reported in our study can adequately discriminate children and youth with poor clustered cardiometabolic risk using the mCAFT, but these values should not be generalized to other CRF tests without proper investigation.

**Strengths and limitations**

This study has many strengths including: the use of a large nationally representative sample of Canadian children and youth; CRF and cardiometabolic health variables that were directly measured (removing issues of recall/response bias associated with self-reported outcomes); the use of international reference standards to standardize the cardiometabolic health variables; prevalence calculated in a separate, nationally representative sample of Canadian children and youth; and, the incorporation of survey and bootstrap weights to account for non-response bias and the complex survey design.

Despite the strengths, this study is not without limitations. The cross-sectional design does not allow for causal inference. We were unable to calculate 95% confidence intervals for the AUC, sensitivity, and specificity results due to the inability to incorporate survey weights and bootstrap weights in the ROC curve analysis. The mCAFT was not validated in children and youth < 15
years adding uncertainty to our cut-points and may partially explain the high values observed when compared with the literature. However, validity is relative to the employed prediction equation and testing protocol, and as a result, should not be an issue when using the mCAFT cut-points in studies, screening, or surveillance efforts that use the same methods. We have also described clustered metabolic risk as being one standard deviation above the standardized mean, equivalent to 16% of the population (although it may be different due to using an international standardized approach). A previous Canadian study found clustered metabolic risk (≥ 2 risk factors) in 10.8% of those aged 10–18 years using the stringent criteria described by the International Diabetes Federation (MacPherson et al. 2016). Similarly, Andersen et al (2006) found that risk factors clustered (≥ 3 risk factors) in 11% of those aged 9–15 years included in the European Youth Heart Study. Therefore, using one standard deviation to classify those at-risk is likely a more liberal approach. Compounding this issue is the fact that there are no agreed upon cut-points for single metabolic syndrome risk factors in paediatric populations. Canadian children and youth today are also potentially at greater risk of chronic disease then previous generations due to an inadequacy of health-enhancing behaviours (e.g., 9.5% met the Canadian 24-Hour Movement Guidelines in 2014–15; Public Health Agency of Canada 2018). Lastly, with screening there is always the potential for misclassification which is certainly possible with the mCAFT cut-points developed in this study.

Conclusions and future directions

The mCAFT is a low cost and easy to administer measure of CRF which is ideal for use in clinical and school-based settings, as well as within national population health surveillance
systems. We have identified potential mCAFT cut-points to help discriminate children and youth with and without cardiometabolic risk. Future studies are needed to further validate these cut-points to determine their accuracy and generalizability. There is also a need to further validate the mCAFT in children and youth.

Disclaimer

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

Conflict of interest statement

The authors have no conflicts of interest to report.
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Table 1. Descriptive statistics by sex for Canadian children (aged 9–13 years) and youth (aged 14–17 years).

