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Assessing Truncal Obesity in Predicting Cardiometabolic Risk in Children: Clinical Measures versus Dual-energy X-ray Absorptiometry

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Abstract

Aim—The objectives of this study were to: 1) Compare the accuracy of waist:hip ratio (WHR) and waist:height ratio (WHtR) by determining their association with reference-standard measures derived from dual-energy X-ray absorptiometry (DXA) and 2) assess the relationship of DXA, WHR, and WHtR to measures of dyslipidemia, insulin resistance, and inflammation in children.

Methods—Subjects aged four to 21 were prospectively recruited. Truncal obesity by DXA was defined as the trunk fat:height ratio and trunk fat:non-trunk fat ratio. 308 subjects were studied, 246 (80%) were obese.

Results—There was a strong correlation between WHtR and trunk fat:height ($r=0.84$, $p<0.01$). DXA measures of truncal obesity had stronger correlations with measures of cardiometabolic risk than WHR and WHtR. Upon multivariable regression, only WHtR had independent associations with cholesterol/HDL, HOMA-IR, and high-sensitivity c-reactive protein.

Conclusion—WHtR is an accurate measure of truncal obesity. WHtR showed stronger associations to measures of insulin resistance and truncal obesity than WHR.

Keywords

dyslipidemia; insulin resistance; obesity; truncal fat

The contribution of truncal obesity to cardiometabolic risk factors - including dyslipidemia, insulin-resistance, and systemic inflammation - has been well established in adults. This relationship is less well defined in children, in part, due to the numerous methods to define obesity and truncal adiposity in children. Body mass index (BMI) is the most frequent clinically used measure to define obesity, however, it does not properly describe the distribution of fat in the body.(1-4) Clinical screening tools, such as waist:hip ratio (WHR) and waist:height ratio (WHtR), are superior to BMI for evaluating truncal obesity.

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Conflicts of interest statement

The authors have no financial conflicts of interest to disclose.

Previous studies have suggested the clinical utility in using WHR and WHtR to predict cardiometabolic risk.(5-13) However, these measures' accuracy and clinical utility in assessing truncal obesity and cardiometabolic risk should be further validated in children. As such, the objectives of this study were to 1) Evaluate the accuracy of WHR and WHtR in assessing truncal obesity by determining their association with reference-standard measures derived from dual-energy X-ray absorptiometry (DXA) and 2) Assess the relationships of these various measures of truncal obesity to measures of dyslipidemia, insulin resistance, and systemic inflammation in children. We hypothesized WHtR would be a more accurate measure of truncal obesity than WHR and that WHtR would have greater associations with markers of cardiometabolic risk than WHR.

Patients and Methods

This was a retrospective, secondary analysis of a previously performed prospective cross-sectional single-center study whose goal was to assess for racial differences in cardiometabolic risk profiles in obese children. All tests were conducted during a single assessment using a standardized protocol. The institutional review board approved the protocol. Informed consent was obtained from the parents or legal guardians of minors or from participants aged 18 years.

Subject Population

Obese subjects were recruited from the Medical University of South Carolina's childhood obesity management clinic. Non-obese healthy subjects were recruited as control patients. Inclusion criteria for obese patients of the initial study were (1) BMI > 95th percentile, (2) aged four to 21 years and (3) white or African-American population ancestry. Subjects who were pregnant, were taking insulin or were taking oral steroids were excluded. Patients were enrolled consecutively as long as they met inclusion criteria.

