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Percentile curves for peripheral and truncal skinfold thickness for Canadian children and youth

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Background: Skinfold thickness (SFT) measurements are a reliable and feasible method for assessing body fat in children but their use and interpretation is hindered by the scarcity of reference values in representative populations of children. The objectives of the present study were to develop age- and sex-specific percentile curves for five SFT measures (biceps, triceps, subscapular, suprailiac, medial calf) and to describe body fat composition in a representative population of Canadian children and youth. **Methods:** We analyzed data from 3938 children and adolescents between 6 and 19 years of age who participated in the Canadian Health Measures Survey cycles 1 (2007/2009) and 2 (2009/2011). Standardized procedures were used to measure SFT. Age- and sex-specific centiles for skinfolds and body fat were calculated using the GAMLSS method. **Results:** Percentile curves were materially different in absolute value and shape for boys and girls. Percentile girls in girls steadily increased with age whereas percentile curves in boys were characterized by a pubertal centered peak. Median body fat percentage at age 18 was 13.2 and 25.4% among boys and girls, respectively. **Conclusions:** The current study has presented for the first time percentile curves for five SFT measures and body fat in a representative sample of Canadian children and youth.

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Percentile curves for peripheral and truncal skinfold thickness for Canadian children and youth

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ABSTRACT

Background: Skinfold thickness (SFT) measurements are a reliable and feasible method for assessing body fat in children but their use and interpretation is hindered by the scarcity of reference values in representative populations of children. The objectives of the present study were to develop age- and sex-specific percentile curves for five SFT measures (biceps, triceps, subscapular, suprailiac, medial calf) and to describe body fat composition in a representative population of Canadian children and youth. **Methods:** We analyzed data from 3938 children and adolescents between 6 and 19 years of age who participated in the Canadian Health Measures Survey cycles 1 (2007/2009) and 2 (2009/2011). Standardized procedures were used to measure SFT. Age- and sex-specific centiles for skinfolds and body fat were calculated using the GAMLSS method. **Results:** Percentile curves were materially different in absolute value and shape for boys and girls. Percentile girls in girls steadily increased with age whereas percentile curves in boys were characterized by a pubertal centered peak. Median body fat percentage at age 18 was 13.2 and 25.4% among boys and girls, respectively. **Conclusions:** The current study has presented for the first time percentile curves for five SFT measures and body fat in a representative sample of Canadian children and youth.

Keywords: children; percentile curves; skinfolds; obesity

INTRODUCTION

The rising prevalence of overweight and obese children and associated public health toll in Canada and other developed countries is well established (1–3). Effective obesity prevention and treatment efforts require reliable identification of the at risk population. Specifically, accurate characterization of childhood body composition is essential for identifying children who currently exceed recommended weight norms or may be at risk of future excess weight and related cardiovascular and metabolic health conditions. Though body mass index is the most commonly used method for assessing childhood body composition, it does not provide an accurate estimate of adiposity (4, 5). Childhood adiposity is potentially more strongly associated with future body composition and metabolic status than childhood BMI (6, 7). Childhood adiposity is also positively associated with certain cardiovascular and metabolic disease risk factors (8, 9). Skinfold thickness (SFT) measures are a feasible and reliable estimate of body fat (10–12), and have been shown to be predictive of elevated levels of cardiovascular disease risk factors (13, 14) and metabolic syndrome (15). The widely used equation developed by Slaughter et al. allows for calculation of the body fat percentage using subscapular and triceps SFT measurements as the sole anthropometric measures (16). Williams et al. reported that body fat percentages exceeding 25% in males and 30% in females significantly predicted presence of cardiovascular disease risk factors in an US population aged 5-18 years (17). A more recent analysis of a US National Health and Nutrition Examination Survey (NHANES) data reported that body fat percentage exceeding 35.1% in boys and 38.6% in girls predicted metabolic syndrome risk at age 18 (18). Interpretation and uptake of SFT measurement as a method for the assessment of body fat is hindered by the lack of reference data. While there are health-related cutoffs for BMI (19, 20), waist circumference (21), and waist-to-height ratio (22), there is no comparable definition based on SFT for either children or adults. Percentile curves have been developed for US (15, 23) and European (24–31) children. The applicability of these values to the Canadian population is limited due to differences in childhood overweight and obesity prevalence. Moreover, previous SFT references have either been developed with a limited number of skinfolds (15, 23, 27, 28) or were based on a narrower age range (24, 26, 32). Therefore, the objective of the present study was to develop age- and sex-specific percentile curves for five SFT measures (biceps, triceps, subscapular, suprailiac, medial calf) and to describe body fat composition in a representative population of Canadian children and youth.

METHODS

The present study used data from the Canadian Health Measures Survey (CHMS) cycles 1 and 2. The CMHS is a representative, cross-sectional survey that assesses indicators of health and wellness in Canadians between 3 and 79 years (33, 34). The survey consists of a household interview to obtain sociodemographic and health information, and a visit to a mobile examination centre to perform a number of physical measurements and tests. The sampling frame of the Canadian Labour Force Survey was used to identify the collection sites for the mobile examination centres. Within each collection site, households were selected using the 2006 Census as the sampling frame. Interviews and examinations for the CHMS Cycle 1 and 2 were performed between 2007 and 2009, and 2009 and 2011, respectively. The overall response rate in the two cycles was 51.7% and 55.7%, respectively. Data from the two cycles was combined as per Statistics Canada guidelines (35) and weighted to account for the design effect and non-response bias (35). A total of 11,999 persons participated in the physical examination part of the survey. The present analysis uses data from 3938 children and adolescents (1996 males and 1942 females) between the ages of 6 and 19 years.

Skinfold thickness measurements

All SFT measurements were performed by trained health professionals at the mobile examination centres using a Harpenden skinfold caliper to the nearest 0.2 mm. Each SFT was measured three times and the average of the three measurements was used. Triceps SFT was measured on the midline of the back of the arm at the mid-point level between the acromium process and the tip of the olecranon process. Biceps SFT was measured over the biceps at the same level as the midpoint for the triceps. Subscapular SFT was measured below the inferior angle of the scapula at an angle of 45 degrees to the spine. Suprailiac SFT was measured in the mid-axillary line above the crest of the ilium. Medial calf SFT was measured at the medial side of the calf at the point of the largest circumference. SFT measurements were not done on individuals with a BMI ≥ 30 kg/m^2.

Body fat percentage

The percentage of body fat was predicted from the triceps and subscapular SFT for each individual in the sample using the equation by Slaughter et al. (16). The equation for boys contains an intercept term for biological maturation; since this information was not available in the CHMS, we used age as a proxy (boys < 12 years: prepubescent; boys 12.0 - < 14 years: pubescent; boys ≥ 14 years: postpubescent) as previously suggested (15).

Statistical analysis

The data were split by sex and modeled using a four parameter (μ, σ, ν, τ) Box–Cox power exponential distribution (36). The GAMLSS method is an extension of the LMS method developed by Cole and Green (37) and assumes that when the data (Y) is transformed using the transformation:

$$z = \frac{(y/\mu)^{\nu} - 1}{\nu\sigma} \qquad \nu \neq 0$$

$$z = \frac{\log_e (y/\mu)}{\sigma} \qquad \nu = 0$$

Z follows a standard power exponential distribution with power parameter τ.

The age-specific distribution expresses the mean, coefficient of variation, skewness, and kurtosis as parameters that change smoothly as a function of age by modeling them as cubic splines. These functions can be plotted as smooth curves in terms of age and are referred to as the μ (mean), σ (variance), ν (skewness), and τ (kurtosis) curves. Centiles for a particular age are computed by using the values of the four parameters for the corresponding age. The 3rd, 10th, 25th, 50th, 75th, 90th, and 97th centile curves were computed for biceps, triceps, subscapular, suprailiac, and medial calf SFT as well as for body fat percentage.

To avoid unusual behaviours of the spline functions near the end of the age range, data from respondents up to age 30 years were used to fit the models. This modification produced smoother curves that more accurately reflect the population characteristics. Residual quantile plots ("worm plots") (38) were used to assess the goodness of fit of each component of the models.

All calculations were performed using the sampling weights provided by Statistics Canada (35) to account for design effect and non-response bias. The CHMS uses a multistage sampling design with two sampling frames to select its sample. The probability of an individual to be selected for the survey is determined as the product of the probability of selection at each stage.

To correct for non-response, the weight of non-respondent households and individuals is redistributed to respondents within homogeneous response groups based on characteristics that are available for both respondents and non-respondents as determined from the Census of Canada (such as dwelling type or household income). A detailed description of the weighting procedure can be found elsewhere (34).

The statistical software package R (39) with the *gamlss* package (40) was used to perform the statistical analyses.

Ethics

All processes used for cycles 1 and 2 of the CHMS were reviewed and approved by the Health Canada Research Ethics Board to ensure that internationally recognized ethical standards for human research were met and maintained. Written informed consent was obtained from all participants aged 14 years and older; parents or guardians gave consent on behalf of children aged 6 to 13 years, while the child provided his or her assent to participate (33, 34). The current project was approved by the IWK Health Centre Research Ethics Board, Halifax, NS, Canada (File # 1014413).

RESULTS

Characteristics of the sample are shown in Table 1. The median and interquartile range for the five SFT measurements by age and sex are shown in Table 2. The parameter values (μ, σ, ν, τ) as well as the 3rd, 10th, 25th, 50th, 75th, 90th, and 97th percentiles for the SFT curves are presented by age and sex (Tables 3-7). Model diagnostics showed an adaequate fit for all models.

Percentile curves are materially different in both absolute values and shape for boys and girls (Figures 1-5). Girls have higher median skinfold thickness than boys at all measurement sites (Table 2). All skinfold thickness measurements among girls are characterized by a relatively steady increase from childhood through adolescence despite differing absolute percentile values and rates of yearly change. Lower body (medial calf, suprailiac) skinfold thickness measurements steadily rise until adolescence at which point the rate of yearly increase diminishes. Among upper body measurements, the biceps percentile curve plateaus in early adolescence, whereas the triceps and subscapular curves steadily increase from age 6 to 19. No substantial differences in truncal (subscapular, suprailiac) and peripheral (triceps, biceps, calf) percentile curves among girls were observed.

