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Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome Markers

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ABSTRACT

Purpose: Waist to hip ratio (WHR) is a valid assessment tool to determine risk for the development or presence of metabolic syndrome, diabetes, and cardiovascular disease in adults. Evidence-based research on its validity with children and adolescents is limited. A retrospective analysis was conducted to determine if WHR in overweight and obese pediatric patients is associated with metabolic syndrome laboratory markers.

Methods: Retrospective chart reviews were performed for 754 patients ages 6 to 17 years who were enrolled in a weight management program. Data collected included WHR, laboratory markers for metabolic disorder, body mass index, demographics, presence of acanthosis nigricans, and Tanner stage.

Results: WHR and high-density lipoprotein were negatively correlated, $r(N = 597) = -0.20$, $p < .001$. WHR and triglycerides were positively correlated, $r(N = 597) = 0.19$, $p < .001$, as were WHR and low-density lipoprotein, $r(N = 596) = 0.09$, $p = .03$, and WHR and insulin, $r(N = 414) = 0.16$, $p = .001$. In a subject sample with very restricted range, a one-way analysis of variance found a significant effect of WHR on body mass index percentile, $F(1, 754) = 22.43$, $p < .001$, $\eta^2 = 0.03$.

Conclusions: Increased WHR correlated in children and adolescents with known indicators that could be suggestive of increased risk for metabolic syndrome, specifically low high-density lipoprotein, high low-density lipoprotein, triglycerides, and insulin. These results suggest that evaluation of WHR may be a useful tool to indicate risk for developing metabolic syndrome and diabetes in children and adolescents. J Pediatr Health Care. (2015) ■, ■-■.

KEY WORDS

Waist hip ratio, childhood obesity, type 2 diabetes, metabolic syndrome

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Childhood obesity is more prevalent now than in all of recorded history. Nearly one in three children and adolescents in the United States are overweight (body mass index [BMI] ≥ 85%-94%) or obese (BMI ≥ 95%). Currently, more than a third of adults and 17% of children and adolescents in the United States are obese (Ogden, Carroll, Kit, & Flegal, 2014; Sardinha et al., 2011). Childhood obesity potentially results in chronic disease previously seen only in the adult population. The acceleration of cardiovascular disease, type 2 diabetes, respiratory difficulties, compromised sleep patterns, psychological illness, and social challenges lead to higher health care costs for overweight and obese children and future adult generations than for their healthy-weight peers. Marder and Chang (2006) found that childhood obesity alone can carry health care costs of nearly $14 billion per year, not including the associated mental, emotional, and physical stress.

As the financial, physiological and mental strain of this epidemic rises, the medical profession needs to shift chronic disease prevention efforts to include children. Risk stratification for obesity and associated diseases in children, including diabetes, metabolic syndrome, and hypercholesterolemia, is now necessary. BMI is increasingly used in medical encounters with children. Although BMI is a useful tool for determining risk for obesity, the additional measurement of waist to hip ratio (WHR) may prove beneficial in assessing persons at risk for metabolic disturbances. National Heart, Lung, and Blood Institute (1998) reports that the World Health Organization (WHO) defines WHR > 0.90 for adult males and > 0.85 in adult females as one of the indicators of metabolic syndrome. WHR is a proven clinical measurement for predicting cardiovascular disease risk in adults (Srikanthan, Seeman, & Karlamangla, 2009; and Welborn, Dhaliwal, & Bennett, 2003).

Although BMI is a useful tool for determining risk for obesity, the additional measurement of waist to hip ratio may prove beneficial in assessing persons at risk for metabolic disturbances.

Fredricks, van Buuren, Fekkes, Verloove-Vanhorick, and Wit (2005) found an expected average trend of decline in WHR from birth to adulthood, with an increase returning during the geriatric period. Thompson (2009) reported that adults between the ages of 18 to 59 years have lower health risks for cardiovascular disease and metabolic disorders when WHR is within the range of 0.70-0.85 for females and 0.80-0.94 for males. Women aged 60 years and older can safely rise to a WHR as high as 0.90 and males to 1.03 (Thompson, 2009). Waist circumference measurements can provide indirect information about visceral adiposity, which tracks with cardiovascular and metabolic risk factors (Barlow, 2007). Although waist circumference measurements are more easily performed than skinfold thickness measurements, according to Barlow (2007), reference values for children that identify risk over and above the risk from BMI category are not available. The ease of obtaining a waist to hip circumference ratio would make it especially useful for a pediatric population if risk standards for children could be identified.

