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..	not available for a specific reference period
...	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
*	significantly different from reference category ($p < 0.05$)

Comparison of waist circumference using the World Health Organization and National Institutes of Health protocols

by Jennifer Patry-Parisien, Margot Shields and Shirley Bryan

Abstract

Background
This study compares waist circumference (WC) measured using the World Health Organization (WHO) and National Institutes of Health (NIH) protocols to determine if the results differ significantly, and whether equations can be developed to allow comparison between WC taken at the two different measurement sites.

Data and Methods
Valid WC measurements using the WHO and NIH protocols were obtained for 6,306 respondents aged 3 to 79 from Cycle 2 of the Canadian Health Measures Survey. Linear regression was used to identify factors associated with the difference between the NIH and WHO values. Separate prediction equations by sex were generated using WC_NIH as the outcome and WC_WHO and age as independent variables. Sensitivity and specificity were calculated to examine whether health risk based on the WC_WHO and on WC_NIH predicted measurements agreed with estimates based on WC_NIH actual measured values.

Results
For adults and children, WC_NIH significantly exceeded WC_WHO (1.0 cm for boys, 2.1 cm for girls, 0.8 cm for men and 2.2 cm for women). Predicted NIH values were statistically similar to measured values. Sensitivity (86% to 98%) and specificity (70% to 100%) values for health risk category based on the NIH predicted values were very high, meaning that respondents would be appropriately classified when compared with actual measured values.

Interpretation
The prediction equations proposed in this study can be applied to historical datasets to compare estimates based on WC data measured using the WHO and NIH protocols.

Keywords
Body composition, central obesity, cross-over study, direct measure, sensitivity, specificity

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Waist circumference (WC) is an important independent measure in the assessment of obesity-related health risk.[1] The 2003 Canadian Guidelines for Weight Classification in Adults recommended that WC be measured on all persons with a body mass index (BMI) between 18.5 and 34.9 kg/m^2, using the World Health Organization (WHO) measurement protocol.[1] In 2006, based on recommendations from an expert panel, the Canadian clinical practice guidelines on the management and prevention of obesity in adults and children suggested that practitioners use the National Institutes of Health (NIH) method to measure WC.[2] Two years later, the Canadian Society for Exercise Physiology (CSEP) adopted the NIH method as part of the measurement protocols in the Canadian Physical Activity and Fitness Lifestyle Approach.[3,4]

In March 2007, Statistics Canada launched the Canadian Health Measures Survey (CHMS), which collects directly measured health data on a nationally representative sample of Canadians. Cycle 1 (2007 to 2009) included WC measurements using the WHO protocol.[5] Cycle 2 (2009 to 2011) used both the WHO and NIH protocols in order to conduct a cross-over study that would compare the measurement techniques based on a large, nationally representative sample.

This paper presents the results of that cross-over study. It compares the measurements of WC using the WHO and NIH measurement protocols, assesses the effect of measurement site on health risk classification, and evaluates the feasibility of predicting WC based on the NIH protocol from WC based on the WHO protocol.

Methods

Data source

The data are from the second cycle of the CHMS. The CHMS is an ongoing survey designed to provide comprehensive, direct health measures at the national level.[6] Cycle 2 covers the population aged 3 to 79 living in private households. Residents of Indian Reserves, institutions and some remote regions, and full-time members of the Canadian Forces are excluded. More than 96% of the Canadian population is represented. Ethics approval for the CHMS was obtained from Health Canada's Research Ethics Board.

Data for Cycle 2 were collected at 18 locations across Canada from August 2009 through December 2011. In addition to a detailed questionnaire administered in the respondent's home, the survey involved physical measures (including WC, height and weight) several days later at a mobile examination centre. Participation in the survey was voluntary, and written informed consent was obtained from respondents for participation in the physical measures component. Additional information about the content and sample design can be found in the *CHMS Cycle 2 Data User Guide*.[7]

Of the households selected for the survey, 75.9% agreed to participate, and 90.5% of selected household members completed the household questionnaire. A total of 6,395 respondents (81.7% of those who completed the household questionnaire) completed the mobile examination centre component. The final response rate, after adjusting for the sampling strategy, was 55.5%. This study pertains to 6,306 respondents for whom WC was measured using both the WHO and NIH protocols. Respondents who had a missing value for either or both protocols were excluded (n=89) from the analysis; this included pregnant women, whose WC was not measured.

