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Comparison of Two Waist Circumference Measurement Protocols: The SEARCH for Diabetes in Youth Study

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Abstract

We compared two protocols for measuring waist circumference (WC) in a sample of youth with diabetes.

Participants were enrolled in the SEARCH for Diabetes in Youth Study (SEARCH). WC was measured at least twice by the National Health and Nutrition Examination Survey (NHANES) protocol and twice by the World Health Organization (WHO) protocol. Method-specific averages were used in these analyses.

Among 6248 participants, the mean NHANES WC (76.3 cm) was greater than the mean WHO WC (71.9 cm). Discrepancies between protocols were greater for females than males, among older participants, and in those with higher body mass index (BMI). In both sexes and four age strata, the WCs using either method were highly correlated with BMI z-score. The within-method differences between the first and second measurements were similar for the two methods.

These analyses do not provide evidence that one of these two methods is more reproducible or is a better indicator of obesity as defined by BMI z-scores.

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Keywords

waist circumference measurement; method comparison; diabetes in youth

Among adults, waist circumference (WC) is correlated with the volume of metabolically active abdominal fat (1,2) and is associated with cardiometabolic risk factors and adverse outcomes (3,4). High waist measurement is one of the major criteria defining the so-called metabolic syndrome (5,6). However, numerous protocols for measuring WC lead to different results and discrepant interpretations (7). Several studies, most relatively small, have compared different methods (7-11). Few reports have examined results from different waist measurement methods applied to young populations (9,10), especially those at high risk of cardiometabolic complications. This report compares WC measurements by two different methods from a large sample of children with diabetes who are participants in the SEARCH for Diabetes in Youth Study (SEARCH).

SEARCH is a multicenter population-based study that, starting in 2001, ascertains youth aged less than 20 years with clinically diagnosed, non-gestational diabetes (12-14). Cases are ascertained from geographically defined populations in Ohio, Colorado, South Carolina and Washington, Indian Health Service beneficiaries from four American Indian populations, and enrollees in managed health care plans in California and Hawaii. Institutional review board(s) for each site approved the study protocol. Youth whose diabetes was not secondary to other conditions were invited to a SEARCH study visit. Females who said they were possibly pregnant were excluded from these analyses.

WC was systematically measured by two protocols during each examination. For each measurement, the measuring tape was positioned parallel to the floor with the participant standing, abdomen relaxed, arms at the sides, feet together and facing the observer with the waist exposed.

The method used in the National Health and Nutrition Examination Survey (NHANES) assessed the circumference just above the right iliac crest at the mid-axillary line (15). The method recommended by the World Health Association (WHO) was taken with the tape midway between the lowest rib margin and the iliac crest at the mid-axillary line (16). The NHANES method was always done first and the WHO method was done last by study personnel trained and certified centrally on both methods. For each method, two measurements were taken and if they differed by more than 1.0 cm a third measurement was made. Data from the mean of the two or three measurements for each method are used for analyses.

A “discrepancy” variable was created (mean NHANES value minus mean WHO value), which resulted in a single variable that could be compared using t-tests to test for significant discrepancies between these alternative values overall, by sex, by age group (2-5yrs, 5-9yrs, 10-14 yrs, and 15-25 yrs old), and BMI z-score percentile groupings (<85th percentile, > 85th percentile). The McNemar test was used to test whether the proportion of participants needing a third measurement was significantly different between the two methods. The discrepancy between the absolute difference between the first and second measurement within each measurement technique was tested using a paired t-test. To test whether the correlations between the different waist measurements and body mass index (BMI) were significantly different, we calculated a Z-score using estimated pair-wise correlations among measures that can detect whether pairs of correlations with a common variable (i.e., two assessments of waist measurements with one assessment of BMI) are significantly different

from each other (17). All data analyses were performed using SAS 9.2 (SAS Institute, Cary, NC) and p-values < 0.05 were considered statistically significant.