Skinfold thickness curves in boys are characterized by a peak around age 12 years. The magnitude of this pubertal centered peak was most notable in the percentiles exceeding the median. Subsequent to the post-pubertal peak, skinfold thickness decreased in the peripheral measures (biceps, calf, triceps) and moderately increased in the truncal measures. There were no apparent distinguishing characteristics between the upper and lower body percentile curves in boys.

Body fat percentile curves, derived from the equation by Slaughter et al. (16), depict similar patterns as the individual skinfold percentile curves among boys and girls (Figure 6). An early adolescent peak and decline in boys was followed by a moderate increase from age 16 years onwards. This trend was most pronounced in percentiles above the median. Among girls, all percentile curves increased steadily throughout childhood and adolescence. Median body percentage at age 18 among boys and girls was 13.2 and 25.4% respectively.

DISCUSSION

The current study has presented for the first time percentile curves for five SFT measures and body fat percentage based on a representative sample of Canadian children and youth aged 6 to 19 years. The percentile curves presented are meant to be descriptive rather than prescriptive as associations with cardiovascular disease markers or outcomes were not assessed. The data may be used by researchers as reference data for future studies.

Our findings are comparable with other studies that have examined the development of SFT in childhood and adolescence. Both the steady upward trend in girls and the pubertal peak in boys were also observed in US (23), German (26, 28, 41), Polish (29), and Norwegian children (27). Of note, the pubertal peak was less pronounced in samples with a narrower age ranges (24, 26–28). The absolute SFT values in our study were largely comparable to US data of 32,783 children ages 1 to 19 years collected between 1963-1994 (23): Median triceps and subscapular SFT at age 12 years were comparable between girls in the CHMS (triceps: 13.5 mm; subscapular: 8.8 mm) and the US study (triceps: 13.1 mm; subscapular: 8.2 mm). Median triceps SFT at age 12 in CHMS boys was slightly lower than reported in US boys (11.3 mm vs. 13.1 mm) whereas median subscapular SFT was slightly higher in the CHMS than in the US sample (7.1 mm vs. 6.0 mm). These differences may be due to heterogeneity in timing of data collection, ethnic distribution, and statistical methodology (LMS vs. GAMLSS) between the two studies. Comparison with SFT in adults is a challenge due to the scarcity of adult SFT data. Data from adults in the NHANES recruited between 1971 and 1974 shows that median subscapular SFT values in the youngest adult age category (ages 18-24 years) were moderately higher than median values at age 18 years among CHMS participants (males 11.0 vs. 9.0 mm, females 13.0

vs. 12.4 mm) (42). Considering that the NHANES data was collected prior to the obesity epidemic, the higher SFT in the US sample is unexpected. It is possible that these differences reflect the higher rate of obesity in the US compared to Canada (3) or the use of a broader age category and the influence of increasing SFT in early adulthood.

Unlike other anthropometric measures such as BMI, which have been used as independent indicators of growth, SFT measurements are commonly used to derive an estimate of body fat percentage (15, 16, 26, 43). The body fat percentile curves derived from SFT among CHMS participants are similar in shape to a US NHANES study that used a similar approach in a sample of 8269 children of comparable age range (15). Median body fat percentages at age 18 years in the CHMS sample were lower than those reported in this US study (boys 13.2 vs. 17.0%, girls 25.4% vs. 27.8%). As previously noted, this difference likely reflects differences in obesity rates between the two countries (3). Comparison with other studies that have derived body fat percentile curves is not straightforward due to differing ages ranges (30) or sample inclusion criteria (31).

Body fat percentages in excess of 25% and 30% in males and females respectively have been identified as indices of potential adverse outcomes (17). Based on this, boys and girls at age 18 that exceed the 90^{th} and 75^{th} percentiles, respectively, for body fat in CHMS may be at increased risk of adverse cardio-metabolic outcomes. However, interpretation of the body fat percentile results warrants recognition of the potential biases inherent in these calculations. While the Slaughter equation has been shown to provide a reasonable estimate of body fat percentage (as a relative index not as an individual measure) in adolescents (43), it was developed based on a historical population and its validity for use in contemporary populations is questionable. Though well correlated with dual energy X-ray absorptiometry, body fat percentage derived from the Slaughter equation may overestimate adiposity in children with larger SFT (44). In recognition of these potential biases, studies that examine the relation between SFT and objectively measured body fat in a current sample of children of all ages are necessary.

To our knowledge, only one study employed the GAMLSS method (36) like we did to model SFT percentiles. The authors of this multicentre European study derived SFT percentile curves for 18,745 children ages 2 to 10 years but excluded overweight, obese, and underweight children from the analysis (31). Thus, a direct comparison of their findings with ours is not feasible. The LMS method (37) has become the most popular choice for modeling percentiles curves for anthropometric measures due to its ease of use, adoption by the World Health Organization (45), and the availability of a simple software tool (LMSchartmaker, Harlow Healthcare, UK) to generate the curves. In a recent analysis of the same sample of children, we generated percentile curves for BMI, waist circumference, waist-to-height ratio, and sum of five skinfolds with an adaequate model fit using the LMS method (46). However, when using the 3-parameter LMS method for the individual SFT measurements in the present study, the diagnostic worm plots revealed a large amount of kurtosis present for some variables. The LMS method attempted to account for the kurtosis with skewness, which lead to a poorer model fit at the tail end of the distribution. By contrast, the GAMLSS method includes a 4^{th} parameter to allow the explicit modeling of kurtosis as a function of age. Diagnostics showed no model inadequacies when the curves were constructed using the GAMLSS method. Future studies should consider using the GAMLSS method if the model fit using an LMS approach is not adaequate.

The strengths of the current study include the nationally representative sample of children and youth, and the use of sample weighting to account for non-response and design effect. The availability of a wide age range in the CHMS study population allowed us to visualize growth related trends that were not apparent in studies with narrower age ranges (24, 26, 27). We did not exclude overweight or obese children as the objective of the present study was to describe body fatness measures in a representative population of Canadian children rather than to attempt to describe what may constitute normal percentile values. Due to the physical burden of the assessments used in the survey, and the need to travel to the mobile examination clinics, there may have been a self-selection toward more mobile, healthier and fitter individuals. Our study is limited by the relatively small sample size, and the cross-sectional nature of the data; longitudinal data may more accurately reflect how body fatness changes with age. The omission of SFT measurements in children with a BMI greater than 30 resulted in an exclusion of 4% of children, which may have resulted in a slight downward shift of the percentiles compared to the full sample. While the flexibility of the GAMLSS method is a notable strength, its flexibility also means that the curves may differ considerably based on the parameter choices made by the researcher.

This study has presented percentile curves for SFT and body fatness in a representative sample of Canadian children and youth. Since we did not examine any relationships with health outcomes or disease markers, the data should be considered as a reference for future studies and not as a growth standard.

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REFERENCES

1. Shields M. Overweight and obesity among children and youth. *Health Rep* 2006; 17: 27-42.
2. Tran BX, Nair AV, Kuhle S, Ohinmaa A, Veugelers PJ. Cost analyses of obesity in Canada: scope, quality, and implications. *Cost Eff Resour Alloc* 2013; 11: 3.
3. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014; 384: 766-781.
4. Frankenfield DC, Rowe WA, Cooney RN, Smith JS, Becker D. Limits of body mass index to detect obesity and predict body composition. *Nutrition* 2001; 17: 26-30.
5. Brambilla P, Bedogni G, Moreno LA, Goran MI, Gutin B, Fox KR et al. Crossvalidation of anthropometry against magnetic resonance imaging for the assessment of visceral and subcutaneous adipose tissue in children. *Int J Obes (Lond)* 2006; 30: 23-30.
6. Freedman DS, Serdula MK, Srinivasan SR, Berenson GS. Relation of circumferences and skinfold thicknesses to lipid and insulin concentrations in children and adolescents: the Bogalusa Heart Study. *Am J Clin Nutr* 1999; 69: 308-317.
7. Nooyens AC, Koppes LL, Visscher TL, Twisk JW, Kemper HC, Schuit AJ et al. Adolescent skinfold thickness is a better predictor of high body fatness in adults than is body mass index: the Amsterdam Growth and Health Longitudinal Study. *Am J Clin Nutr* 2007; 85: 1533-1539.
8. Going SB, Lohman TG, Cussler EC, Williams DP, Morrison JA, Horn PS. Percent body fat and chronic disease risk factors in U.S. children and youth. *Am J Prev Med* 2011; 41: S77-

86.

9. Dai S, Fulton JE, Harrist RB, Grunbaum JA, Steffen LM, Labarthe DR. Blood lipids in children: age-related patterns and association with body-fat indices: Project HeartBeat. *Am J Prev Med* 2009; 37: S56-64.

10. Boeke CE, Oken E, Kleinman KP, Rifas-Shiman SL, Taveras EM, Gillman MW. Correlations among adiposity measures in school-aged children. *BMC Pediatr* 2013; 13: 99.

11. Sardinha LB, Going SB, Teixeira PJ, Lohman TG. Receiver operating characteristic analysis of body mass index, triceps skinfold thickness, and arm girth for obesity screening in children and adolescents. *Am J Clin Nutr* 1999; 70: 1090-1095.

12. Bedogni G, Iughetti L, Ferrari M, Malavolti M, Poli M, Bernasconi S et al. Sensitivity and specificity of body mass index and skinfold thicknesses in detecting excess adiposity in children aged 8-12 years. *Ann Hum Biol* 2003; 30: 132-139.

13. Steinberger J, Jacobs DR, Raatz S, Moran A, Hong CP, Sinaiko AR. Comparison of body fatness measurements by BMI and skinfolds vs dual energy X-ray absorptiometry and their relation to cardiovascular risk factors in adolescents. *Int J Obes (Lond)* 2005; 29: 1346-1352.

14. Petkeviciene J, Klumbiene J, Kriaucioniene V, Raskiliene A, Sakyte E, Ceponiene I. Anthropometric measurements in childhood and prediction of cardiovascular risk factors in adulthood: Kaunas cardiovascular risk cohort study. *BMC Public Health* 2015; 15: 218.