Waist circumference measurement and classification

CHMS health measures specialists were trained to measure WC using both the NIH and WHO protocols. WC was measured to the nearest 0.1 cm, directly on the landmarked skin with a flexible, inelastic measuring tape with a tension meter attached.[7] For the NIH protocol, the measure is taken at the highest point of the iliac crest.[8] For the WHO protocol, the measure is taken at the mid-point between the highest point of the iliac crest and the last floating rib[5] (Figure 1). The two measurements were taken consecutively near the beginning of the visit to the mobile examination centre. The health measures specialists landmarked the location of the tape, marked it with a washable marker, and took the measure at the end of a normal expiration, on the right side of the back, using the reflection of the left side of the body in a mirror to ensure that the tape was horizontal.

Based on their WC measurements, adults aged 20 or older were classified into three health risk categories according to cut-offs recommended by the WHO,[5] Health Canada,[1] and Obesity Canada.[2] Those cut-offs were also applied to the NIH protocol. The three categories are: low risk (men, WC 93.9 cm or less; women, WC 79.9 cm or less); increased risk (men, WC 94.0 to 101.9 cm; women, WC 80.0 to 87.9 cm); and high risk (men, WC 102.0 cm or more; women, WC 88.0 cm or more). Adolescents aged 12 to 19 were classified into low-, increased, and high-risk WC categories according to the age- and sex-specific cut-offs proposed by Jolliffe et al.[9] These cut-offs were developed using growth curve modeling, and they correspond to the cut-offs at entry into adulthood at age 20.[9] Comparable WC cut-offs are not available for children younger than 12.

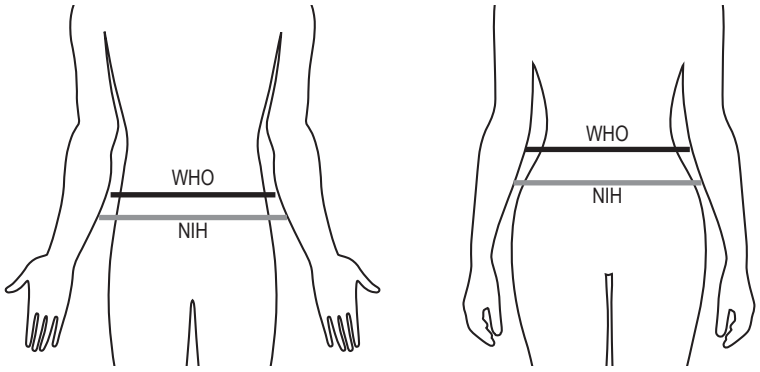
Body mass index measurement and classification

BMI is calculated as weight (kg) divided by height squared (m^2). Height was measured to the nearest 0.1 cm using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA), and weight, to the nearest 0.1 kg with a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada).

Adults aged 18 or older were classified into six BMI categories: underweight (less than 18.5 kg/m^2), normal weight (18.5 to 24.9 kg/m^2), overweight (25.0 to 29.9 kg/m^2), obese class I (30 to 34.9 kg/m^2), obese class II (35 to 39.9 kg/m^2), and obese class III (40 kg/m^2 or more).[1,2,5]

Children and teenagers aged 3 to 17 were classified into BMI categories based on growth curves using age- and sex-specific cut-offs of the WHO. The WHO recommends that 5- to 17-year-olds whose BMI is more than two standard deviations (SD) above the mean

Figure 1
Waist circumference measurement sites for men and women based on World Health Organization (WHO) and National Institutes of Health (NIH) protocols



Note: Following the WHO protocol, the measure is taken midway between the highest point of the iliac crest and the bottom of the ribcage. Following the NIH protocol, the measure is taken at the highest point of the iliac crest.

be considered obese, and those whose BMI is between one and two SD above the mean, overweight.[10] Although the WHO recommends a different set of cut-offs for children younger than 5,[11] for this analysis the one- and two-SD cut-offs were used to define overweight and obesity for children aged 3 and 4.