Both WC measurements were available from 6248 SEARCH participants who were examined between 2001 and 2006 or in 2008. Data were collected at a mean (SD) age of 12.4 (4.5) years with a range of 26 months to 25 years; 5476 participants had type 1 and 729 had type 2 diabetes; 3175 participants were female and 3073 were male. For participants examined on more than one occasion, only data from the first examination with completed measurements by both methods were used. Most data (n=5984) were collected at baseline examinations but 264 youth did not have a complete set suitable for inclusion until a follow-up examination.

The mean (SD) NHANES WC was 76.3 (19.2) cm, 4.5 cm greater than 71.9 (17.1) cm for the WHO WC ($p<0.001$). The mean discrepancy for females was 5.7 (4.4) cm, greater than 3.2 (3.7) cm for males ($p<0.001$), increased with age group from 0.8 (3.1) cm in the < 5 year old age group to 6.2 (4.7) cm among those aged ≥ 15 years ($p<0.001$), and was 5.9 (4.9) cm among those with a BMI z-score ≥ 85 percent but 3.5 (3.5) among those with a lower BMI z-score ($p<0.001$).

The averages of the absolute value of the difference between the first and second measurements (within-method difference) by the NHANES protocol and between the first and second measurements by the WHO protocol are shown in table 1. The only age-sex-obesity stratum in which this within-method difference remained significant was the oldest females. In all other age strata in both sexes, the within-method differences between first and second measurements were similar for the two methods.

A similar proportion of participants required a third measurement (first two measurements differed by > 1.0 cm) by the NHANES method (n=124 males, 145 females) and by the WHO method (n=101 males, 126 females, McNemar's p=0.093 and 0.219, respectively, table 1).

Table 2 shows simple correlations between BMI z-score and WC by each method for males and females separately stratified by age group. The only group in which this discrepancy was statistically significant was <5 year old males.

Several studies have examined WC in children and adolescents and developed standards for various populations of youth (16, 18-21). The diversity of methods and of the interpretation of the findings points to a need for a generally accepted method. One of the studies that compared four methods included the two used in SEARCH. Although that study was limited to obese, primarily Caucasian, youth with a narrower age range (8-17 years) it found a similar difference (4.2 cm) as was found in the present study (4.5 cm). On average, the NHANES method results in a larger WC value, but the discrepancy between the two types of measurements is so variable that it would not be feasible to attempt to extrapolate one from the other. This larger circumference measurement by the NHANES method was observed consistently in females and males, at all ages and obesity levels. In fact, the discrepancy increased significantly with increasing age and BMI percentile categories. However, each method is reproducible as assessed by an immediate repeated measurement and by the infrequent need for a third measurement. Waist circumference in the SEARCH study was collected for the purpose of identifying an association with metabolic parameters and not primarily for the purpose of comparing two measurement methods. To minimize within-method variability, the NHANES measurements were uniformly collected before the WHO measurements but one always worries that this may have introduced a bias. This would have been of some concern if this study had found that one of the methods showed clinically significant differences in measurement reproducibility. As it turned out, neither

method stood out as better and the difference between the two measurements is what would be expected in measurements of different portions of the anatomy.

Despite differences in absolute values, the WC measured by either method is significantly correlated with the BMI z-score and may be a useful estimate of adiposity. Although the generalizability of our findings might be limited because all of our participants had diabetes, the data were collected from a large, diverse national sample of youth across a wide range of age and adiposity status. This study evaluated two of the most common WC methods.

WC measurement methods need to be standardized so that comparisons can be made between studies and over time within studies. The data from SEARCH do not provide evidence that one of these two WC methods is any more reproducible than the other. Further studies evaluating the long-term predictability of various methods for their associations with cardiometabolic risk factors or events will possibly shed more light on potential differences between the protocols. As SEARCH is a longitudinal study, such analyses can be initiated in this population. This preliminary paper established that both protocols yield reproducible results and the authors will now proceed to examine the association of the waist circumferences, as well as waist-to-height ratios, with the various cardiometabolic risk factors that are being collected by SEARCH.