15. Laurson KR, Eisenmann JC, Welk GJ. Body fat percentile curves for U.S. children and adolescents. *Am J Prev Med* 2011; 41: S87-92.

16. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Van Loan MD et al.

Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* 1988; 60: 709-723.

17. Williams DP, Going SB, Lohman TG, Harsha DW, Srinivasan SR, Webber LS et al. Body fatness and risk for elevated blood pressure, total cholesterol, and serum lipoprotein ratios in children and adolescents. *Am J Public Health* 1992; 82: 358-363.
18. Laurson KR, Eisenmann JC, Welk GJ. Development of youth percent body fat standards using receiver operating characteristic curves. *Am J Prev Med* 2011; 41: S93-9.
19. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; 320: 1240-1243.
20. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007; 85: 660-667.
21. World Health Organization. Waist circumference and waist–hip ratio: report of a WHO expert consultation. Geneva: WHO; 2008
22. McCarthy HD, Ashwell M. A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message--'keep your waist circumference to less than half your height'. *Int J Obes (Lond)* 2006; 30: 988-992.
23. Addo OY, Himes JH. Reference curves for triceps and subscapular skinfold thicknesses in US children and adolescents. *Am J Clin Nutr* 2010; 91: 635-642.
24. Moreno LA, Mesana MI, González-Gross M, Gil CM, Ortega FB, Fleta J et al. Body fat distribution reference standards in Spanish adolescents: the AVENA Study. *Int J Obes (Lond)* 2007; 31: 1798-1805.
25. Heude B, Kettaneh A, de Lauzon Guillain B, Lommez A, Borys JM, Ducimetière P et al.

Growth curves of anthropometric indices in a general population of French children and comparison with reference data. *Eur J Clin Nutr* 2006; 60: 1430-1436.

26. Haas GM, Liepold E, Schwandt P. Percentile curves for fat patterning in German adolescents. *World J Pediatr* 2011; 7: 16-23.

27. Brannsether B, Roelants M, Bjerknes R, Júlíusson PB. References and cutoffs for triceps and subscapular skinfolds in Norwegian children 4-16 years of age. *Eur J Clin Nutr* 2013; 67: 928-933.

28. Kromeyer-Hauschild K, Glässer N, Zellner K. Percentile curves for skinfold thickness in 7- to 14-year-old children and adolescents from Jena, Germany. *Eur J Clin Nutr* 2012; 66: 613-621.

29. Jaworski M, Kułaga Z, Płudowski P, Grajda A, Gurzkowska B, Napieralska E et al. Population-based centile curves for triceps, subscapular, and abdominal skinfold thicknesses in Polish children and adolescents--the OLAF study. *Eur J Pediatr* 2012; 171: 1215-1221.

30. Wohlfahrt-Veje C, Tinggaard J, Winther K, Mouritsen A, Hagen CP, Mieritz MG et al. Body fat throughout childhood in 2647 healthy Danish children: agreement of BMI, waist circumference, skinfolds with dual X-ray absorptiometry. *Eur J Clin Nutr* 2014; 68: 664-670.

31. Nagy P, Kovacs E, Moreno LA, Veidebaum T, Tornaritis M, Kourides Y et al. Percentile reference values for anthropometric body composition indices in European children from the IDEFICS study. *Int J Obes (Lond)* 2014; 38 Suppl 2: S15-25.

32. Klimek-Piotrowska W, Koziej M, Hołda MK, Piątek K, Wszołek K, Tyszka A et al. Anthropometry and body composition of adolescents in cracow, poland. *PLoS One* 2015;

10: e0122274.

33. Statistics Canada. Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 1. Ottawa: Statistics Canada; 2011.

34. Statistics Canada. Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 2. Ottawa: Statistics Canada; 2012.

35. Statistics Canada. Canadian Health Measures Survey (CHMS): Instructions for combining cycle 1 and cycle 2 data. Ottawa: Statistics Canada; 2013.

36. Rigby RA, Stasinopoulos DM. Smooth centile curves for skew and kurtotic data modelled using the Box-Cox power exponential distribution. *Stat Med* 2004; 23: 3053-3076.

37. Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalized likelihood. *Stat Med* 1992; 11: 1305-1319.

38. van Buuren S, Fredriks M. Worm plot: a simple diagnostic device for modelling growth reference curves. *Stat Med* 2001; 20: 1259-1277.

39. R Core Team. R: A Language and Environment for Statistical Computing [Internet]. Vienna, Austria: 2015 [cited Available from: http://www.R-project.org

40. Rigby RA, Stasinopoulos DM. Using the Box-Cox t distribution in GAMLSS to model skewness and kurtosis. *Stat Modelling* 2006; 6: 209-229.

41. Neuhauser HK, Schienkiewitz A, Schaffrath-Rosario A, Dortschy R, Kurth BM. Referenzperzentile für anthropometrische Maßzahlen und Blutdruck aus der Studie zur Gesundheit von Kindern und Jugendlichen in Deutschland (KiGGS) 2003–2006. Berlin: Robert-Koch Institut; 2011

42. Bowen PE, Custer PB. Reference values and age-related trends for arm muscle area, arm fat area, and sum of skinfolds for United States adults. *J Am Coll Nutr* 1984; 3: 357-376.

43. Rodríguez G, Moreno LA, Blay MG, Blay VA, Fleta J, Sarría A et al. Body fat measurement in adolescents: comparison of skinfold thickness equations with dual-energy X-ray absorptiometry. *Eur J Clin Nutr* 2005; 59: 1158-1166.

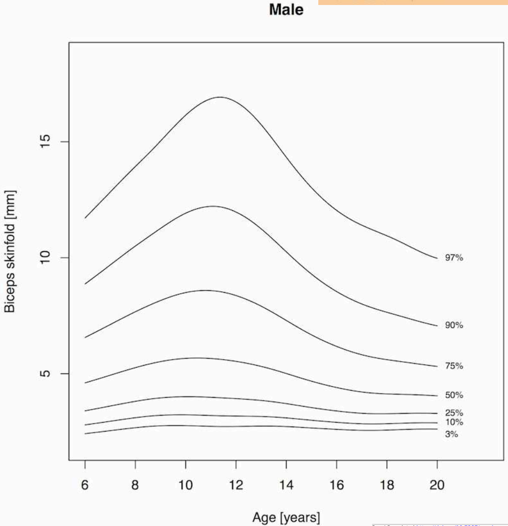
44. Freedman DS, Horlick M, Berenson GS. A comparison of the Slaughter skinfold-thickness equations and BMI in predicting body fatness and cardiovascular disease risk factor levels in children. *Am J Clin Nutr* 2013; 98: 1417-1424.

45. de Onis M, Onyango A, Borghi E, Siyam A, Nishida C, Pinol A. WHO child growth standards: growth velocity based on weight, length and head circumference: methods and development. Geneva: WHO; 2009

46. Kuhle S, Maguire B, Ata N, Hamilton D. Percentile Curves for Anthropometric Measures for Canadian Children and Youth. *PLoS One* 2015; 10: e0132891.

Figure 1(on next page)

Percentile curves for biceps skinfold thickness for male and female Canadian children and youth aged 6 to 19 years.


Male
Biceps skinfold [mm]
5
10
15
97%
90%
75%
50%
25%
10%
3%
6
8
10
12
14
16
18
20
Age [years]

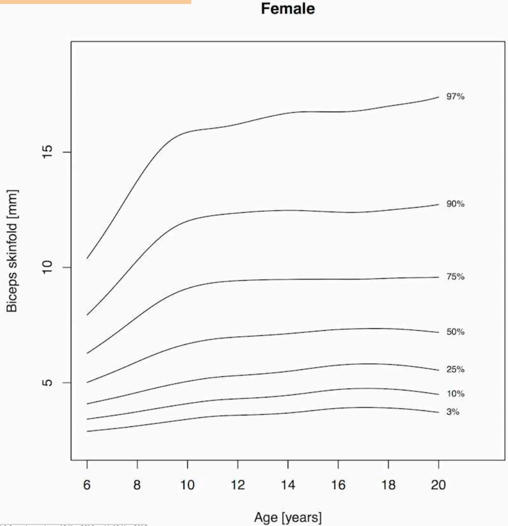

Female
Biceps skinfold [mm]
5
10
15
97%
90%
75%
50%
25%
10%
3%
6
8
10
12
14
16
18
20
Age [years]

Figure 2(on next page)

Percentile curves for triceps skinfold thickness for male and female Canadian children and youth aged 6 to 19 years.

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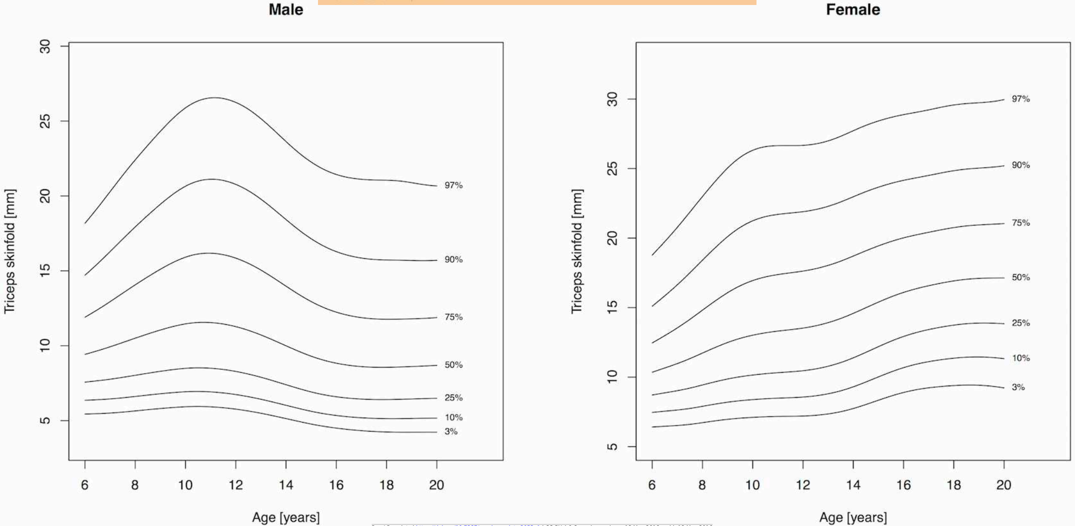
Male
Female
Triceps skinfold [mm]
Age [years]
97%
90%
75%
50%
25%
10%
3%
5
10
15
20
25
30
6
8
10
12
14
16
18
20

Figure 3 (on next page)

Percentile curves for subscapular skinfold thickness for male and female Canadian children and youth aged 6 to 19 years.