|                  | Males                      |                          | Females                      |                          |
|------------------|----------------------------|--------------------------|------------------------------|--------------------------|
|                  | Children (9–13 years)      | Youth (14–17 years)      | Children (9–13 years)        | Youth (14–17 years)      |
| **CHMS 2007-11** |                            |                          |                              |                          |
| n                | 661                        | 418                      | 681                          | 346                      |
| Age (years)      | 11.2 (11.0–11.3)           | 15.5 (15.4–15.7)         | 11.2 (11.0–11.3)             | 15.5 (15.3–15.6)         |
| Parental education (%) |                       |                          |                              |                          |
| Less than college | 16.5 (11.5–21.5)          | 16.1 (10.7–21.4)         | 20.2 (14.6–25.7)             | 21.7 (14.1–29.3)         |
| College          | 40.5 (32.3–48.8)           | 30.6 (23.2–38.1)         | 39.0 (32.8–45.2)             | 35.8 (26.7–45.0)         |
| University       | 38.3 (28.5–48.1)           | 50.9 (42.2–59.5)         | 38.7 (31.7–45.7)             | 39.3 (28.2–50.5)         |
| Household income (%) |                       |                          |                              |                          |
| Less than $40,000 | 18.1 (14.4–21.8)          | 13.9 (8.7–19.1)          | 16.8 (12.4–21.2)             | 17.3 (11.8–22.8)         |
| $40,000 to $79,999| 34.6 (26.4–42.8)          | 29.8 (20.7–39.0)         | 36.6 (30.2–42.9)             | 25.9 (20.8–31.0)         |
| $80,000 or more  | 47.3 (38.8–55.9)           | 56.3 (47.4–65.1)         | 46.6 (40.2–53.0)             | 56.8 (49.3–64.3)         |
| **Cardiorespiratory fitness** |               |                          |                              |                          |
| Predicted $VO_{\text{2peak}}$ (mL•kg•min\(^{-1}\)) | 51.3 (50.7–51.8) | 52.0 (51.4–52.7) | 49.6 (49.2–50.0) | 44.6 (44.0–45.1) |
| **Cardiometabolic variables** |                     |                          |                              |                          |
| Sum of four skinfolds (mm) | 42.7 (39.4–46.0) | 36.5 (34.5–38.6) | 46.5 (44.1–49.0) | 58.2 (54.8–61.5) |
| High risk (%)* | 30.2 (22.5–38.0)          | 17.6 (13.4–21.7)         | 23.3 (17.1–29.5)             | 27.7 (18.4–36.9)         |
| Total cholesterol:HDL ratio | 3.2 (3.1–3.3)        | 3.1 (3.0–3.3)            | 3.1 (3.0–3.2)                | 3.1 (3.0–3.2)            |
| High risk (%)* | 23.2 (17.4–28.9)          | 12.7 (8.4–17.1)          | 14.7 (11.5–17.9)             | 20.7 (14.4–27.0)         |
| Systolic blood pressure (mmHg) | 94.8 (93.8–95.7) | 90.2 (90.0–101.3) | 94.6 (93.9–95.4) | 96.9 (95.8–98.0) |
| High risk (%)* | 1.5 (0.3–2.7)             | 0.6 (0.0–1.6)            | 1.1 (0.3–1.9)                | 0.7 (0.0–1.6)            |
| Diastolic blood pressure (mmHg) | 60.7 (59.4–61.9) | 61.5 (60.4–62.7) | 60.9 (60.1–61.6) | 62.5 (61.4–63.6) |
| High risk (%)* | 7.9 (5.7–10.2)            | 6.1 (2.7–9.5)            | 8.7 (6.0–11.4)               | 7.6 (3.2–12.0)           |
| Cardiometabolic risk z-score | -0.09 (-0.20–0.02) | -0.38 (-0.48–0.28) | -0.17 (-0.24–0.11) | -0.20 (-0.30–0.10) |
| High risk (%)* | 10.1 (6.2–14.1)           | 2.9 (0.7–5.2)            | 3.8 (1.9–5.7)                | 3.9 (0.8–7.0)            |

|                  | CHMS 2016-17               |                          |                              |                          |
| n                | 338                        | 200                      | 339                          | 207                      |
| Age (years)      | 11.1 (10.8–11.3)           | 15.5 (15.3–15.7)         | 11.0 (10.7–11.2)             | 15.4 (15.1–15.6)         |
| Parental education (%) |                       |                          |                              |                          |
| Less than college | 10.4 (4.1–16.8)           | 14.5 (6.1–23.0)          | 9.4 (6.8–12.1)               | 9.6 (6.6–18.7)           |
| College          | 39.6 (32.2–47.1)           | 36.2 (22.7–49.6)         | 36.4 (20.8–52.0)             | 33.4 (17.0–49.8)         |
| University       | 49.9 (39.3–60.6)           | 49.3 (34.4–64.2)         | 54.2 (39.7–68.7)             | 57.0 (37.6–76.3)         |
| **Cardiorespiratory fitness** |               |                          |                              |                          |
| Predicted $VO_{\text{2peak}}$ (mL•kg•min\(^{-1}\)) | 50.3 (49.4–51.3) | 50.8 (49.6–52.0) | 49.0 (48.1–49.9) | 43.9 (42.5–45.4) |

*High risk was calculated as the percentage of individuals that were 1 standard deviation above the age- and sex-specific mean value.