Analytical techniques

The feasibility of predicting WC based on the NIH protocol (WC_NIH) from WC based on the WHO protocol (WC_WHO) was assessed. Scatter plots and linear regression were used to identify factors associated with the difference between the two measurements. The difference was significantly associated with three variables: WC_WHO, BMI, and age (continuous age for children and adult males, and age group for adult females). Because of the high correlation between WC_WHO and BMI, it was not possible to include both in the regression models. WC_WHO was retained because R-squared values were higher for the models using WC_WHO as a predictor of the difference (data not shown).

The sample was then randomly divided into split-sample A and split-sample B, each containing about 50% of respondents. Split-sample A was used to generate prediction equations using WC_NIH as the outcome and WC_WHO and age as independent variables. Separate prediction equations were generated for men and women (ages 20 to 79) and for boys and girls (ages 3 to 19). Outliers (respondents for whom the difference between WC_NIH and WC_WHO was more than three SD from the mean) were excluded when generating the prediction equations; this was the case for 56 (fewer than 2%) of the 3,202 records in split-sample A.

The prediction equations generated from split-sample A were applied to split-sample B. The WC_NIH value calculated from WC_WHO measurement is referred to as "WC_NIH_predicted." To evaluate the success of the prediction equations, the WC_NIH_predicted measurements from split-sample B were compared with the actual measurements. Outliers in split-sample B were included in this evaluation. The estimates were compared by sex for six age groups: 3 to 5, 6 to 11, 12 to 19, 20 to 39, 40 to 59, and 60 to 79. Comparisons were also made by BMI categories, by sex, for adults and for children.

Using split-sample B, the health risk cut-offs were applied to WC_WHO, WC_NIH and WC_NIH_predicted measurements. The percentages of respondents whose WC put them in a high health risk category were compared among the three measurements. Sensitivity and specificity were calculated to examine the extent to which health risk estimates based on WC_WHO and WC_NIH_predicted measurements agreed with health risk estimates based on WC_NIH measurements (WC_NIH was the "gold-standard").

Sensitivity refers to the percentage of true positives—in this case, the percentage of respondents classified at high health risk based on their WC_NIH measurements who were also classified at high health risk based on their WC_WHO and WC_NIH_predicted measurements. Specificity refers to the percentage of true negatives—in this case, the percentage of respondents who were not classified at high health risk based on the WC_NIH measurements who were also not classified at high health risk based on their WC_WHO and on WC_NIH_predicted measurements. Estimates were also calculated and compared for the combined increased/high health risk group.

Prediction equations for detailed age-sex groups were evaluated (data not shown), but the results were similar to those based on the four prediction equations presented in the current study. Crude adjustments were also evaluated, whereby the differences between WHO and NIH measurements were calculated based on split-sample A and then applied to split-sample B. Crude adjustments were made by detailed age-sex groups and by BMI categories (by sex, for adults and for children). The results based on these crude adjustments (data not shown) were not as favourable as those based on the four regression models.

Estimates of percentages, means and regression coefficients were calculated using weighted data. Differences between estimates were tested for statistical significance, which was set at 0.05. Standard errors were estimated with the bootstrap technique; the number of degrees of freedom was specified as 13 to account for the sample design of the data. Weighted estimates were produced to adjust for unequal probabilities of selection and to take advantage of the adjustments made to reduce non-response bias in the CHMS.

Results

Measurements and equations

For men and women aged 20 to 79, the difference between WC_NIH and WC_WHO was negatively associated with WC_WHO; that is, the larger the WC_WHO measurement, the smaller

Table 1
Equations to predict National Institutes of Health waist circumference measures (WC_NIH_predicted) based on waist circumference measured using World Health Organization protocols (WC_WHO), by age group and sex