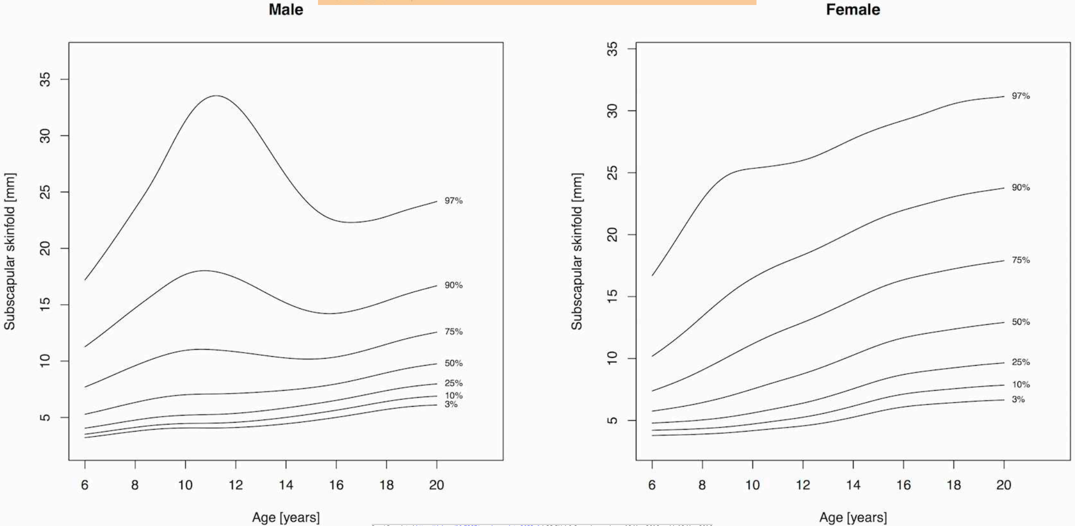

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Figure 4(on next page)

Percentile curves for suprailiac skinfold thickness for male and female Canadian children and youth aged 6 to 19 years.

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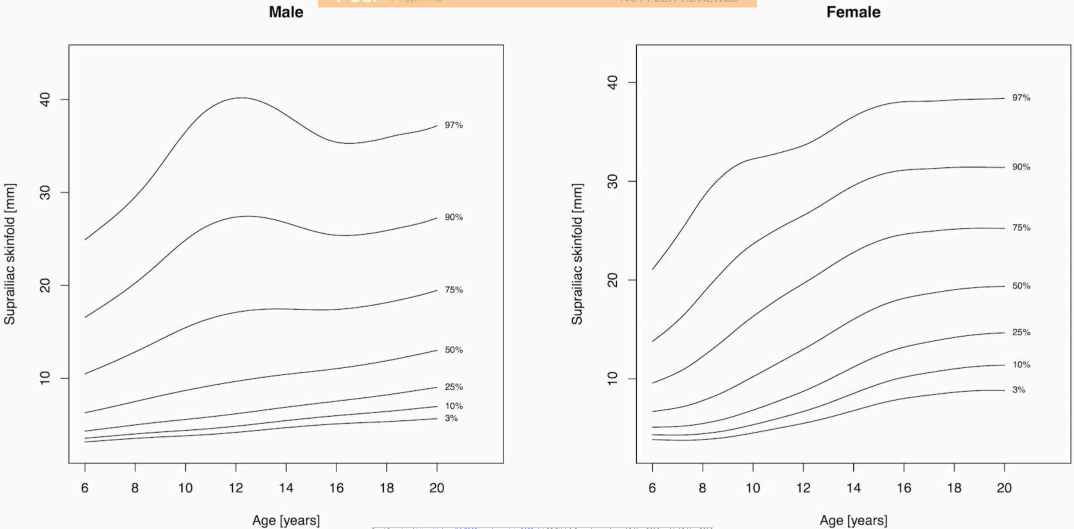
Male
Female
Suprailiac skinfold [mm]
Age [years]
10
20
30
40
6
8
10
12
14
16
18
20
97%
90%
75%
50%
25%
10%
3%

Figure 5(on next page)

Percentile curves for medial calf skinfold thickness for male and female Canadian children and youth aged 6 to 19 years.

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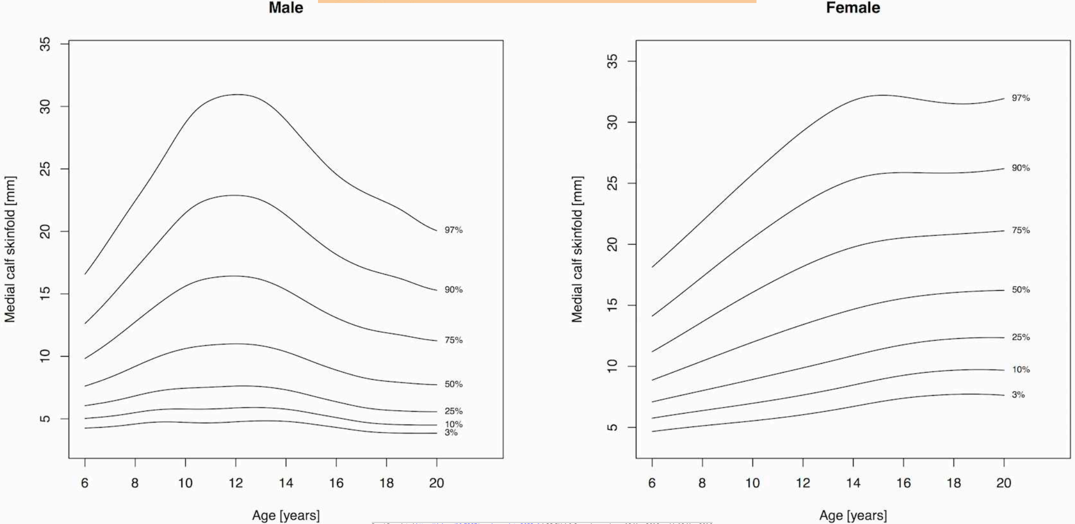
Male
Female
Medial calf skinfold [mm]
Age [years]
5
10
15
20
25
30
35
6
8
10
12
14
16
18
20
97%
90%
75%
50%
25%
10%
3%

Figure 6(on next page)

Percentile curves for body fat percentage for male and female Canadian children and youth aged 6 to 19 years based on the equation by Slaughter et al. (16).

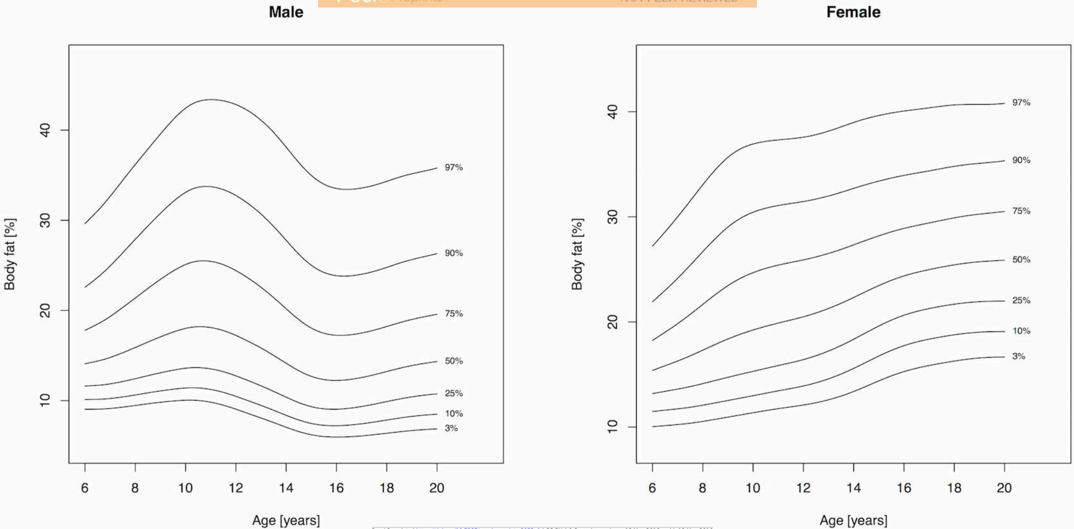
Male
Female
Body fat [%]
Age [years]
6 8 10 12 14 16 18 20
10 20 30 40
97%
90%
75%
50%
25%
10%
3%

Table 1(on next page)

Characteristics of 4115 Canadian children and youth aged 6 to 19 years in the Canadian Health Measures Survey cycles 1 and 2.

[E] Coefficient of variation between 16.6% and 33.3%; interpret with caution as per Statistics Canada sampling variability reporting guidelines.

	Prevalence [%]
Sex	
Male	51.5
Female	48.5
Region of Canada	
Atlantic Canada	6.7[E]
Québec	22.5
Ontario	40.9
Prairies	17.8
British Columbia	12.1
Racial origin	
White	83.3
Black	6.3[E]
Asian	8.1
Other	2.3[E]
Weight status	
Underweight	7.2
Normal weight	66.2
Overweight	17.0
Obese	9.6
Household education	
Secondary school or less	14.1
College	50.2
University	35.7
Household income	
$30,000 or less	13.6
$30,001 - $60,000	23.3
$60,001 - $80,000	19.4
$80,001 - $100,000	16.6
> $100,000	27.1

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Table 2(on next page)

Sample size, median, and interquartile range for biceps, triceps, subscapular, suprailiac, and medial calf skinfold thickness [mm] for Canadian children and youth aged 6 to 19 years.

Abbreviations: *IQR* Interquartile range.