Study Procedures

Patients' anthropomorphic assessments (height, weight, hip circumference, and waist circumference) were performed at the Clinical and Translational Research Center. Participants wore light clothing with no footwear during measurements. Weight and height were measured, with the subject standing, to the nearest 0.1 kg and 1 cm, respectively, using a strain gauge scale, which was also equipped with a stadiometer. Waist and hip circumferences were measured to the nearest 0.1 cm using a flexible metric measuring tape with the subject in a standing position. Waist circumference was measured around the abdomen at the level of the umbilicus. Hip circumference was measured at the level of the maximum extension of the buttocks posteriorly in a horizontal plane. Fasting status was confirmed prior to phlebotomy. Labs obtained included serum insulin, glucose, low-density lipoprotein (LDL), very low-density lipoprotein (VLDL), high-density lipoprotein (HDL), triglycerides, and high sensitivity c-reactive protein (hsCRP). Insulin resistance was assessed using homeostatic model assessment – insulin resistance (HOMA-IR).(14) Measures of dyslipidemia included the total cholesterol/HDL ratio and the triglyceride/HDL ratio.

Whole body DXA scans were performed on a Hologic Discovery A DXA scanner (Hologic Inc., Waltham, MA) and analyzed with the software program Hologic APEX software, version 3.0. During the scan, the participant was asked to lie supine on the scanning bed with their arms at their sides. The scanner was calibrated daily with a spine phantom and its performance was monitored as per a quality assurance protocol. Body composition variables included total body fat, percentage body fat and trunk fat mass. Non-trunk fat mass was calculated as total body fat – trunk fat mass.

Measures of truncal obesity

Measures of truncal obesity derived from DXA included 1) trunk fat/non-trunk fat ratio and 2) trunk fat/height ratio. Measures of truncal obesity derived from anthropomorphic measures included 1) WHR and 2) WHtR.

Statistics

The distribution of data was tested using the Shapiro-Wilk test. Differences between obese and non-obese patients were tested using independent t-tests, Mann Whitney U tests, or chi-square tests, as appropriate. Pearson correlation was performed to evaluate for a linear relationship between measures of truncal obesity and measures of cardiometabolic risk. Multivariable regression was used to assess the associations between both WHR and WHtR to measures of dyslipidemia, insulin resistance, and inflammation while controlling for age, sex, race, and BMI Z-score. A p-value less than 0.05 was considered statistically significant. All statistics were performed using IBM SPSS Statistics software v. 24.

Results

A total of 308 subjects were studied; 246 (80%) were obese. Differences in demographic, anthropomorphic, laboratory data, and DXA measures between obese and non-obese patients can be found in Table 1. Age, sex, race, and BMI Z-score were not associated with any of the below outcomes upon multivariable regression analyses.

Measures of truncal obesity – DXA vs. WHR and WHtR

WHR correlated weakly with trunk fat:non-trunk fat ($r = 0.37$, $p < 0.01$) (Figure 1). WHR also correlated weakly with trunk fat:height ($r = 0.29$, $p < 0.01$). WHtR correlated moderately with trunk fat:non-trunk fat ($r = 0.56$, $p < 0.01$) and strongly with trunk fat:height ($r = 0.84$, $p < 0.01$) (Figure 2).

Truncal obesity associations with dyslipidemia

Analysis of the DXA measures found that trunk fat:non-trunk fat correlated with total cholesterol:HDL ($r = 0.38$, $p < 0.01$) and triglyceride:HDL ($r = 0.46$, $p < 0.01$). Trunk fat:height correlated with (LDL+VLDL)/HDL ($r = 0.30$, $p < 0.01$) and triglyceride:HDL ($r = 0.23$, $p < 0.01$).

Analysis of the clinically derived measures found that WHR correlated with total cholesterol:HDL ($r = 0.28$, $p < 0.01$) and triglyceride:HDL ($r = 0.29$, $p < 0.01$). WHtR

correlated with total cholesterol:HDL ($r = 0.31$, $p < 0.01$) and triglyceride:HDL ($r = 0.22$, $p < 0.01$).

Upon multivariable regression of the clinically derived measures of truncal obesity, only WHtR had an independent association with total cholesterol:HDL ($\beta = 0.23$, $p < 0.01$), while WHR did not. In contrast, only WHR had an independent association with triglyceride:HDL ($\beta = 0.20$, $p < 0.01$), while WHtR did not.