Age group (years)/ Sex	Equation	R^2
3 to 19		
Boys	WC_NIH_predicted = -0.89911 + 1.01829*(WC_WHO) + 0.05164*(age)	0.99
Girls	WC_NIH_predicted = -0.70299 + 1.01891*(WC_WHO) + 0.12297*(age)	0.99
20 to 79		
Men	WC_NIH_predicted = 3.83072 + 0.98613*(WC_WHO) - 0.03609*(age)	0.99
Women	WC_NIH_predicted = 3.53771 + 0.98479*(WC_WHO) + 0.21949*(x) (where x is set to 1 if age is 20 to 39; otherwise x=0)	0.98

Table 2
Mean waist circumference based on World Health Organization (WHO) and National Institutes of Health (NIH) protocols, by sex and age group, household population aged 3 to 79, Canada, 2009 to 2011

Sex/Age group (years)	Sample size	Measured			NIH predicted			
		NIH	WHO	Difference (NIH minus WHO)	NIH predicted	Difference (NIH predicted minus NIH measured)	95% confidence interval	
							from	to
	Number	Centimetres						
Boys	**702**	**68.8**	**67.8**	**1.0***	**68.7**	**-0.1**	**-0.3**	**0.0**
3 to 5	151	52.4	52.0	0.4*	52.2	-0.1	-0.4	0.1
6 to 11	277	61.0	60.2	0.8*	60.8	-0.2	-0.5	0.1
12 to 19	274	81.3	79.8	1.5*	81.1	-0.1	-0.4	0.1
Girls	**670**	**66.7**	**64.7**	**2.1***	**66.6**	**-0.2**	**-0.4**	**0.1**
3 to 5	143	51.5	50.8	0.7*	51.5	0.1	-0.2	0.4
6 to 11	274	59.5	58.2	1.3*	59.7	0.2	-0.1	0.5
12 to 19	253	76.1	73.1	3.1*	75.6	-0.5*	-0.9	-0.1
Men	**824**	**95.3**	**94.5**	**0.8***	**95.4**	**0.1**	**-0.2**	**0.4**
20 to 39	270	88.8	87.5	1.3*	89.0	0.2	-0.2	0.6
40 to 59	303	97.1	96.4	0.8*	97.1	-0.1	-0.6	0.5
60 to 79	251	103.2	103.3	-0.1	103.3	0.1	-0.3	0.4
Women	**908**	**89.2**	**87.0**	**2.2***	**89.3**	**0.1**	**-0.3**	**0.4**
20 to 39	355	85.6	82.8	2.8*	85.3	-0.3	-0.9	0.2
40 to 59	284	89.4	87.4	2.1*	89.6	0.2	-0.2	0.5
60 to 79	269	95.2	93.7	1.5*	95.8	0.6	-0.02	1.2

* significantly different from zero ($p < 0.05$)
Note: Estimates are generated from sub-sample B.
Source: 2009 to 2011 Canadian Health Measures Survey.

Table 3
Difference between waist circumference measured according to National Institutes of Health (NIH) and World Health Organization (WHO) protocols, by sex and age group, household population aged 3 to 79, Canada, 2009 to 2011

Sex/Age group (years)	Difference									
	NIH measured versus WHO measured					NIH predicted versus NIH measured				
	≤1 cm	≤2 cm	≤3 cm	≤4 cm	> 4 cm	≤1 cm	≤2 cm	≤3 cm	≤4 cm	>4 cm
	%					%				
Boys	**53**	**81**	**92**	**98**	**2**	**69**	**93**	**97**	**99**	**1**
3 to 5	71	96	100	100	0	74	96	100	100	0
6 to 11	65	88	96	97	3	72	94	96	98	2
12 to 19	36	69	87	98	2	64	91	97	98	2
Girls	**34**	**58**	**75**	**85**	**15**	**53**	**80**	**92**	**95**	**5**
3 to 5	67	87	97	99	1	66	95	99	100	0
6 to 11	47	75	90	96	4	58	85	98	100	0
12 to 19	16	38	57	73	27	45	73	85	91	9
Men	**45**	**75**	**91**	**96**	**4**	**50**	**86**	**94**	**97**	**3**
20 to 39	41	73	91	98	2	53	87	97	99	1
40 to 59	47	76	93	96	4	47	88	95	97	3
60 to 79	49	78	90	95	5	53	79	90	95	5
Women	**25**	**48**	**67**	**81**	**19**	**38**	**71**	**89**	**96**	**4**
20 to 39	15	36	55	69	31	34	63	87	97	3
40 to 59	27	52	75	90	10	46	82	93	97	3
60 to 79	40	59	73	83	17	31	62	82	90	10

Note: Estimates are generated from sub-sample B.
Source: 2009 to 2011 Canadian Health Measures Survey.

the difference (Appendix Table A). For men, the association with age was negative. For women, the association with age was not linear, but when age groups were included in the regression model, a positive association emerged for women aged 20 to 39.