			Biceps		Triceps		Subscapular		Suprailiac		Medial calf	
Sex	**Age [years]**	**n**	**Median**	**IQR**	**Median**	**IQR**	**Median**	**IQR**	**Median**	**IQR**	**Median**	**IQR**
Female	6	154	5.0	1.6	10.5	3.1	5.4	2.3	5.9	2.7	8.7	3.3
	7	140	5.1	2.9	11.0	5.0	5.6	2.7	6.8	5.1	10.0	4.3
	8	164	6.4	4.3	11.9	6.8	6.6	6.0	8.1	7.7	10.5	7.0
	9	174	7.3	4.4	13.1	7.7	8.1	8.4	11.2	11.0	12.1	7.3
	10	193	6.9	3.4	13.1	6.4	8.3	6.4	10.6	10.0	12.7	7.3
	11	209	7.2	4.1	12.4	6.3	8.5	4.9	11.9	10.3	13.2	7.0
	12	127	7.5	4.1	13.9	6.4	8.9	7.7	13.6	11.9	12.7	9.4
	13	131	7.3	3.1	14.0	7.9	9.1	8.3	16.1	14.7	13.6	10.0
	14	116	7.8	4.1	16.1	8.8	12.0	7.4	17.3	12.3	15.9	9.4
	15	118	7.4	4.3	16.3	8.0	11.1	8.5	17.7	14.4	15.0	9.5
	16	109	7.0	1.8	17.0	4.5	10.6	5.4	18.9	8.9	15.9	7.1
	17	111	7.5	3.5	16.8	6.1	12.9	7.7	21.1	12.3	17.0	8.7
	18	104	7.4	2.7	17.3	5.1	11.8	8.3	19.4	10.4	14.8	7.0
	19	92	7.2	4.2	17.5	7.9	11.8	6.0	19.8	11.2	16.9	8.1
Male	6	152	4.3	2.6	9.0	3.6	5.0	2.4	5.3	3.4	7.7	4.2
	7	163	5.0	3.6	10.2	7.0	5.3	5.3	5.6	8.1	9.1	7.0
	8	167	5.2	3.6	10.4	5.9	6.1	3.8	7.2	8.5	8.2	5.6
	9	164	6.0	4.8	11.1	7.5	6.2	5.3	7.0	10.3	9.8	9.1
	10	204	6.8	5.8	12.8	8.8	7.5	9.4	9.6	15.2	12.4	11.5
	11	185	5.5	4.5	11.1	8.8	6.8	4.8	9.9	9.6	10.3	9.1
	12	148	5.7	4.4	12.1	8.4	6.8	5.0	7.9	13.4	10.6	9.3
	13	141	5.3	4.6	10.8	8.3	7.0	5.7	9.7	10.4	10.5	9.8
	14	136	4.4	2.3	9.0	3.1	7.3	2.4	9.8	5.5	9.5	5.7
	15	119	4.4	2.2	8.1	5.0	7.2	2.3	9.2	5.2	7.9	5.7
	16	130	4.0	1.8	8.2	4.9	7.8	2.9	10.2	6.7	7.9	5.5
	17	11	3.9	1.9	8.4	4.6	8.5	3.8	10.2	11.5	8.4	5.3

		4										
	18	91	4.2	3.3	8.8	5.7	9.4	4.6	13.2	12.9	7.4	8.5

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Table 3(on next page)

Parameter values (μ, σ, ν, τ) and percentiles of biceps skinfold thickness [mm] by age and sex for Canadian children and youth aged 6 to 19 years.

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Sex	Age [years]	μ	σ	ν	τ	3rd	10th	25th	50th	75th	90th	97th
Female	6	5.0119	0.3284	-0.4418	1.8070	2.89	3.42	4.08	5.01	6.28	7.94	10.40
	6.5	5.2250	0.3435	-0.4262	1.9030	2.94	3.50	4.20	5.22	6.64	8.49	11.18
	7	5.4445	0.3591	-0.4114	2.0020	3.00	3.57	4.32	5.44	7.03	9.07	12.01
	7.5	5.6746	0.3742	-0.3977	2.1006	3.06	3.65	4.45	5.67	7.44	9.69	12.89
	8	5.9118	0.3874	-0.3847	2.1941	3.13	3.74	4.58	5.91	7.85	10.31	13.76
	8.5	6.1425	0.3979	-0.3716	2.2785	3.20	3.83	4.71	6.14	8.25	10.89	14.55
	9	6.3538	0.4052	-0.3583	2.3518	3.27	3.92	4.84	6.35	8.60	11.39	15.20
	9.5	6.5358	0.4087	-0.3444	2.4148	3.34	4.01	4.95	6.54	8.88	11.76	15.64
	10	6.6843	0.4085	-0.3318	2.4636	3.42	4.09	5.06	6.68	9.09	12.01	15.87
	10.5	6.8017	0.4061	-0.3223	2.4902	3.48	4.17	5.15	6.80	9.24	12.16	15.97
	11	6.8887	0.4035	-0.3159	2.4912	3.54	4.23	5.22	6.89	9.33	12.25	16.03
	11.5	6.9462	0.4021	-0.3131	2.4669	3.57	4.28	5.27	6.95	9.39	12.31	16.11
	12	6.9848	0.4016	-0.3135	2.4202	3.59	4.30	5.31	6.98	9.43	12.36	16.22
	12.5	7.0172	0.4014	-0.3167	2.3565	3.60	4.33	5.35	7.02	9.45	12.41	16.35
	13	7.0502	0.4005	-0.3224	2.2830	3.62	4.36	5.39	7.05	9.46	12.44	16.48
	13.5	7.0857	0.3986	-0.3305	2.2067	3.65	4.40	5.44	7.09	9.47	12.47	16.60
	14	7.1271	0.3956	-0.3402	2.1308	3.69	4.45	5.49	7.13	9.48	12.48	16.69
	14.5	7.1747	0.3910	-0.3507	2.0577	3.74	4.52	5.56	7.17	9.49	12.47	16.75
	15	7.2244	0.3855	-0.3612	1.9904	3.79	4.59	5.64	7.22	9.49	12.45	16.76
	15.5	7.2719	0.3802	-0.3707	1.9315	3.85	4.65	5.71	7.27	9.49	12.42	16.75
	16	7.3094	0.3760	-0.3782	1.8827	3.89	4.71	5.76	7.31	9.49	12.40	16.75
	16.5	7.3323	0.3737	-0.3836	1.8459	3.92	4.74	5.80	7.33	9.49	12.39	16.77
	17	7.3447	0.3733	-0.3873	1.8256	3.93	4.75	5.82	7.34	9.49	12.40	16.82
	17.5	7.3491	0.3747	-0.3893	1.8254	3.92	4.75	5.81	7.35	9.51	12.44	16.91
	18	7.3424	0.3774	-0.3895	1.8451	3.90	4.73	5.80	7.34	9.53	12.49	16.99
	18.5	7.3213	0.3812	-0.3886	1.8817	3.88	4.69	5.76	7.32	9.55	12.54	17.08
	19	7.2844	0.3863	-0.3872	1.9314	3.83	4.64	5.70	7.28	9.56	12.59	17.16
	19.5	7.2355	0.3926	-0.3849	1.9906	3.78	4.57	5.62	7.24	9.56	12.65	17.26
Male	6	4.6047	0.4244	-0.4739	3.4627	2.42	2.79	3.40	4.60	6.56	8.87	11.71
	6.5	4.7687	0.4305	-0.4661	3.5181	2.48	2.87	3.50	4.77	6.84	9.27	12.27
	7	4.9358	0.4363	-0.4586	3.5741	2.55	2.95	3.61	4.94	7.12	9.69	12.83
	7.5	5.1030	0.4417	-0.4516	3.6290	2.61	3.03	3.71	5.10	7.40	10.10	13.39
	8	5.2617	0.4471	-0.4447	3.6814	2.67	3.10	3.81	5.26	7.67	10.50	13.93
	8.5	5.4051	0.4527	-0.4387	3.7288	2.72	3.17	3.90	5.41	7.92	10.89	14.47
	9	5.5233	0.4601	-0.4341	3.7636	2.76	3.21	3.96	5.52	8.16	11.26	15.03
	9.5	5.6104	0.4689	-0.4318	3.7813	2.77	3.23	4.00	5.61	8.35	11.62	15.61
	10	5.6625	0.4775	-0.4333	3.7815	2.76	3.23	4.01	5.66	8.50	11.92	16.15
	10.5	5.6775	0.4843	-0.4396	3.7661	2.75	3.22	4.00	5.68	8.58	12.13	16.58
	11	5.6570	0.4881	-0.4520	3.7424	2.73	3.20	3.98	5.66	8.58	12.21	16.85
	11.5	5.6073	0.4872	-0.4719	3.7241	2.72	3.18	3.96	5.61	8.51	12.16	16.91
	12	5.5336	0.4807	-0.5000	3.7181	2.73	3.18	3.93	5.53	8.37	11.97	16.71
	12.5	5.4364	0.4702	-0.5358	3.7237	2.73	3.17	3.89	5.44	8.17	11.66	16.31
	13	5.3165	0.4566	-0.5778	3.7347	2.74	3.16	3.85	5.32	7.91	11.24	15.74
	13.5	5.1723	0.4417	-0.6236	3.7404	2.74	3.13	3.79	5.17	7.62	10.76	15.05
	14	5.0096	0.4270	-0.6718	3.7345	2.72	3.09	3.71	5.01	7.30	10.25	14.33
	14.5	4.8405	0.4130	-0.7220	3.7191	2.69	3.05	3.63	4.84	6.98	9.76	13.64
	15	4.6786	0.4001	-0.7736	3.6995	2.66	3.00	3.54	4.68	6.68	9.30	13.02
	15.5	4.5328	0.3883	-0.8253	3.6730	2.63	2.95	3.46	4.53	6.41	8.89	12.49
	16	4.4054	0.3778	-0.8752	3.6340	2.60	2.90	3.39	4.41	6.18	8.54	12.04
	16.5	4.2974	0.3687	-0.9217	3.5769	2.58	2.87	3.34	4.30	5.98	8.25	11.68
	17	4.2135	0.3604	-0.9645	3.5010	2.56	2.84	3.29	4.21	5.82	8.01	11.40
	17.5	4.1592	0.3521	-1.0039	3.4112	2.56	2.84	3.28	4.16	5.70	7.81	11.17
	18	4.1304	0.3435	-1.0395	3.3156	2.57	2.85	3.28	4.13	5.61	7.65	10.95
	18.5	4.1142	0.3347	-1.0703	3.2195	2.59	2.86	3.29	4.11	5.53	7.49	10.70
	19	4.0987	0.3261	-1.0957	3.1256	2.61	2.88	3.30	4.10	5.46	7.34	10.43

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Table 4(on next page)

Parameter values (μ, σ, ν, τ) and percentiles of triceps skinfold thickness [mm] by age and sex for Canadian children and youth aged 6 to 19 years.