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Table 1

Within-method differences between first and second measurement for each method, discrepancy between these differences, and need for a third waist measurement[*] by each method.

Category	Age Category (years)	BMI percentile	N	NHANES within-method Difference[†]	WHO within-method Difference[†]	Discrepancy[‡] between within-method diffferences	p-value from paired t-test	3rd NHANES n (%)	3rd WHO n (%)	McNemar p-value
Male	All	All	3073	0.2946	0.2913	+0.003	0.7068	124 (4.0)	101 (3.3)	0.0926
Female	All	All	3175	0.3246	0.2863	+0.038	<.0001	145 (4.6)	126 (4.0)	0.2191
Male	2-5	< 85th	119	0.2613	0.2252	+0.036	0.1987	2 (1.7)	2 (1.7)	1.0000
		≥85th	72	0.3153	0.2722	+0.043	0.3641	5 (6.9)	3 (4.2)	0.3173
	5-9	< 85th	508	0.2421	0.2563	−0.014	0.4152	10 (2.0)	11 (2.2)	0.8185
		≥ 85th	251	0.3251	0.3211	+0.004	0.9035	14 (5.6)	15 (6.0)	0.8415
	10-14	< 85th	706	0.2712	0.2860	−0.015	0.3746	26 (3.7)	24 (3.4)	0.7518
		≥85th	437	0.3741	0.3378	+0.036	0.2563	28 (6.4)	17 (3.9)	0.0705
	15-25	< 85th	580	0.2653	0.2741	−0.009	0.5489	18 (3.1)	11 (19)	0.1444
		≥85th	400	0.3347	0.3237	+0.021	0.4676	21 (5.3)	18 (4.5)	0.6219
Female	2-5	< 85th	116	0.2422	0.2397	+0.003	0.9361	2 (1.7)	4 (3.5)	0.4142
		≥85th	72	0.2708	0.2236	+0.047	0.2626			
	5-9	< 85th	542	0.3031	0.2756	+0.027	0.1453	28 (5.2)	22 (4.1)	0.3304
		≥85th	260	0.3400	0.3170	+0.024	0.4342	12 (4.6)	16 (6.2)	0.3938
	10-14	< 85th	739	0.2884	0.2729	+0.015	0.3754	26 (3.5)	28 (3.8)	0.7815
		≥85th	509	0.3688	0.3275	+0.041	0.1215	30 (5.9)	25 (4.9)	0.4922
	15-25	< 85th	414	0.3384	0.2698	+0.069	0.0084	18 (4.4)	13 (3.1)	0.3532
		≥85th	523	0.3623	0.2929	+0.069	0.0009	29 (5.5)	18 (3.4)	0.0782

[*] Third measurement done if first and second measurement differ by > 1.0 cm.

[†] Average of the absolute value of the first measurement minus second measurement (in cm).

[‡] Average of the absolute NHANES difference minus the absolute WHO difference (in cm).

Table 2

Correlations between NHANES measurement or the WHO measurement and BMI-z score, and the significance of the discrepancy in these correlations.

Variable	Category	NHANES Correlation	WHO Correlation	z-value*	p-value*
Male					
BMI z-score	Age 2-5	0.4555	0.6655	4.20	<.001
	Age 5-9	0.6655	0.6687	0.48	0.632
	Age 10-14	0.7932	0.7852	−1.88	0.060
	Age 15-25	0.8353	0.8359	0.16	0.870
Female					
BMI z-score	Age 2-5	0.6437	0.6704	1.22	0.223
	Age 5-9	0.6831	0.6814	−0.29	0.775
	Age 10-14	0.8403	0.8413	0.28	0.783
	Age 15-25	0.8205	0.8160	−0.85	0.393

* z-value and p-value for the discrepancy in the correlations between the NHANES and the WHO methods