For boys and girls aged 3 to 19, a positive relationship was observed between the difference and both WC_WHO and age. That is, higher values of WC_WHO and age were associated with larger differences.

The prediction equations derived from split-sample A to calculate WC_NIH_predicted based on WC_WHO and age are presented in Table 1.

Measured and predicted waist circumferences

Regardless of age and sex, mean values of WC_NIH significantly exceeded those of WC_WHO: 1.0 cm for boys, 2.1 cm for girls; 0.8 cm for men, and 2.2 cm for women (Table 2). The differences were greatest for girls aged 12 to 19 (3.1 cm) and women aged 20 to 39 (2.8 cm).

Overall, the measured and predicted NIH values were statistically similar (mean differences range from -0.2 cm to 0.1 cm) (Table 2). For the detailed age-sex groups, the only significant difference was for girls aged 12 to 19 (-0.5 cm).

At ages 3 to 19, WC_NIH_predicted was within 1 cm of WC_NIH measured for 69% of boys and 53% of girls (Table 3). A difference of more than 2 cm was observed for 7% of boys and 20% of girls overall, and 27% of girls aged 12 to 19.

Half of men had a predicted NIH value within 1 cm of the measured value; a difference of more than 2 cm was observed in 14% of cases. For women, the predicted value was within 1 cm of the measured value in 38% of cases; in 29% of cases, the difference was more than 2 cm.

For all age-sex groups, the predicted value was within 4 cm of the measured value in at least 90% of cases.

Body mass index

Among children and adolescents, differences between measured WC_

WHO and WC_NIH were greater for those classified as obese: a mean difference of 1.6 cm for boys and 2.5 cm for girls (Table 4). Among adults, differences were greater for those in the normal weight range: 1.3 cm for men and 2.7 cm for women.

The only significant difference between the measured and predicted NIH values was for obese boys (-0.4 cm). Although the measured and predicted NIH means were fairly close for women in obese categories II and III, a difference of more than 2 cm was observed in 50% of cases (Table 5).

Health risk

For men and boys, the percentages whose waist circumference put them in a high health risk category were similar whether based on WHO, NIH or NIH-predicted measures (Table 6). For men, the prevalence of increased/high health risk was slightly elevated when WC was based on NIH rather than on WHO, and the prevalence of increased/high health risk based on the predicted NIH values was similar to the estimate based on the measured NIH values.

For women and girls, the percentages whose waist circumference put them in a high (or increased/high) health risk category were significantly greater based on NIH rather than WHO measures, while estimates based on the predicted NIH values were similar to those based on NIH measured values.

Sensitivity and specificity

Sensitivity and specificity were very high when based on NIH predicted values, meaning that in almost all cases, respondents would be classified in the appropriate health risk category—that is, the same category in which they would be placed based on measured values (Table 7). Sensitivity and specificity were 90% or more, with two exceptions: specificity was somewhat low (70%) for increased/high risk for women aged 60 to 79, and sensitivity for girls aged 12 to 19 was 86% for high risk and 89% for increased/high risk. However, these sensitivity values were an improvement over those based on WHO.