Sex	**Age [years]**	μ	σ	ν	τ	**3rd**	**10th**	**25th**	**50th**	**75th**	**90th**	**97th**
Female	6	10.3527	0.2772	-0.4045	1.7405	6.41	7.46	8.71	10.35	12.46	15.1	18.77
	6.5	10.6593	0.2898	-0.3782	1.8402	6.47	7.55	8.87	10.66	12.99	15.85	19.74
	7	10.9767	0.3028	-0.3527	1.9457	6.52	7.64	9.03	10.98	13.54	16.64	20.77
	7.5	11.3334	0.3151	-0.3301	2.0578	6.61	7.75	9.21	11.33	14.16	17.50	21.87
	8	11.7320	0.3256	-0.3103	2.1734	6.73	7.90	9.44	11.73	14.82	18.41	22.99
	8.5	12.1291	0.3348	-0.2919	2.2869	6.86	8.06	9.66	12.13	15.47	19.29	24.06
	9	12.4911	0.3431	-0.2737	2.3917	6.97	8.20	9.87	12.49	16.07	20.11	25.04
	9.5	12.7889	0.3498	-0.2538	2.4833	7.05	8.31	10.03	12.79	16.57	20.77	25.81
	10	13.0158	0.3544	-0.2315	2.5568	7.11	8.38	10.15	13.02	16.94	21.24	26.31
	10.5	13.1858	0.3567	-0.2062	2.6095	7.15	8.44	10.25	13.19	17.20	21.54	26.57
	11	13.3113	0.3576	-0.1770	2.6435	7.17	8.49	10.32	13.31	17.38	21.70	26.65
	11.5	13.4136	0.3580	-0.1454	2.6597	7.19	8.52	10.38	13.41	17.50	21.80	26.65
	12	13.5272	0.3579	-0.1136	2.6561	7.20	8.57	10.46	13.53	17.63	21.90	26.67
	12.5	13.6910	0.3569	-0.0836	2.6324	7.26	8.66	10.59	13.69	17.80	22.05	26.77
	13	13.9211	0.3550	-0.0573	2.5904	7.36	8.80	10.79	13.92	18.04	22.29	26.99
	13.5	14.2201	0.3518	-0.0366	2.5346	7.52	9.02	11.05	14.22	18.34	22.60	27.32
	14	14.5871	0.3466	-0.0219	2.4691	7.74	9.30	11.39	14.59	18.71	22.97	27.72
	14.5	14.9915	0.3394	-0.0108	2.3963	8.03	9.65	11.78	14.99	19.09	23.34	28.10
	15	15.3946	0.3311	-0.0005	2.3207	8.34	10.02	12.19	15.39	19.44	23.66	28.42
	15.5	15.7700	0.3229	0.0106	2.2476	8.64	10.37	12.58	15.77	19.75	23.93	28.68
	16	16.0934	0.3159	0.0236	2.1810	8.90	10.68	12.92	16.09	20.02	24.15	28.88
	16.5	16.3567	0.3106	0.0384	2.1230	9.09	10.93	13.2	16.36	20.23	24.33	29.04
	17	16.5739	0.3074	0.0549	2.0757	9.23	11.11	13.42	16.57	20.42	24.51	29.22
	17.5	16.7618	0.3058	0.0727	2.0406	9.33	11.25	13.6	16.76	20.60	24.69	29.41
	18	16.9205	0.3048	0.0917	2.0177	9.39	11.36	13.74	16.92	20.75	24.85	29.57
	18.5	17.0364	0.3044	0.1114	2.0040	9.43	11.43	13.84	17.04	20.87	24.96	29.67
	19	17.1018	0.3049	0.1318	1.9946	9.42	11.45	13.89	17.10	20.95	25.03	29.73
	19.5	17.1266	0.3072	0.1525	1.9862	9.35	11.41	13.88	17.13	20.99	25.10	29.81
Male	6	9.4200	0.3219	-0.2987	2.2897	5.44	6.36	7.57	9.42	11.90	14.71	18.18
	6.5	9.6662	0.3372	-0.2968	2.4350	5.47	6.40	7.66	9.67	12.41	15.47	19.20
	7	9.9299	0.3520	-0.2951	2.5915	5.51	6.45	7.77	9.93	12.94	16.29	20.29
	7.5	10.2151	0.3651	-0.2933	2.7567	5.57	6.52	7.89	10.22	13.51	17.12	21.37
	8	10.5047	0.3761	-0.2908	2.9221	5.65	6.61	8.03	10.50	14.07	17.93	22.41
	8.5	10.7871	0.3856	-0.2881	3.0790	5.73	6.71	8.16	10.79	14.60	18.71	23.38
	9	11.0506	0.3943	-0.2861	3.2188	5.81	6.79	8.29	11.05	15.11	19.45	24.32
	9.5	11.2822	0.4020	-0.2859	3.3368	5.88	6.87	8.41	11.28	15.56	20.11	25.18
	10	11.4608	0.4081	-0.2879	3.4329	5.93	6.93	8.49	11.46	15.91	20.65	25.88
	10.5	11.5533	0.4127	-0.2912	3.5032	5.95	6.95	8.53	11.55	16.13	20.99	26.35
	11	11.5478	0.4160	-0.2954	3.5419	5.92	6.92	8.50	11.55	16.18	21.12	26.55
	11.5	11.4527	0.4182	-0.3004	3.5484	5.86	6.85	8.42	11.45	16.08	21.04	26.51
	12	11.2775	0.4193	-0.3065	3.5262	5.77	6.74	8.29	11.28	15.85	20.77	26.25
	12.5	11.0300	0.4197	-0.3135	3.4821	5.64	6.60	8.11	11.03	15.50	20.35	25.79
	13	10.7229	0.4191	-0.3213	3.4194	5.49	6.43	7.90	10.72	15.05	19.79	25.16
	13.5	10.3697	0.4183	-0.3293	3.3374	5.32	6.23	7.65	10.37	14.53	19.13	24.42
	14	9.9979	0.4173	-0.3373	3.2383	5.14	6.02	7.40	10.00	13.98	18.43	23.64
	14.5	9.6331	0.4169	-0.3444	3.1272	4.95	5.82	7.15	9.63	13.44	17.75	22.89
	15	9.3037	0.4173	-0.3498	3.0095	4.77	5.62	6.92	9.30	12.95	17.15	22.27
	15.5	9.0358	0.4179	-0.3528	2.8902	4.62	5.47	6.73	9.04	12.55	16.66	21.78
	16	8.8355	0.4189	-0.3524	2.7730	4.50	5.34	6.59	8.84	12.24	16.28	21.44
	16.5	8.6954	0.4204	-0.3477	2.6613	4.40	5.25	6.50	8.70	12.02	16.02	21.23
	17	8.6080	0.4222	-0.3389	2.5605	4.33	5.19	6.44	8.61	11.88	15.86	21.12
	17.5	8.5657	0.4241	-0.3264	2.4764	4.28	5.15	6.41	8.57	11.80	15.76	21.07
	18	8.5609	0.4257	-0.3112	2.4147	4.24	5.13	6.41	8.56	11.77	15.73	21.05
	18.5	8.5809	0.4262	-0.2939	2.3794	4.23	5.14	6.42	8.58	11.78	15.71	21.00
	19	8.6121	0.4256	-0.2749	2.3676	4.23	5.15	6.45	8.61	11.80	15.69	20.89

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Table 5 (on next page)

Parameter values (μ, σ, ν, τ) and percentiles of subscapular skinfold thickness [mm] by age and sex for Canadian children and youth aged 6 to 19 years.

