Published in final edited form as:

Int J Pediatr Obes. 2010 ; 5(1): 97–101. doi:10.3109/17477160903111722.

Utility of waist circumference percentile for risk evaluation in obese children

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Abstract

Objective—Increased waist circumference has been shown to contribute to cardiovascular risk in obese adults. This study was designed to examine whether routinely assessing waist circumference in obese children adds predictive value for the development of diabetes and other cardiovascular risk factors.

Methods—This is a cross-sectional study on a community sample of 188 apparently healthy obese children 7–11 yrs, 60% black, 39% male. Anthropometry, fasting lipid profile, oral glucose tolerance test, and magnetic resonance imaging of abdominal fat were done. High waist circumference was defined as $\geq 90^{\text{th}}$ percentile for age and sex. Statistical analyses were done to examine the relationship between waist circumference and the different cardiovascular risk factors.

Results—Those with a high waist circumference had significantly lower high-density lipoprotein, higher triglycerides, fasting insulin, insulin response to glucose, subcutaneous and visceral abdominal fat than those with a normal waist circumference. Children with a high waist circumference were 3.6 times more likely than those with a normal waist status to have a low high-density lipoprotein level, 3.0 times more likely to have high triglycerides, and 3.7 times more likely to have a high fasting insulin level.

Conclusions—Obese children with waist circumference at or above the 90th percentile are at higher risk for dyslipidemia and insulin resistance than obese children with normal waist circumference. These results indicate that routine waist circumference evaluation in obese children may help clinicians identify which obese children are at greater risk of diabetes and other cardiovascular disease.

Keywords

insulin resistance; lipids; obesity; visceral fat; waist circumference

Introduction

Waist circumference (WC) is a simple measurement that constitutes one of the criteria for the metabolic syndrome, and has been well recognized in adults to be a useful risk indicator,

independent of measuring body mass index (BMI) (1,2). WC correlates at $r = .80$ with visceral adiposity in children (3), though it can also increase with the deposition of subcutaneous fat. BMI and WC have been shown to jointly predict risk factor clustering among children and adolescents (4,5). In 2004, Fernandez and colleagues published the first percentile tables for waist circumference for U.S. children, based on the Third National Health and Nutrition Examination Survey data (6). Since the publication of the new growth charts including BMI percentiles published by the Centers for Disease Control in 2000 (7), pediatricians have increasingly used BMI percentile to screen for obesity. The purpose of this study is to examine if routinely evaluating WC percentile in obese children will have any additional predictive value for identifying cardiovascular risk.

Methods

One hundred eighty-eight obese children ($\geq 95^{\text{th}}$ BMI percentile, 39% male, 60% black) 7-11 yrs recruited from local public schools, underwent anthropometry, abdominal magnetic resonance imaging (MRI), fasting blood samples, and oral glucose tolerance test (OGTT). Children and parents completed written informed assent and consent. The study was reviewed and approved by the Institutional Review Board of the Medical College of Georgia. Anthropometrics were measured at least twice until consistent measures were obtained. Waist circumference was measured in cm with a Gulick fiberglass tape with tension gauge (M-22C, Creative Health Products, Plymouth MI); with the subject standing, feet slightly apart, and abdomen relaxed, a horizontal measure was taken at the narrowest point of the torso above the umbilicus and below the ribcage. Height and weight were measured by standard methods using a wall-mounted stadiometer and a scale, respectively. BMI percentiles and z-scores (in terms of standard deviations above the population mean) were determined based on current U.S. norms (7). Tanner staging (ratings of breast/testes and pubic hair development) was performed by a pediatrician. Seated blood pressure was measured 5 times at 1 min intervals after a 10 minute rest using a Dinamap device, and the last 3 measures were averaged. Subcutaneous and visceral abdominal adipose tissue (SAAT and VAT) were quantified in cm^3 via magnetic resonance imaging (five 1 cm transverse slices centered around the L4-L5 disk of the lumbar spine). The basic technique was described previously (8). Fasting glucose, insulin, and lipid profile were assayed. Glucose and insulin area under the curve (AUC) during the 2 hour OGTT (1.75 g/kg dextrose based on ideal body weight, samples q30') were calculated via the trapezoidal rule ($n=165$ due to missing data). AUC are reported in mmol/L for glucose and pmol/mL for insulin due to large values.