D'Adamo, Santoro, and Caprio (2009) report that metabolic syndrome is a clustering of metabolic abnormalities such as dyslipidemia, elevated waist circumference, insulin resistance, hypertension, and acanthosis nigricans. The International Diabetes Federation (Zimmet et al., 2007) definition of metabolic syndrome among children consists of abdominal obesity and two or more clinical risk features, including high blood pressure, hypertriglyceridemia, low high-density lipoprotein-cholesterol complex (HDL-C), and elevated fasting glucose. Gardner, Parker, Krishnan, and Chalmers (2013) found that metabolic syndrome in children and adults increases the risk of developing type 2 diabetes, cardiovascular disease, and resultant cardiovascular morbidity and mortality. According to the IDF, an insufficient quantity of research data limits the diagnosis of metabolic syndrome in children younger than 10 years (D'Adamo et al., 2009). As shown in Table 1, children 6 to 16 years of age with a waist circumference equal to or greater than 90th percentile have abdominal obesity (Zimmet et al., 2007). These children and adult caregivers should be monitored and counseled extensively regarding the importance of weight reduction and healthy lifestyle habits (D'Adamo et al., 2009). According to the IDF, metabolic syndrome is defined as having abdominal obesity with at least two other factors (Zimmet et al., 2007). Those factors and criteria are presented in Table 1. Ferreira et al. (2011) report that excess body fat may be the most identifiably important risk factor for metabolic syndrome. Early identification by health professionals of metabolic syndrome or factors leading toward the syndrome diagnosis may reduce the adverse consequences associated with central adiposity.

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The purpose of this study was to explore the relationship of WHR measurements to blood serum laboratory values and physical findings associated with metabolic

TABLE 1. International Diabetes Federation–defined metabolic syndrome factors[a]

Factor	Age (year) 6- < 10[b]	10- < 16	16+
Abdominal obesity by WC	≥ 90th percentile	≥ 90th percentile or 16+ years old criteria (if lower)	European males WC ≥ 94 cm; other males ≥ 90 cm Females WC ≥ 80 cm
High triglycerides		≥ 150 mg/dl	≥ 150 mg/dl[c]
Low HDL cholesterol		< 40 mg/dl	Males < 40 mg/dl[c] Females < 50 mg/dl[c]
High BP		Systolic BP ≥ 130 or diastolic BP ≥ 85 mm Hg	Systolic BP ≥ 130 or diastolic BP ≥ 85 mm Hg[c]
High FPG		FPG ≥ 100 mg/dl or type 2 diabetes	FPG ≥ 100 mg/dl or type 2 diabetes

Note. *BP, blood pressure; FPG, fasting plasma glucose; HDL, high-density lipoprotein; WC, waist circumference.*
[a] *Zimmet et al., (2007).*
[b] *Metabolic syndrome was not diagnosed for group.*
[c] *In treatment for the condition.*

syndrome. The primary objective was to identify whether WHR was correlated with blood laboratory values for insulin, low-density lipoprotein (LDL), HDL, triglycerides, and total cholesterol. The secondary objective was to examine differences in WHR for subgroups based on Tanner staging, waist circumference, presence of acanthosis nigricans, BMI, BMI percentile, and demographic variables that include gender, race, and ethnicity.

METHODS

This study was approved by the Florida Hospital Institutional Review Board. All data were analyzed using SPSS version 21 statistical software (SPSS, Inc., Chicago, IL). All data were entered into secure electronic files and de-identified prior to analysis.

Participants

The sample included 754 children and adolescents enrolled in the Florida Hospital for Children's Center for Child and Family Wellness weight management program between May 1, 2010, and May 31, 2012. Patients aged 6 to 17 years with a BMI ≥ 85th percentile for age were included in the study. The study included 452 females (60%) and 302 males (40%). The racial breakdown was 20% African American, 35% White, 39% Hispanic, and 6% other.

Procedure

Informed consent and demographic data such as race, age, gender, and ethnicity were obtained from a questionnaire filled out by the patient and/or adult caregiver at intake. All measures as detailed below were obtained from the patient charts.