Discussion

In the present study, WC for Canadian adults and children was significantly greater when measured using the NIH protocol than the WHO protocol. The difference was greatest among girls and young women. These findings add to the limited information about WC measurements taken at different sites.[12,13] In a study based on 111 healthy volunteers aged 7 to 83, Wang et al.[12] compared measurements at four sites—immediately below the lowest rib, at the narrowest waist, midway between the lowest rib and iliac crest (WHO), and immediately above the iliac crest (NIH). In that study, males' mean WC at the narrowest waist was significantly lower than at the other three sites. For females, mean WC at each site differed significantly from means at the others, and WC measurements using the NIH protocol significantly exceeded those using the WHO protocol (1.82 cm).[12]

Mason et al.[13] conducted a more recent study (2009) of 542 healthy volunteers aged 20 to 67 to assess whether WC differed across four commonly used measurement sites. They noted no significant differences between sites for men. For women, the mean for each site differed significantly from the means for the others, except for the means at the sites used for the NIH and WHO protocols, which did not differ.[13]

In the present study, the differences that emerged between the NIH and WHO protocols may be related to the sample size or sample characteristics (the Mason sample consisted of healthy adult volunteers, while the CHMS

Table 4
Mean waist circumference based on World Health Organization (WHO) and National Institutes of Health (NIH) protocols, by age group, sex and body mass index (BMI) category, household population aged 3 to 79, Canada, 2009 to 2011

Age group/ Sex/ BMI category	Sample size	Measured			NIH predicted			
		NIH	WHO	Difference (NIH minus WHO)	NIH predicted	Difference (NIH predicted minus NIH measured)	95% confidence interval	
							from	to
	Number	Centimetres						
Ages 3 to 19								
Boys								
Normal weight	438	63.4	62.5	0.9*	63.3	-0.1	-0.3	0.1
Overweight	139	69.7	68.7	1.0*	69.6	-0.1	-0.5	0.2
Obese	111	87.0	85.4	1.6*	86.7	-0.4*	-0.7	-0.01
Girls								
Normal weight	467	62.5	60.5	2.0*	62.3	-0.1	-0.4	0.1
Overweight	137	71.9	69.6	2.3*	71.5	-0.4	-1.0	0.2
Obese	58	90.2	87.7	2.5*	90.2	0.1	-1.0	1.1
Ages 20 to 79								
Men								
Normal weight	219	83.0	81.7	1.3*	83.0	0.0	-0.5	0.5
Overweight	360	95.9	95.1	0.8*	95.9	0.1	-0.4	0.5
Obese class I	174	107.6	107.3	0.3	107.8	0.2	-0.3	0.7
Obese class II/III	67	125.1	125.1	0.0	125.3	0.3	-0.4	0.9
Women								
Normal weight	365	78.2	75.5	2.7*	78.0	-0.2	-0.6	0.2
Overweight	270	91.6	89.6	2.0*	91.8	0.2	-0.3	0.7
Obese class I	156	101.9	100.2	1.7*	102.2	0.3	-0.2	0.9
Obese class II/III	97	117.4	115.9	1.5*	117.8	0.4	-0.7	1.4

* significantly different from zero ($p < 0.05$)
Notes: Estimates are generated from sub-sample B. Estimates for underweight are not included because of small sample sizes.
Source: 2009 to 2011 Canadian Health Measures Survey.

Table 5
Difference between waist circumference measured according to National Institutes of Health (NIH) and World Health Organization (WHO) protocols, by age group, sex and body mass index (BMI) category, household population aged 3 to 79, Canada, 2009 to 2011

Age group/ Sex/ BMI category	Difference									
	NIH measured versus WHO measured					NIH predicted versus NIH measured				
	≤1 cm	≤2 cm	≤3 cm	≤4 cm	> 4 cm	≤1 cm	≤2 cm	≤3 cm	≤4 cm	>4 cm
	%					%				
Ages 3 to 19										
Boys										
Normal weight	59	85	96	98	2	70	94	98	99	1
Overweight	50	85	91	98	2	75	94	98	100	0
Obese	33	61	80	95	5	54	87	92	96	4
Girls										
Normal weight	35	61	76	87	13	56	82	94	96	4
Overweight	30	51	74	81	19	51	75	85	94	6
Obese	38	51	62	77	23	27	79	93	93	7
Ages 20 to 79										
Men										
Normal weight	39	71	92	98	2	49	88	97	99	1
Overweight	47	75	91	96	4	51	86	94	95	5
Obese class I	53	83	93	95	5	56	84	94	99	1
Obese class II/III	42	81	86	95	5	36	80	87	96	4
Women										
Normal weight	18	40	61	76	24	37	72	90	97	3
Overweight	31	55	71	89	11	41	77	92	97	3
Obese class I	40	55	79	88	12	42	68	87	91	9
Obese class II/III	25	47	64	72	28	28	50	76	92	8

Notes: Estimates are generated from sub-sample B. Estimates for underweight are not included because of small sample sizes.
Source: 2009 to 2011 Canadian Health Measures Survey.