Clinical cutoffs used to determine abnormal levels were: waist $\geq 90^{\text{th}}$ percentile for age and sex (6), HDL < 1.16 , LDL > 2.82 , cholesterol > 4.37 (9), triglyceride > 2.79 in males and > 2.95 mmol/L in females (10,11), fasting glucose > 5.5 , 2 hr glucose > 7.72 mmol/L (12), and fasting insulin > 90 pmol/L (13). Severe obesity was defined as a BMI z-score of 2.5 or greater. Means and standard deviations are reported in Table 1.

Statistical analyses

Descriptive statistics were calculated for all variables. T-tests were used to examine differences by waist status for BMI z-score, total cholesterol, LDL, HDL, triglycerides, fasting insulin and glucose, 2 hour glucose, insulin and glucose AUC, systolic and diastolic blood pressure, SAAT and VAT. Sensitivity, specificity, and positive predictive value (PPV) of waist status predicting other categorical variables were determined from cross tabulations. Logistic regression, controlling for severe obesity status, was used to examine whether high waist circumference status predicted high total cholesterol, LDL, low HDL, high triglycerides, insulin, impaired fasting glucose (IFG), and impaired glucose tolerance (IGT). Blood pressure status was not analyzed due to low prevalence (4 children with SBP and none with DBP $> 90^{\text{th}}$ percentile)

(14). Distributions were inspected for normality. Natural log transformation was applied to triglycerides, fasting insulin, insulin and glucose AUC, 2 hour glucose, and BMI z-score prior to analysis of continuous variables. All two and three level interactions of sex or Tanner stage (breast/testes, pubic hair) with waist status were examined. All statistical analyses were performed using SAS 9.1.3 and statistical significance was assessed using an alpha level of 0.05.

Results

Table 1 gives the untransformed descriptive statistics for the sample. Comparisons (t-tests) between those with high vs. normal waist circumference are shown in Table 2. Those with a high waist circumference had significantly higher BMI z-scores, lower HDL, higher triglycerides, higher fasting insulin and insulin AUC, and more SAAT and VAT. WC was correlated with SAAT ($r = .79$) and VAT ($r = .51$).

Table 3 provides the cross tabulations of waist status with status on other variables, the sensitivity, specificity and PPV of waist status as a screen, and logistic regression results indicating whether the variables were predicted by waist status with severe obesity status covaried. While the sensitivity of WC status to severe obesity is 97%, the positive predictive value of high waist circumference predicting severe obesity is only 29%, and the specificity is low. Among moderately obese children, waist circumference percentile provides additional information about risk that is not indicated by BMI. High WC was quite sensitive (81%) but not very specific (40-50%) for HDL and triglyceride abnormalities. It was not sensitive or specific for high total cholesterol and LDL. It was moderately sensitive and specific for hyperinsulinemia, resulting in a high positive predictive value (87%). However, it did not predict glucose abnormalities. Children with a high waist circumference were approximately 27 times more likely to have a severe BMI, 3.6 times more likely than those with a normal waist status to have a low HDL level, approximately 3 times more likely to have high triglycerides, and approximately 3.7 times more likely to have a high fasting insulin level. No differences in total cholesterol, LDL, or glucose tolerance were detected. Results were very similar when BMI z-score, instead of severe obesity status, was covaried. No statistically significant interactions were detected.

Discussion

These results in a community sample demonstrate that obese children who have high WC are at higher risk compared to those who have normal WC, regardless of sex or pubertal development, and independent of severe obesity status.