Measures

Height

Height was measured using a Seca 216 stadiometer model 2161814009 (Seca Deutschland, Hamburg, Germany). The stadiometer was positioned on a carpeted floor. Patients stood barefoot against the wall with their heels together. Patients were instructed to relax their shoulders, keep their eyes forward, and keep their arms down while their height was obtained at the highest point at the top of head (rounded to the nearest ½ inch).

Weight

Weight was measured with a Tanita bioelectrical impedance (BIA) scale SC-331S (Tanita Corporation of America, Inc., Arlington Heights, IL). Patients were encouraged to urinate to empty the bladder 10 minutes prior to weighing. Standard body type, age, and patient height were recorded by a staff member. Socks and shoes were removed before stepping on the metal foot pads (see the Figure). The ball of each foot covered the forward pad, and the heel of each foot contacted the rear pad. Weight was obtained to the nearest 0.1 lb, and 1.0 lb for clothing estimation was reduced from the recorded weight.

BMI, BMI percentile, and body fat

BMI was calculated by the BIA scale utilizing the standard calculation of weight in kilograms/[height in meters × height in meters], reported in kg/m^2. The Tanita BIA scale also reported the total body fat and the body fat percentage. The BMI was plotted on the age-appropriate Centers for Disease Control and Prevention (CDC, 2009) growth chart to obtain the BMI percentile. Thirty-eight subjects (5%) had a BMI in the 85th to 94th percentile and were categorized as overweight, and 715 subjects (95%) had a BMI > 95th percentile and were categorized as obese.

Body circumferences

Measurements were obtained with a 60-inch (or 120-inch if necessary) round spring-loaded cloth tape measure. Patients stood with their feet together as a staff

FIGURE. Tanita bioelectrical impedance (BIA) scale SC-331S. This figure appears in color online at www.jpedhc.org.

member obtained measurements (rounded to the nearest ¼ inch). Hip circumference was obtained by measuring the widest area of the hips and the greatest protuberance of the buttocks. Waist circumference was obtained by measuring at the umbilicus at the end of exhalation, to allow the diaphragm to return to normal position. Exhalation endpoint was determined by having the patient talk and taking the measurement at the end of the sentence. The waist circumference landmarks—umbilicus, midpoint between the lowest rib and the iliac crest, and just above the iliac crest—are equally effective in identifying all-cause mortality, cardiovascular disease, and diabetes risk, and therefore exercise professionals are encouraged to use the anatomic landmark that works best with the clients (Kravitz, 2010). The umbilicus was selected as the waist circumference landmark because of the ease of reproducibility and identifying the measurement point for the tape as the "belly button" area.

Laboratory tests

Venous serum samples were obtained from the patients and analyzed at a local laboratory to obtain total cholesterol, triglycerides, HDL, LDL, and insulin. Patients were instructed to fast for 8 hours prior to laboratory testing, and the time it took to perform the venous sample test was approximately 30 minutes.

Tanner stage

The Tanner stage was determined on a paper chart by the bariatric pediatrician during the physical examination of the patient. The Tanner scale defines stages based on the development of pubic hair, breast development in females, and testicular volume in males. According to Kapoor (2010), the possible categories are I, I-II, II, II-III, III, III-IV, IV, IV-V, and V. For analysis, the recorded Tanner stages were collapsed into three groups. There were 269 subjects (35.7%) in group 1 (Tanner stage I, I-II), 215 subjects (28.5%) in group 2 (Tanner stage II or III), and 270 subjects (35.8%) in group 3 (Tanner stage IV or V).

Acanthosis nigricans

The presence or absence of the dermatologic condition acanthosis nigricans, which is commonly seen in diabetic or obese individuals, was determined by the bariatric pediatrician based on physical examination. Two hundred sixty-one subjects (35%) had acanthosis nigricans, and 493 subjects (65%) did not have this condition.

RESULTS

WHR and Laboratory Metabolic Disorder Markers

WHR, total cholesterol, LDL, and HDL had fairly normal distributions. Both insulin and triglycerides had distributions that were slightly skewed right. Although LDL and HDL contained a few points that could be considered outliers, the decision was made to retain all values because of the large sample size. Pearson correlation coefficients were computed to assess the relationships, the results of which are presented in Table 2.

WHR and Subgroups

A two-way analysis of variance (ANOVA) was used to determine if there were main or interaction effects on WHR using the following variables: Tanner staging group, acanthosis nigricans, BMI percentile group, gender, and ethnicity. No significant two-way interactions were found, and the only variable that was significant was BMI percentile.