Truncal obesity associations with insulin resistance

Analysis of the DXA measures found that trunk fat:non-trunk fat correlated with HOMA-IR ($r = 0.39$, $p < 0.01$). Trunk fat:height correlated slightly better with HOMA-IR ($r = 0.51$, $p < 0.01$).

Analysis of the clinically derived measures found that WHR had a worse correlation with HOMA-IR ($r = 0.26$, $p < 0.01$) than WHtR ($r = 0.42$, $p < 0.01$). Upon multivariable regression of the clinically derived measures of truncal obesity, only WHtR had an independent association with HOMA-IR ($\beta = 0.43$, $p < 0.01$), WHR did not.

Truncal obesity associations with inflammation

Analysis of the DXA measures found that trunk fat:non-trunk fat correlated with hsCRP ($r = 0.42$, $p < 0.01$). Trunk fat:height correlated significantly better with hsCRP ($r = 0.67$, $p < 0.01$).

Analysis of the clinically derived measures found that WHR had a worse correlation with hsCRP ($r = 0.27$, $p < 0.01$) than WHtR ($r = 0.62$, $p < 0.01$). Upon multivariable regression of the clinically derived measures of truncal obesity, only WHtR had an independent association with hsCRP ($\beta = 0.55$, $p < 0.01$), WHR did not.

Discussion

The main findings of this study are that 1) DXA measures of abdominal obesity had a stronger association to measures of dyslipidemia, insulin resistance, and inflammation than the clinically derived measures WHR and WHtR, 2) WHtR was a better measure of abdominal obesity than WHR when compared to DXA, and 3) WHtR had a stronger relationship to measures of dyslipidemia, insulin resistance, and inflammation than WHR.

Few studies have assessed the relationship of DXA derived measures of abdominal obesity to cardiometabolic risk factors in children.(15-17) Similar to the current study, Ali et al found that measures of central adiposity by DXA were associated with insulin resistance and triglyceride levels in adolescents.(15) That study also suggested that these measures were more predictive of metabolic syndrome in adolescents than they were in adults. Our data suggest that the assessment of abdominal obesity by DXA may be useful in the assessment of cardiometabolic risk.

While DXA offers the most accurate assessment of truncal obesity, it is more costly, exposes children to ionizing radiation, and is more time consuming than clinical measurements.(18)

In addition, obtaining DXA in the clinical environment may not be feasible to many practitioners. An alternative method to measure abdominal obesity using clinically derived variables is attractive. A number of studies have suggested using WHR and WHtR as clinically derived measures of abdominal obesity in children.(19-23) However, to our knowledge, this is the first study to assess the accuracy of clinically derived measures to measure abdominal obesity when compared to DXA. We found that WHtR had a stronger correlation to DXA measures of abdominal obesity than WHR ratio. These results suggest that WHtR is a more accurate surrogate for abdominal obesity than WHR when DXA is unavailable. This may be due to the fact that there is less variability in measuring height measurements versus hip measurements.(24)

In this study, we found that WHtR was more strongly associated with dyslipidemia, insulin resistance, and inflammation than WHR in children. This is in line with other previous studies.(25-27) Some studies refute the added value of assessing WHtR. (7, 28, 29) However, the difference in results in those studies may be due to the use of clustered outcome variables. Clustered outcome variables likely result in some data loss and it is unknown if these clustered variables are superior or inferior markers of cardiometabolic risk compared to individual markers in children. Due to WHtR's simplicity, low measurement variability(24), superior association with measures of the metabolic syndrome compared to WHR – to which this study adds evidence, and its superior accuracy as a measure of abdominal obesity when compared to WHR, we suggest WHtR be strongly considered as an important measure of health when following obese patients clinically.

Limitations

The primary foci of this study were serum markers of the metabolic syndrome, therefore, blood pressure was not included in the analysis. There is no commonly accepted reference-standard measure of abdominal obesity, for this study we used measures derived from DXA which is a reference-standard method to assess body composition. The cross-sectional design of the study does not allow us to assess if the relationships between markers of abdominal obesity and cardiometabolic risk can predict cardiovascular outcomes later in life.