We are not only experiencing an increase in childhood obesity but also an increase in WC among children (15). Though obesity as measured by BMI-for-age is an excellent predictor of cardiovascular risk and the development of diabetes, certain obese individuals seem to have higher risks and are more prone to develop these complications than others (16). Waist circumference is an easily obtained measurement that is a criterion for assessing cardiometabolic risk. WC percentile norms have been developed in Italian (16), Spanish (17), British (18), German (19), as well as American children (6).

Several studies on adults support the use of WC as a predictor for cardiovascular risk (20). In children, Flodmark and colleagues showed that WC correlates to a potentially atherogenic lipoprotein profile in obese 12-14-year-old children (21). Also, the use of WC to predict insulin resistance has been suggested (22). Freedman's team analyzed data from the Bogalusa Heart study on about 3,000 children and adolescents 5–17 years of age and concluded that WC measurement may help to identify children likely to have adverse concentrations of lipids and

insulin (23). Though not a large-scale epidemiological investigation, this study provides detailed data on insulin resistance, glucose tolerance, and visceral fat in a community sample. In this study, correlations of WC with MRI derived measures were strong though somewhat lower than those of Brambilla et al (3).

In summary, obese children who have a WC above the 90th percentile are at higher risk than those with lower WC for dyslipidemia, insulin resistance, and greater visceral and subcutaneous abdominal fat. Routine WC assessment in obese children is a practical tool that may help clinicians identify a subgroup of obese children at greater risk of diabetes and other cardiovascular disease. Because of the high yield of high WC as a screen among obese children, it may be useful to more closely monitor this group of children for the development of risk factors. Though this strategy might not lead to a pharmaceutical intervention, pediatricians should focus their strongest prevention efforts on this high-risk group of obese children who have WC above the 90th percentile (6).

Acknowledgments

A preliminary version of this work was presented as a poster at Pediatric Academic Societies, 2006. This work was supported by NIH R01 DK60692. The authors have no industry links or affiliations.

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References

1. Klein S, Allison DB, Heymsfield SB, et al. Waist Circumference and Cardiometabolic Risk: A Consensus Statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, The Obesity Society; the American Society for Nutrition; and the American Diabetes Association. *Obesity* (Silver Spring) May;2007 15(5):1061–7. [PubMed: 17495180]
2. Janiszewski PM, Janssen I, Ross R. Does waist circumference predict diabetes and cardiovascular disease beyond commonly evaluated cardiometabolic risk factors? *Diabetes Care* Dec;2007 30(12): 3105–9. [PubMed: 17712026]
3. Brambilla P, Bedogni G, Moreno LA, et al. Crossvalidation of anthropometry against magnetic resonance imaging for the assessment of visceral and subcutaneous adipose tissue in children. *Int J Obes (Lond)* Jan;2006 30(1):23–30. [PubMed: 16344845]
4. Katzmarzyk PT, Srinivasan SR, Chen W, Malina RM, Bouchard C, Berenson GS. Body mass index, waist circumference, and clustering of cardiovascular disease risk factors in a biracial sample of children and adolescents. *Pediatrics* Aug;2004 114(2):e198–205. [PubMed: 15286257]
5. Janssen I, Katzmarzyk PT, Srinivasan SR, et al. Combined influence of body mass index and waist circumference on coronary artery disease risk factors among children and adolescents. *Pediatrics* Jun; 2005 115(6):1623–30. [PubMed: 15930225]
6. Fernandez JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. *J Pediatr* Oct;2004 145(4):439–44. [PubMed: 15480363]
7. Ogden CL, Kuczmarski RJ, Flegal KM, et al. Centers for Disease Control and Prevention 2000 growth charts for the United States: Improvements to the 1977 National Center for Health Statistics version. *Pediatrics* Jan;2002 109(1):45–60. [PubMed: 11773541]
8. Owens S, Gutin B, Ferguson M, Allison J, Karp W, Le NA. Visceral adipose tissue and cardiovascular risk factors in obese children. *J Pediatr* Jul;1998 133(1):41–5. [PubMed: 9672508]
9. Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. *Circulation* Dec 17;2002 106(25):3143–421. [PubMed: 12485966]
10. Behrman, RE.; Kliegman, RM.; Arvin, A., editors. *Nelson Textbook of Pediatrics*. 15th. Philadelphia: W. B. Saunders; 1996.