Table 6
Percentage with high and increased/high health risk based on waist circumference according to World Health Organization (WHO) and National Institutes of Health (NIH) protocols, by sex and age group, household population aged 12 to 79, Canada, 2009 to 2011

Sex/Age group (years)	High health risk			Increased/High health risk		
	WHO measured	NIH measured	NIH predicted	WHO measured	NIH measured	NIH predicted
	%			%		
Boys aged 12 to 19	**13[E]**	**14[E]**	**14[E]**	**20[E]**	**20[E]**	**20[E]**
Girls aged 12 to 19	**15*[E]**	**22[E]**	**20[E]**	**31***	**41**	**37**
Men	**26**	**29**	**28**	**47***	**50**	**48**
20 to 39	12[E]	16[E]	15[E]	24[E]	27[E]	26[E]
40 to 59	26[E]	30	27[E]	54	56	55
60 to 79	51	50	51	75	76	76
Women	**41***	**46**	**46**	**60***	**70**	**67**
20 to 39	28*	33	30	45*	54	52
40 to 59	42*	47	50	65*	77	70
60 to 79	62*	69	67	79*	85	88

* significantly different from NIH measured ($p<0.05$)
[E] use with caution
Note: Estimates are generated from sub-sample B.
Source: 2009 to 2011 Canadian Health Measures Survey.

sample is representative of the Canadian population aged 3 to 79).

In a comprehensive review, Ross et al.[14] suggested that the protocol used to measure WC does not substantially influence the association between WC and all-cause mortality, cardiovascular disease mortality, and cardiovascular disease and diabetes morbidity. In the present study, the classification of men and boys into the high health risk category was similar regardless of whether WC was measured using the WHO or NIH protocol. However, the prevalence of high health risk for women and girls, and the prevalence of combined increased/high health risk among men were significantly greater when measures were based on the NIH protocols than on the WHO protocols. Similarly, Mason et al.[13] reported that the prevalence of abdominal obesity (more than 88 cm for women; more than 102 cm for men) depended on the WC measurement protocol used. When comparing the WHO and NIH protocols, they noted no difference in the prevalence of abdominal obesity for men (32.7% versus 31.8%), but for women, the prevalence was higher based on the NIH protocol (47.0%) than on the WHO protocol (41.1%).[13] Willis et al.[15] used different WC measurement protocols, but they also noted that classification of health risk depends on which protocol is used. When WC was measured at the umbilicus rather than the minimal waist, 54% more men and 68% more women met the National Cholesterol Education Program criteria for abdominal obesity.[15]

To assess the accuracy of the prediction equations proposed in this study, the difference between the measured NIH value and the predicted NIH value was calculated on a portion of the sample. For the majority of cases, the equations yield statistically similar WC values. And although the results show a difference greater than 2 cm for 50% of women in obese class II and III, this would not be a meaningful difference for health-risk assessment at these levels of BMI.

Table 7
Sensitivity and specificity for high and increased/high health risk according to waist circumference, based on World Health Organization (WHO) and predicted National Institutes of Health (NIH) protocols, by sex and age group, household population aged 12 to 79, Canada, 2009 to 2011