Sex	Age [years]	μ	σ	ν	τ	3rd	10th	25th	50th	75th	90th	97th
Female	6	5.7916	0.3158	-1.4955	2.0865	3.79	4.21	4.79	5.75	7.38	10.19	16.69
	6.5	5.9375	0.3313	-1.4087	2.2978	3.81	4.24	4.84	5.90	7.75	10.90	18.18
	7	6.0924	0.3474	-1.3221	2.5290	3.83	4.26	4.90	6.06	8.15	11.67	19.75
	7.5	6.2641	0.3640	-1.2361	2.7759	3.86	4.30	4.96	6.24	8.58	12.51	21.34
	8	6.4656	0.3805	-1.1513	3.0269	3.90	4.35	5.05	6.45	9.07	13.41	22.83
	8.5	6.6905	0.3963	-1.0679	3.2661	3.95	4.41	5.15	6.68	9.59	14.29	24.02
	9	6.9464	0.4105	-0.9870	3.4737	4.01	4.49	5.28	6.94	10.12	15.12	24.80
	9.5	7.2332	0.4223	-0.9091	3.6298	4.09	4.59	5.43	7.23	10.66	15.86	25.18
	10	7.5377	0.4317	-0.8357	3.7182	4.18	4.71	5.61	7.54	11.18	16.49	25.34
	10.5	7.8500	0.4388	-0.7676	3.7348	4.27	4.84	5.80	7.85	11.66	17.05	25.46
	11	8.1575	0.4441	-0.7052	3.6890	4.37	4.98	5.99	8.16	12.11	17.53	25.60
	11.5	8.4551	0.4477	-0.6491	3.5998	4.46	5.11	6.19	8.46	12.52	17.95	25.77
	12	8.7644	0.4495	-0.6001	3.4892	4.56	5.26	6.40	8.76	12.92	18.35	26.00
	12.5	9.1037	0.4494	-0.5588	3.3729	4.70	5.44	6.65	9.10	13.34	18.79	26.34
	13	9.4771	0.4476	-0.5258	3.2654	4.86	5.66	6.93	9.48	13.79	19.28	26.77
	13.5	9.8715	0.4441	-0.5003	3.1753	5.05	5.90	7.24	9.87	14.26	19.79	27.26
	14	10.2792	0.4393	-0.4810	3.1074	5.26	6.16	7.56	10.28	14.74	20.30	27.74
	14.5	10.6873	0.4334	-0.4669	3.0654	5.50	6.44	7.89	10.69	15.22	20.80	28.18
	15	11.0716	0.4272	-0.4570	3.0425	5.73	6.70	8.21	11.07	15.66	21.25	28.56
	15.5	11.4057	0.4219	-0.4497	3.0273	5.93	6.94	8.49	11.41	16.04	21.65	28.91
	16	11.6741	0.4182	-0.4439	3.0112	6.09	7.13	8.71	11.67	16.36	21.98	29.23
	16.5	11.8843	0.4163	-0.4389	2.9901	6.21	7.27	8.88	11.88	16.61	22.27	29.55
	17	12.0601	0.4156	-0.4342	2.9646	6.30	7.38	9.01	12.06	16.83	22.54	29.90
	17.5	12.2198	0.4158	-0.4289	2.9386	6.37	7.47	9.14	12.22	17.04	22.81	30.26
	18	12.3746	0.4158	-0.4219	2.9175	6.44	7.56	9.25	12.37	17.24	23.06	30.56
	18.5	12.5249	0.4154	-0.4125	2.9008	6.51	7.65	9.37	12.52	17.42	23.28	30.79
	19	12.6650	0.4149	-0.4006	2.8872	6.57	7.73	9.47	12.67	17.59	23.45	30.94
	19.5	12.7914	0.4146	-0.3862	2.8775	6.62	7.80	9.57	12.79	17.75	23.60	31.04
Male	6	5.2871	0.3836	-1.0960	4.8016	3.21	3.51	4.05	5.29	7.70	11.28	17.20
	6.5	5.5388	0.3904	-1.0977	5.0401	3.35	3.66	4.22	5.54	8.16	12.09	18.69
	7	5.8079	0.3965	-1.0994	5.2828	3.49	3.82	4.41	5.81	8.64	12.96	20.26
	7.5	6.0797	0.4021	-1.1001	5.5045	3.64	3.97	4.59	6.08	9.13	13.84	21.88
	8	6.3370	0.4077	-1.0994	5.6729	3.78	4.12	4.77	6.33	9.60	14.71	23.55
	8.5	6.5751	0.4133	-1.0974	5.7598	3.90	4.25	4.93	6.57	10.03	15.54	25.25
	9	6.7747	0.4203	-1.0946	5.7440	3.99	4.36	5.06	6.77	10.42	16.36	27.21
	9.5	6.9283	0.4281	-1.0916	5.6129	4.05	4.43	5.15	6.92	10.74	17.12	29.36
	10	7.0323	0.4352	-1.0889	5.3693	4.07	4.47	5.21	7.02	10.96	17.69	31.32
	10.5	7.0859	0.4402	-1.0870	5.0319	4.07	4.48	5.24	7.07	11.04	17.99	32.76
	11	7.1096	0.4423	-1.0872	4.6343	4.07	4.49	5.26	7.08	11.03	18.00	33.47
	11.5	7.1329	0.4406	-1.0906	4.2149	4.08	4.52	5.30	7.10	10.94	17.78	33.43
	12	7.1737	0.4348	-1.0971	3.8024	4.11	4.58	5.37	7.14	10.83	17.39	32.71
	12.5	7.2268	0.4254	-1.1057	3.4165	4.17	4.66	5.46	7.19	10.69	16.88	31.45
	13	7.2915	0.4130	-1.1155	3.0718	4.24	4.76	5.57	7.26	10.54	16.30	29.85
	13.5	7.3647	0.3986	-1.1256	2.7784	4.33	4.88	5.70	7.33	10.40	15.71	28.13
	14	7.4489	0.3831	-1.1352	2.5417	4.44	5.01	5.85	7.42	10.28	15.16	26.46
	14.5	7.5468	0.3677	-1.1438	2.3642	4.56	5.15	6.00	7.52	10.20	14.71	24.97
	15	7.6669	0.3533	-1.1508	2.2436	4.70	5.31	6.16	7.65	10.18	14.39	23.76
	15.5	7.8138	0.3410	-1.1553	2.1705	4.85	5.47	6.34	7.80	10.24	14.23	22.92
	16	7.9923	0.3316	-1.1565	2.1345	5.01	5.64	6.52	7.98	10.37	14.24	22.45
	16.5	8.2078	0.3247	-1.1538	2.1262	5.18	5.83	6.73	8.20	10.59	14.39	22.30
	17	8.4528	0.3197	-1.1467	2.1359	5.36	6.03	6.94	8.44	10.86	14.65	22.35
	17.5	8.7139	0.3161	-1.1350	2.1547	5.55	6.23	7.17	8.71	11.17	14.98	22.53
	18	8.9755	0.3145	-1.1183	2.1759	5.72	6.42	7.38	8.97	11.50	15.35	22.83
	18.5	9.2212	0.3145	-1.0964	2.1938	5.87	6.59	7.58	9.22	11.82	15.73	23.20
	19	9.4349	0.3157	-1.0691	2.2048	5.98	6.72	7.75	9.43	12.10	16.08	23.54

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Table 6(on next page)

Parameter values (μ, σ, ν, τ) and percentiles of suprailiac skinfold thickness [mm] by age and sex for Canadian children and youth aged 6 to 19 years.

Sex	**Age [years]**	μ	σ	ν	τ	**3rd**	**10th**	**25th**	**50th**	**75th**	**90th**	**97th**
Female	6	6.6972	0.4008	-0.9029	3.3367	3.86	4.34	5.11	6.70	9.58	13.80	21.08
	6.5	6.8654	0.4266	-0.8326	3.4717	3.81	4.32	5.14	6.86	10.07	14.77	22.74
	7	7.0730	0.4535	-0.7626	3.6134	3.78	4.31	5.18	7.07	10.64	15.87	24.51
	7.5	7.3765	0.4800	-0.6931	3.7620	3.79	4.34	5.29	7.38	11.37	17.17	26.42
	8	7.8030	0.5037	-0.6240	3.9130	3.86	4.45	5.48	7.80	12.28	18.65	28.33
	8.5	8.2923	0.5230	-0.5551	4.0595	3.95	4.59	5.72	8.29	13.24	20.07	29.86
	9	8.8705	0.5363	-0.4870	4.1943	4.10	4.80	6.03	8.87	14.27	21.43	31.02
	9.5	9.5357	0.5422	-0.4201	4.3053	4.30	5.06	6.42	9.54	15.34	22.66	31.82
	10	10.2176	0.5420	-0.3544	4.3718	4.53	5.36	6.84	10.22	16.32	23.65	32.26
	10.5	10.9024	0.5379	-0.2901	4.3767	4.76	5.67	7.28	10.90	17.22	24.46	32.54
	11	11.5991	0.5315	-0.2274	4.3136	5.00	6.00	7.75	11.60	18.08	25.21	32.85
	11.5	12.2912	0.5237	-0.1671	4.1882	5.24	6.34	8.23	12.29	18.89	25.89	33.20
	12	12.9890	0.5145	-0.1106	4.0133	5.49	6.70	8.74	12.99	19.65	26.54	33.62
	12.5	13.7280	0.5043	-0.0598	3.8054	5.77	7.10	9.30	13.73	20.45	27.26	34.22
	13	14.5051	0.4933	-0.0163	3.5869	6.09	7.55	9.92	14.51	21.27	28.05	34.99
	13.5	15.2862	0.4817	0.0199	3.3771	6.43	8.04	10.56	15.29	22.07	28.84	35.81
	14	16.0317	0.4695	0.0499	3.1880	6.79	8.53	11.2	16.03	22.80	29.55	36.55
	14.5	16.7126	0.4571	0.0748	3.0276	7.14	9.02	11.81	16.71	23.44	30.15	37.16
	15	17.3039	0.4453	0.0953	2.8954	7.48	9.47	12.37	17.30	23.96	30.61	37.61
	15.5	17.7850	0.4348	0.1126	2.7869	7.78	9.86	12.84	17.78	24.36	30.93	37.90
	16	18.1484	0.4259	0.1274	2.6967	8.01	10.17	13.21	18.15	24.63	31.12	38.05
	16.5	18.4145	0.4185	0.1401	2.6189	8.20	10.42	13.50	18.41	24.80	31.21	38.09
	17	18.6318	0.4121	0.1503	2.5499	8.36	10.63	13.75	18.63	24.92	31.27	38.11
	17.5	18.8355	0.4064	0.1579	2.4865	8.51	10.83	13.98	18.84	25.04	31.34	38.16
	18	19.0186	0.4015	0.1640	2.4234	8.64	11.01	14.19	19.02	25.15	31.40	38.23
	18.5	19.1639	0.3973	0.1694	2.3582	8.75	11.17	14.37	19.16	25.22	31.43	38.29
	19	19.2661	0.3942	0.1752	2.2932	8.81	11.28	14.51	19.27	25.24	31.43	38.32
	19.5	19.3275	0.3924	0.1820	2.2315	8.84	11.35	14.60	19.33	25.24	31.41	38.34
Male	6	6.3018	0.5203	-0.6962	6.1066	3.16	3.56	4.33	6.30	10.49	16.56	24.91
	6.5	6.5930	0.5288	-0.6668	6.2092	3.26	3.67	4.49	6.59	11.05	17.42	25.96
	7	6.8933	0.5374	-0.6381	6.3102	3.36	3.79	4.66	6.89	11.62	18.31	27.04
	7.5	7.2022	0.5462	-0.6105	6.4014	3.46	3.91	4.83	7.20	12.22	19.25	28.21
	8	7.5126	0.5562	-0.5844	6.4749	3.55	4.03	5.00	7.51	12.85	20.26	29.55
	8.5	7.8236	0.5672	-0.5608	6.5276	3.63	4.13	5.15	7.82	13.50	21.36	31.09
	9	8.1293	0.5793	-0.5399	6.5518	3.70	4.23	5.30	8.13	14.17	22.55	32.87
	9.5	8.4238	0.5915	-0.5219	6.5395	3.76	4.31	5.44	8.42	14.84	23.76	34.76
	10	8.7035	0.6017	-0.5068	6.4882	3.83	4.40	5.58	8.70	15.46	24.88	36.53
	10.5	8.9678	0.6086	-0.4954	6.4021	3.90	4.49	5.72	8.97	16.01	25.84	38.04
	11	9.2171	0.6113	-0.4875	6.2895	3.98	4.60	5.87	9.22	16.46	26.57	39.13
	11.5	9.4540	0.6099	-0.4830	6.1530	4.08	4.72	6.03	9.45	16.82	27.06	39.82
	12	9.6782	0.6052	-0.4808	5.9886	4.19	4.86	6.19	9.68	17.10	27.35	40.15
	12.5	9.8876	0.5978	-0.4800	5.7993	4.31	5.00	6.36	9.89	17.30	27.44	40.13
	13	10.0850	0.5877	-0.4799	5.5886	4.44	5.15	6.54	10.09	17.42	27.35	39.77
	13.5	10.2667	0.5761	-0.4790	5.3571	4.57	5.31	6.72	10.27	17.47	27.10	39.16
	14	10.4305	0.5638	-0.4759	5.1099	4.70	5.46	6.90	10.43	17.46	26.73	38.33
	14.5	10.5803	0.5516	-0.4696	4.8578	4.81	5.60	7.06	10.58	17.42	26.31	37.43
	15	10.7272	0.5403	-0.4599	4.6105	4.92	5.74	7.23	10.73	17.39	25.91	36.56
	15.5	10.8808	0.5305	-0.4468	4.3691	5.02	5.87	7.39	10.88	17.37	25.58	35.84
	16	11.0471	0.5234	-0.4305	4.1337	5.10	5.99	7.55	11.05	17.42	25.40	35.41
	16.5	11.2298	0.5191	-0.4113	3.9077	5.17	6.11	7.71	11.23	17.53	25.37	35.28
	17	11.4314	0.5170	-0.3898	3.6947	5.23	6.21	7.87	11.43	17.69	25.47	35.38
	17.5	11.6547	0.5158	-0.3666	3.4997	5.29	6.32	8.04	11.65	17.90	25.65	35.59
	18	11.8974	0.5153	-0.3423	3.3301	5.35	6.44	8.23	11.90	18.15	25.90	35.90
	18.5	12.1575	0.5147	-0.3177	3.1943	5.41	6.56	8.42	12.16	18.43	26.19	36.21
	19	12.4347	0.5131	-0.2935	3.0962	5.50	6.70	8.62	12.43	18.74	26.47	36.45