11. Gunn, VL.; Nechyba, C., editors. The Harriet Lane Handbook: A manual for pediatric house officers. 16th. Philadelphia: Mosby; 2002.
12. Report of the expert committee on the diagnosis and classification of diabetes mellitus. *Diabetes Care* 1997;20:1183–97. [PubMed: 9203460]
13. Williams CL, Hayman LL, Daniels SR, et al. Cardiovascular health in childhood: A statement for health professionals from the Committee on Atherosclerosis, Hypertension, and Obesity in the Young (AHOY) of the Council on Cardiovascular Disease in the Young, American Heart Association. *Circulation* Jul 2;2002 106(1):143–60. [PubMed: 12093785]
14. National High Blood Pressure Education Program (NHBPEP). The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics* Aug;2004 114(2 Suppl 4th Report):555–76. [PubMed: 15286277]
15. Li C, Ford ES, Mokdad AH, Cook S. Recent trends in waist circumference and waist-height ratio among US children and adolescents. *Pediatrics* Nov;2006 118(5):e1390–8. [PubMed: 17079540]
16. Zannolli R, Morgese G. Waist percentiles: a simple test for atherogenic disease? *Acta Paediatr Nov*; 1996 85(11):1368–9. [PubMed: 8955469]
17. Moreno LA, Fleta J, Mur L, Rodriquez G, Sarria A, Bueno M. Waist circumference values in Spanish children--gender related differences. *Eur J Clin Nutr Jun*;1999 53(6):429–33. [PubMed: 10403577]
18. McCarthy HD, Jarrett KV, Crawley HF. The development of waist circumference percentiles in British children aged 5.0-16.9 y. *Eur J Clin Nutr Oct*;2001 55(10):902–7. [PubMed: 11593353]
19. Schwandt P, Kelishadi R, Haas GM. First reference curves of waist circumference for German children in comparison to international values: the PEP Family Heart Study. *World J Pediatr Nov*; 2008 4(4):259–66. [PubMed: 19104889]
20. Janssen I, Katzmarzyk P, Ross R. Body mass index, waist circumference, and health risk: evidence in support of current National Institutes of Health guidelines. *Archives of Internal Medicine Oct* 14;2002 162(18):2074–9. 2002. [PubMed: 12374515]
21. Flodmark CE, Sveger T, Nilsson-Ehle P. Waist measurement correlates to a potentially atherogenic lipoprotein profile in obese 12-14-year-old children. *Acta Paediatr Sep*;1994 83(9):941–5. [PubMed: 7819691]
22. Hirschler V, Aranda C, Calcagno Mde L, Maccalini G, Jadzinsky M. Can waist circumference identify children with the metabolic syndrome? *Arch Pediatr Adolesc Med Aug*;2005 159(8):740–4. [PubMed: 16061781]
23. 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. *American Journal of Clinical Nutrition* 1999;69(2):308–17. [PubMed: 9989697]

Table 1

Descriptive Statistics (N=188)

Variable	Mean	SD
Age (yrs)	9.4	1.1
Waist (cm)	78.8	9.2
BMI z-score (SDs)	2.2	0.3
Tanner stage (breast/testes)	1.5	0.8
Tanner stage (pubic hair)	1.4	0.7
Total Cholesterol (mmol/L)	4.23	0.83
LDL (mmol/L)	2.57	0.72
HDL (mmol/L)	1.21	0.28
Triglycerides (mmol/L)	2.08	1.06
Fasting Insulin (pmol/L)	141.6	75
Insulin Area Under the Curve (pmol/mL)	104.4	64.8
Fasting Glucose (mmol/L)	5.16	0.42
2 hour Glucose (mmol/L)	6.81	1.2
Glucose Area Under the Curve (mmol/L)	893.71	133.22
Systolic Blood Pressure (mmHg)	98.0	9.2
Diastolic Blood Pressure (mmHg)	53.5	5.6
Subcutaneous Abdominal Adipose Tissue (cm ³)	297.4	94.2
Visceral Abdominal Adipose Tissue (cm ³)	35.2	15.0

BMI = body mass index, LDL = low-density lipoprotein, HDL = high-density lipoprotein, SD = standard deviation

Table 2

T-tests by waist status.