	NIH predicted				WHO measured			
	Sensitivity (% true positives)		Specificity (% true negatives)		Sensitivity (% true positives)		Specificity (% true negatives)	
Sex/Age group (years)	High risk	Increased /High risk	High risk	Increased /High risk	High risk	Increased /High risk	High risk	Increased /High risk
Boys aged 12 to 19	**98**	**98**	**100**	**100**	**94**	**97**	**100**	**100**
Girls aged 12 to 19	**86**	**89**	**99**	**99**	**69**	**77**	**100**	**100**
Men	**91**	**95**	**98**	**98**	**86**	**94**	**99**	**98**
20 to 39	92	95	100	99	73	88	100	99
40 to 59	86	95	98	98	84	94	99	98
60 to 79	96	96	94	89	96	96	94	90
Women	**95**	**93**	**95**	**93**	**88**	**85**	**100**	**99**
20 to 39	88	93	99	96	84	83	100	100
40 to 59	98	90	91	95	89	84	100	99
60 to 79	95	98	95	70	90	92	100	96

Note: Estimates are generated from sub-sample B using NIH measured as the standard.
Source: 2009 to 2011 Canadian Health Measures Survey.

Sensitivity and specificity were calculated to examine the extent to which health risk estimates based on WC_WHO and WC_NIH_predicted measurements agreed with those based on WC_NIH measurements. The sensitivity and specificity values were generally very high for WC_NIH_ predicted values, which means that respondents would be correctly classified into the appropriate health risk category based on the predicted NIH values. In a few cases, the absolute differences between the predicted and measured NIH values were large, but from a clinical perspective, the predicted values result in the correct health risk assessment. These findings suggest that the equations generated from the CHMS dataset can be applied to historical WHO data so that WHO and NIH waist circumference data can be compared. These equations can be applied to a broader age range (including 3- to 19-year-olds) than those proposed by Mason et al.[13]

A strength of this analysis is the large sample from the general population, ranging in age from 3 to 79, which made it possible to examine differences in WC by age, sex and BMI.

The differences between the measurement protocols that emerged are not the result of inter- or intra-tester variability. CHMS staff underwent biannual training with a measurement expert, were regularly observed as they measured the respondents, and were monitored by assessments of the technical error of measurement (TEM)[16] once a year. The TEM compares measurements made by CHMS staff with measurements of a gold standard. To ensure high data quality, a low TEM threshold (1.5%) was set, based on the literature.[16] On average, the relative TEM result was 1.42% for measurements taken using the WHO protocol, and ranged from 1.79% to 3.06% for measurements taken using the NIH protocol, which are very close to the target.

Another strength of the study is that measurements using the two protocols were taken one after another on the same day. Consequently, factors such as food and beverage consumption, time of day and menstrual cycle did not affect differences between them.

What is already known on this subject?

- Abdominal obesity is associated with increased all-cause and cardiovascular mortality, and cardiovascular disease and diabetes morbidity.
- Waist circumference provides information beyond body mass index in the assessment of obesity-related health risk in clinical settings.
- Waist circumference measurements differ, depending on the measurement protocol used.

What does this study add?

- This study examines the difference between waist circumference measured using the World Health Organization (WHO) and National Institutes of Health (NIH) protocols on a large, representative sample of Canadians aged 3 to 79.
- Waist circumference measures based on the WHO and NIH protocols differ significantly.
- The prediction equations in this study can be used to compare estimates based on the WHO and NIH protocols on a wide range of age groups.

Conclusion

The CSEP and the Canadian clinical practice guidelines have adopted the NIH protocol as the standard method for WC measurement in Canada. The prediction equations proposed in this study can be applied to historical Canadian datasets in which the WHO protocol was used. This will allow researchers to assess WC trends over time. ■

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Appendix

Table A
Regression coefficients for difference between waist circumference based on National Institutes of Health and World Health Organization (WHO) protocols, by age group and sex, household population aged 3 to 79, Canada, 2009 to 2011

	Ages 3 to 19		Ages 20 to 79	
	Boys	Girls	Men	Women
	Regression coefficient (B)			
Intercept	-1.20268*	-1.02162*	4.01038*	3.70067*
WHO waist circumference (cm)	0.02574*	0.02349*	-0.01952*	-0.01852*
Age continuous	0.03825*	0.12454*	-0.02881*	
Age group				
20 to 39	...	...	...	0.48826*
40 to 79†	...	...	...	...
Adjusted R squared	0.18	0.25	0.13	0.04

† reference group
* significantly different from zero ($p < 0.05$)
... not applicable
Source: 2009 to 2011 Canadian Health Measures Survey.