WHR and BMI percentile

A one-way ANOVA found a significant effect in WHR by BMI percentile, $F(1, 754) = 22.43$, $p < .001$, $\eta^2 = 0.029$. The subjects were restricted, because only overweight ($N = 38$) or obese ($N = 716$) subjects were included in this study. The average WHR for overweight subjects was $M = 0.85$ ($SD = 0.07$), whereas the average WHR for obese subjects was $M = 0.90$ ($SD = 0.07$).

TABLE 2. Waist to hip correlations to laboratory metabolic disorder markers, body fat percentage, body mass index, and waist circumference

Variable	*r*
HDL	−0.20**
LDL	0.09*
Triglycerides	0.19**
Insulin	0.16***
Total cholesterol	0.08
Body fat percentage	0.20**
BMI	0.18**
Waist circumference	0.46**

Note. *BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein.*
N = *597 except for insulin (*N = *414); body fat percentage, BMI, waist circumference (*N = *754).*
*p = *.03.*
**p < *.001.*
***p = *.001.*

WHR and Body Fat Percentage, BMI, and Waist Circumference

Pearson correlation coefficients were computed to assess the relationships between WHR and body fat percentage, BMI, and waist circumference, as presented in Table 2. Caution should be exercised when interpreting the significance of the relationship between WHR and waist circumference because waist circumference is a value used in the calculation of the WHR.

Body Fat Percentage, BMI, Waist Circumference, and Metabolic Disease Markers

Pearson correlation coefficients were computed to assess the relationships between body fat percentage, BMI, and waist circumference and the laboratory values in patients who complied with venous serum testing: total cholesterol, HDL, triglycerides, LDL, and insulin. The statistically significant correlations are presented in Table 3.

DISCUSSION

The primary objective of the study was to identify whether WHR was correlated with metabolic disease indicators. The correlations between WHR and the laboratory values were statistically significant except for total cholesterol, p = .06. The secondary objective was to determine if differences in WHR were significant across the following subgroups: Tanner staging, acanthosis nigricans, BMI percentile, gender, and ethnicity. The only variable that was statistically significant in the ANOVA model was BMI percentile. However, the sample was restricted in that it included only overweight and obese subjects. Further, the smaller sample size of only 38 subjects in the overweight group, compared with 716 in the obese group, limits conclusions that can be drawn.

TABLE 3. Significant body fat, body mass index, and waist circumference correlations with laboratory metabolic markers

Variable	Body fat	BMI	Waist circumference
HDL		−0.16**	−0.21**
Triglycerides			0.09*
Insulin	0.29**	0.37**	0.41**

Note. *BMI, body mass index; HDL, high-density lipoprotein.*
N = *597 except for insulin correlations, where* N = *414.*
*p < *.05.*
**p < *.001.*

A major strength of this study is the large sample size. Our results showed statistically significant correlations between WHR and all metabolic disease indicators except total cholesterol. These results support the usefulness of WHR as a tool for identification of metabolic disease risk factors in children and adolescents.

This study did have some limitations. Our primary focus was on blood factors, and therefore we did not include hypertension in our analyses. Waist and hip measurements have an inherent risk of variability, including the time of day measurement was obtained and variable time lapses from the last consumption of food or beverages. Despite adherence to standard protocol for obtaining measurements, the use of multiple examiners may have introduced variability in waist and hip measurements. Data collection was performed by hand and paper charting, which may increase the potential for error. Variation in patient foot size (subjects with smaller feet may not cover the entire Tanita foot pad) may introduce measurement error. Some patients may not have emptied their bladder prior to weighing, which could affect the accuracy of weight, total body fat, and body fat percentile. Multiple laboratories were used for analyzing blood specimens, which may introduce variability in reporting and processing methods. Lastly, WHR does not account for a reduction in both waist and hip circumferences due to weight loss.

If health care professionals are able to utilize a quick yet efficient risk factor determinant in the office or school setting, many at-risk children can receive earlier identification and possible treatment or preventive steps for potential future health issues, including metabolic syndrome, diabetes, dyslipidemia, and early-onset cardiovascular disease. Future research should include a normal weight pediatric population to establish a pediatric risk range, similar to that which exists for adults.

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