Variable	High Waist		Normal Waist		p
	Mean	SD	Mean	SD	
BMI z-score	2.3	0.3	2.0	0.2	<.0001
Total Cholesterol (mmol/L)	4.2	0.82	4.28	0.84	.5070
LDL (mmol/L)	2.56	0.73	2.58	0.71	.8635
HDL (mmol/L)	1.15	0.25	1.31	0.29	.0001
Triglycerides (mmol/L)	2.25	1.17	1.78	0.75	.0034
Fasting Insulin (pmol/L)	156.6	70.8	115.2	75	<.0001
Fasting Glucose (mmol/L)	5.17	0.42	5.15	0.43	.7696
2 hour Glucose (mmol/L)	6.82	1.09	6.79	1.39	.8643
Insulin Area Under the Curve (pmol/mL)	117	61.8	82.2	65.4	<.0001
Glucose Area Under the Curve (mmol/L)	893.7	133.2	899.2	133.2	.7802
Systolic Blood Pressure (mmHg)	99.0	9.5	96.3	8.6	.0537
Diastolic Blood Pressure (mmHg)	53.6	5.4	53.3	6.1	.7884
Subcutaneous Abdominal Adipose Tissue (cm ³)	335.9	89.2	229.4	57.2	<.0001
Visceral Abdominal Adipose Tissue (cm ³)	40.4	14.8	26.0	10.3	<.0001

BMI = body mass index, LDL = low-density lipoprotein, HDL = high-density lipoprotein, SD = standard deviation.

Table 3

Cross tabulation and logistic regression of variables predicted by waist status, controlling for severe obesity status. (N=188)

	Cross tabulation					Logistic regression			
	Status	Waist status (n)		Sens	Spec	PPV	OR	95% CI	P
		High	Normal						
Severe obesity	Yes	34	1	.97	.44	.29	27.19	3.63-203.72	.001
	No	85	68						
Total	High	42	32	.57	.32	.35	0.64	0.34-1.23	.180
cholesterol	Normal	77	37						
LDL	High	36	25	.59	.35	.30	0.83	0.43-1.61	.580
cholesterol	Normal	83	44						
HDL	Low	65	15	.81	.50	.55	3.62	1.78-7.34	<.001
cholesterol	Normal	54	54						
Triglycerides	High	26	6	.81	.40	.22	3.03	1.14-8.05	.026
	Normal	93	63						
Fasting insulin	High	103	41	.72	.64	.87	3.74	1.76-7.91	<.001
	Normal	16	28						
Impaired fasting glucose	Yes	22	15	.59	.36	.18	0.85	0.39-1.85	.674
	No	97	54						
Impaired glucose tolerance	Yes	18	11	.62	.35	.17	1.02	0.43-2.40	.973
	No	89	47						

Sens = sensitivity, Spec = specificity, PPV = positive predictive value, OR = odds ratio, CI = confidence interval, LDL = low-density lipoprotein, HDL = high-density lipoprotein. Abnormal levels were defined as: severe obesity, BMI-for-age z-score > 2.5; waist $\geq$ 90th percentile; total cholesterol > 4.37; LDL > 2.82; HDL < 1.16; triglyceride > 2.79 in males, > 2.95 mmol/L in females; fasting insulin > 90 pmol/L; impaired fasting glucose > 5.5; impaired glucose tolerance, 2 hour glucose > 7.72 mmol/L. N = 165 for impaired glucose tolerance due to missing data.