Note: Data reported as means with 95% confidence intervals, unless otherwise stated. Source: 2007–09 and 2009–11 (cycles 1 and 2) of the Canadian Health Measures Survey, combined; cycle 5 (2016–17) of the Canadian Health Measures Survey. Abbreviations: % = percent; CHMS = Canadian Health Measures Survey; HDL = high-density lipoprotein; kg = kilogram min = minute; mL = millilitres; mm = millimeters; mmHg = millimeter of mercury; $VO_{\text{2peak}}$ = peak oxygen consumption;
Table 2. Receiver operation characteristic (ROC) curve results for cardiometabolic health variables among 1079 Canadian male children (aged 9–13 years) and youth (aged 14–17 years).

|                      | mCAFT cut-point (mL·kg⁻¹·min⁻¹) | AUC   | Sensitivity | Specificity |
|----------------------|---------------------------------|-------|-------------|-------------|
| **Children (n = 661)** |                                 |       |             |             |
| Sum of five skinfolds| 49.9                            | 0.82  | 0.79        | 0.75        |
| Total cholesterol:HDL ratio | 50.1                           | 0.62  | 0.58        | 0.63        |
| Systolic blood pressure   | 53.3                            | 0.72  | 1.00        | 0.44        |
| Diastolic blood pressure  | 50.8                            | 0.63  | 0.73        | 0.55        |
| Cardiometabolic z-score  | 48.7                            | 0.82  | 0.76        | 0.78        |
| **Youth (n = 418)**     |                                 |       |             |             |
| Sum of five skinfolds   | 51.0                            | 0.80  | 0.83        | 0.73        |
| Total cholesterol:HDL ratio | 51.2                           | 0.65  | 0.63        | 0.65        |
| Systolic blood pressure  | 53.0                            | 0.65  | 1.00        | 0.38        |
| Diastolic blood pressure | 52.5                            | 0.54  | 0.69        | 0.46        |
| Cardiometabolic z-score  | 46.1                            | 0.84  | 0.80        | 0.87        |

Note. Source: 2007–09 and 2009–11 (cycles 1 and 2) of the Canadian Health Measures Survey, combined. Abbreviations: CRF = cardiorespiratory fitness; AUC = area under the curve; HDL = high-density lipoprotein
Table 3. Receiver operation characteristic (ROC) curve results for cardiometabolic health variables among 1027 Canadian female children (aged 9–13 years) and youth (aged 14–17 years).

|                      | mCAFT cut-point (mL·kg⁻¹·min⁻¹) | AUC | Sensitivity | Specificity |
|----------------------|----------------------------------|-----|-------------|-------------|
| **Children (n = 681)** |                                  |     |             |             |
| Sum of four skinfolds| 49.0                             | 0.80| 0.78        | 0.70        |
| Total cholesterol:HDL ratio | 48.6                     | 0.68| 0.60        | 0.70        |
| Systolic blood pressure  | 54.5                             | 0.68| 0.58        | 0.81        |
| Diastolic blood pressure  | 54.5                             | 0.53| 0.32        | 0.82        |
| Cardiometabolic risk  | 46.4                             | 0.76| 0.64        | 0.82        |
| **Youth (n = 346)**   |                                  |     |             |             |
| Sum of five skinfolds | 42.5                             | 0.69| 0.56        | 0.73        |
| Total cholesterol:HDL ratio | 42.4                     | 0.57| 0.47        | 0.69        |
| Systolic blood pressure  | 41.8                             | 0.60| 1.00        | 0.28        |
| Diastolic blood pressure  | 43.1                             | 0.52| 0.60        | 0.58        |
| Cardiometabolic risk  | 36.5                             | 0.69| 0.33        | 0.99        |

Note: Source: 2007–09 and 2009–11 (cycles 1 and 2) of the Canadian Health Measures Survey, combined. Abbreviations: CRF = cardiorespiratory fitness; AUC = area under the curve; HDL = high-density lipoprotein
FIGURE CAPTIONS

**Figure 1.** Receiver operating characteristic (ROC) curves summarizing the ability for CRF to discriminate high/low cardiometabolic risk among male (n = 1079) and female (n = 1027) children (9–13 years) and youth (14–17 years). Data source: Canadian Health Measures Survey, 2007–11. AUC = area under the curve.

**Figure 2.** Line graph describing the prevalence of males (n = 538) and females (n = 546), by age, meeting the mCAFT criterion-referenced cut-points. The dash-line represents the total mean value across all age groups for males and females, separately. Data source: Canadian Health Measures Survey, 2016–17.
FIGURE 1

Children (9-13 years)  Youth (14-17 years)

Boy

Girl

Sensitivity

1 - Specificity

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