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Table 7 (on next page)

Parameter values (μ, σ, ν, τ) and percentiles of medial calf skinfold thickness [mm] by age and sex for Canadian children and youth aged 6 to 19 years.

Sex	Age [years]	μ	σ	ν	τ	3rd	10th	25th	50th	75th	90th	97th
Female	6	8.8756	0.3546	-0.1545	1.7494	4.67	5.76	7.09	8.88	11.20	14.12	18.13
	6.5	9.2641	0.3628	-0.1300	1.8386	4.79	5.92	7.33	9.26	11.80	14.90	19.06
	7	9.6544	0.3713	-0.1055	1.9318	4.91	6.08	7.56	9.65	12.41	15.70	20.00
	7.5	10.0464	0.3798	-0.0817	2.0269	5.02	6.23	7.79	10.05	13.03	16.52	20.95
	8	10.4394	0.3880	-0.0590	2.1171	5.13	6.38	8.02	10.44	13.65	17.34	21.91
	8.5	10.8320	0.3960	-0.0376	2.1960	5.23	6.53	8.24	10.83	14.28	18.16	22.88
	9	11.2226	0.4034	-0.0180	2.2604	5.33	6.67	8.47	11.22	14.89	18.97	23.85
	9.5	11.6082	0.4099	-0.0009	2.3108	5.43	6.82	8.70	11.61	15.49	19.76	24.81
	10	11.9874	0.4154	0.0128	2.3480	5.54	6.98	8.93	11.99	16.07	20.52	25.75
	10.5	12.3598	0.4200	0.0225	2.3743	5.65	7.14	9.17	12.36	16.63	21.27	26.67
	11	12.7243	0.4237	0.0285	2.3936	5.77	7.30	9.41	12.72	17.17	21.99	27.57
	11.5	13.0793	0.4265	0.0308	2.4083	5.90	7.47	9.64	13.08	17.69	22.68	28.45
	12	13.4235	0.4281	0.0299	2.4180	6.04	7.65	9.88	13.42	18.18	23.33	29.28
	12.5	13.7571	0.4283	0.0271	2.4199	6.19	7.84	10.13	13.76	18.64	23.93	30.05
	13	14.0787	0.4274	0.0232	2.4129	6.36	8.04	10.38	14.08	19.06	24.47	30.74
	13.5	14.3853	0.4249	0.0189	2.3988	6.53	8.25	10.63	14.39	19.44	24.93	31.33
	14	14.6745	0.4210	0.0150	2.3798	6.71	8.47	10.88	14.67	19.77	25.31	31.78
	14.5	14.9414	0.4156	0.0139	2.3578	6.90	8.69	11.13	14.94	20.04	25.59	32.08
	15	15.1812	0.4092	0.0180	2.3359	7.08	8.90	11.37	15.18	20.25	25.76	32.20
	15.5	15.3921	0.4024	0.0278	2.3153	7.25	9.10	11.58	15.39	20.41	25.85	32.19
	16	15.5739	0.3958	0.0429	2.2962	7.39	9.27	11.77	15.57	20.53	25.88	32.07
	16.5	15.7273	0.3898	0.0617	2.2790	7.51	9.41	11.94	15.73	20.62	25.87	31.91
	17	15.8549	0.3849	0.0820	2.2666	7.59	9.53	12.07	15.85	20.7	25.84	31.74
	17.5	15.9602	0.3811	0.1014	2.2608	7.66	9.62	12.18	15.96	20.76	25.83	31.61
	18	16.0453	0.3785	0.1179	2.2603	7.70	9.68	12.26	16.05	20.82	25.84	31.52
	18.5	16.1127	0.3774	0.1309	2.2605	7.73	9.72	12.32	16.11	20.89	25.88	31.50
	19	16.1645	0.3779	0.1405	2.2579	7.72	9.74	12.35	16.16	20.95	25.95	31.57
	19.5	16.2024	0.3800	0.1470	2.2522	7.69	9.72	12.36	16.20	21.02	26.06	31.71
Male	6	7.6139	0.3532	-0.4290	2.0886	4.25	5.03	6.05	7.61	9.82	12.62	16.57
	6.5	7.9514	0.3740	-0.4000	2.2278	4.30	5.11	6.21	7.95	10.47	13.61	17.96
	7	8.3241	0.3942	-0.3711	2.3743	4.37	5.21	6.38	8.32	11.18	14.70	19.45
	7.5	8.7435	0.4118	-0.3426	2.5227	4.47	5.34	6.59	8.74	11.95	15.84	20.96
	8	9.1952	0.4264	-0.3147	2.6629	4.58	5.50	6.84	9.20	12.75	17.00	22.45
	8.5	9.6377	0.4404	-0.2878	2.7854	4.69	5.64	7.07	9.64	13.55	18.14	23.92
	9	10.0372	0.4568	-0.2627	2.8827	4.75	5.74	7.25	10.04	14.31	19.31	25.50
	9.5	10.3692	0.4757	-0.2405	2.9490	4.75	5.78	7.38	10.37	15.02	20.46	27.15
	10	10.6239	0.4941	-0.2228	2.9851	4.71	5.78	7.45	10.62	15.62	21.48	28.69
	10.5	10.7952	0.5074	-0.2113	2.9966	4.68	5.77	7.49	10.80	16.03	22.21	29.84
	11	10.9036	0.5136	-0.2077	2.9961	4.67	5.79	7.53	10.90	16.27	22.62	30.50
	11.5	10.9717	0.5145	-0.2128	2.9980	4.71	5.82	7.58	10.97	16.39	22.83	30.84
	12	11.0043	0.5115	-0.2262	3.0093	4.76	5.87	7.62	11.00	16.43	22.88	30.95
	12.5	10.9698	0.5073	-0.2460	3.0302	4.81	5.90	7.63	10.97	16.35	22.80	30.88
	13	10.8526	0.5017	-0.2700	3.0602	4.84	5.90	7.58	10.85	16.15	22.51	30.54
	13.5	10.6446	0.4947	-0.2959	3.0972	4.83	5.86	7.48	10.64	15.79	22.00	29.86
	14	10.3584	0.4868	-0.3214	3.1372	4.80	5.77	7.32	10.36	15.31	21.30	28.89
	14.5	10.0042	0.4798	-0.3446	3.1788	4.71	5.64	7.11	10.00	14.75	20.47	27.75
	15	9.6173	0.4750	-0.3643	3.2226	4.58	5.46	6.85	9.62	14.15	19.64	26.61
	15.5	9.2415	0.4714	-0.3799	3.2679	4.45	5.28	6.60	9.24	13.59	18.85	25.52
	16	8.9001	0.4694	-0.3911	3.3148	4.31	5.10	6.37	8.90	13.09	18.15	24.57
	16.5	8.5901	0.4703	-0.3978	3.3649	4.17	4.92	6.14	8.59	12.66	17.59	23.82
	17	8.3241	0.4727	-0.4010	3.4191	4.03	4.76	5.93	8.32	12.32	17.15	23.24
	17.5	8.1317	0.4742	-0.4017	3.4752	3.93	4.64	5.79	8.13	12.06	16.81	22.75
	18	8.0090	0.4733	-0.4007	3.5298	3.88	4.57	5.70	8.01	11.88	16.53	22.31
	18.5	7.9196	0.4702	-0.3983	3.5766	3.86	4.53	5.64	7.92	11.73	16.25	21.81
	19	7.8366	0.4643	-0.3943	3.6102	3.84	4.51	5.60	7.84	11.55	15.90	21.17
	19.5	7.7663	0.4572	-0.3887	3.6266	3.84	4.50	5.57	7.77	11.37	15.55	20.53

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