Conclusions

DXA measures of abdominal obesity showed stronger relationships to cardiometabolic risk factors compared to clinically derived measures of abdominal obesity. Of the clinically derived measures, WHtR was a more accurate measure of truncal obesity compared to WHR. In addition, WHtR showed stronger associations to measures of insulin resistance and truncal obesity than WHtR. In clinical practice, WHtR may be useful in predicting cardiometabolic risk in obese children.

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List of Abbreviations

BMI	body mass index
DXA	dual-energy X-ray absorptiometry
HDL	high-density lipoprotein
HOMA-IR	homeostatic model assessment – insulin resistance
hsCRP	high sensitivity c-reactive protein
LDL	low-density lipoprotein (LDL)
VLDL	very low-density lipoprotein
WHR	waist:hip ratio

WHtR waist:height ratio

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Key Notes

- The aim of this study was to assess different measures of abdominal obesity to determine which method had the greatest association with measures of the metabolic syndrome in children.
- We found that waist:height accurately measured abdominal obesity when compared to dual-energy absorptiometry.
- Waist:height also had the strongest associations with measures of dyslipidemia, insulin resistance, and inflammation.

Figure 1. Scatterplot displaying the association between waist:hip ratio and trunk fat:non-trunk fat ratio

Figure 2.
Scatterplot displaying the association between waist:height ratio and trunk fat:height ratio

Table 1

Differences between obese and non-obese subjects

	Non-Obese (n= 62)	Obese (n = 246)	p-value
Age (years)	12.2 (4.9)	11.8 (7.1)	0.99
Female, n (%)	41 (66%)	129 (52%)	0.06
White, n (%)	50 (81%)	106 (43%)	< 0.01
Height (cm)	153 (32)	157 (20)	0.08
Weight (cm)	48 (32)	82 (43)	< 0.01
BMI Z-score	0.7 (1.4)	2.4 (0.5)	< 0.01
Hip (cm)	85 ± 16	110 ± 18	< 0.01
Waist (cm)	67 (15)	98 (23)	< 0.01
SBP (mm Hg)	107 (17)	113 (19)	< 0.01
DBP (mm Hg)	61 ± 8	61 ± 8	0.82
Cholesterol (mg/dL)	168 (36)	160 (37)	0.05
Triglycerides (mg/dL)	61 (47)	76 (57)	< 0.01
HDL (mg/dL)	56 ± 12	43 ± 8	< 0.01
LDL (mg/dL)	97 (34)	99 (32)	0.88
VLDL (mg/dL)	12 (10)	15 (11)	< 0.01
Total cholesterol/HDL	3.0 (1.0)	3.7 (1.2)	< 0.01
Triglyceride/HDL	1.2 (1.0)	1.8 (1.8)	< 0.01
Insulin (μIU/mL)	14 (8)	27 (20)	< 0.01
Glucose (mg/dL)	89 (7)	92 (9)	0.01
HOMA-IR	3.0 (1.9)	6.3 (4.7)	< 0.01
% body fat	29 ± 8	41 ± 5	< 0.01
Truncal fat (kg)	4.6 (6.4)	14.4 (10.3)	< 0.01
Total fat (kg)	13.3 (12.9)	32.1 (20.0)	< 0.01
Waist:hip	0.82 ± 0.07	0.90 ± 0.07	< 0.01
Waist:height	0.46 (0.08)	0.62 (0.08)	< 0.01
Trunk:Non-trunk fat	0.58 (0.25)	0.81 (0.21)	< 0.01
Trunk fat:height (g/cm)	31 (38)	92 (51)	< 0.01

Data reported as mean ± standard deviation for parametric data and median (interquartile range) for non-parametric data. BMI = body mass index. DBP = diastolic blood pressure. HDL = high-density lipoprotein. HOMA-IR = homeostatic model assessment – insulin resistance. LDL = low-density lipoprotein. VLDL = very low-density lipoprotein. SBP = systolic blood pressure.