Simple Anthropometric Indices in Relation to Cardiovascular Risk Factors in Chinese Type 2 Diabetic Patients

Hong-Yan Wu[1, 2], Lu-Lu Chen[1], Juan Zheng[1], Yun-Fei Liao[1], and Min Zhou[1]

[1]*Department of Endocrinology, Union Hospital, Tongji Medical School,*
Huazhong Technology University,
Wuhan 430022, Hubei
and
[2]*Department of Endocrinology, Jingzhou No.1 People's Hospital,*
Yangtze University,
Jingzhou 434000, Hubei, P.R. China

Abstract

To determine which is the best anthropometric index among body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR) and waist to height ratio (WHtR) in type 2 diabetic patients, we examined the relationship between these indices and cardiovascular risk factors using partial correlation analysis, chi-square test, logistic regression analysis and Receiver Operator Characteristic (ROC) curves. Partial correlation analysis showed that among the 4 obesity indices, WHtR had the highest *r* values for all the cardiovascular risk factors in both sexes, followed by WC. Chi-square analysis which revealed that an increased WHtR was more strongly associated with hypertension, hypertriglyceridemia (high TG) and low high-density lipoprotein cholesterol (HDL-C) than the other indices. Logistic regression analysis showed that, after controlling for age, the hypertension, high TG and low HDL-C odds ratios of WHtR ≥ 0.5 were 2.56 (95%CI: 1.24, 5.29), 2.87 (95%CI: 1.43, 5.78), 2.59 (95%CI: 1.03, 6.59) in men and 3.75 (95%CI: 1.75, 8.05), 3.21 (95%CI: 1.52, 6.79), 3.62 (95%CI: 1.43, 9.21) in women, respectively. In ROC analysis, the areas under curve of WHtR were the largest for at least one risk factor in both men and women. These results indicated that WHtR had a higher correlation with cardiovascular risk factors than WC, WHR or BMI in newly diagnosed type 2 diabetes. We proposed the measurement of WHtR as a screening tool for cardiovascular risk factors in this population.

Key Words: obesity, waist to height ratio, diabetes mellitus, cardiovascular risk factors

Introduction

The leading cause of mortality in type 2 diabetes is atherosclerotic vascular disease. Obesity is a well-known risk factor for type 2 diabetes mellitus and cardiovascular disease. Simple anthropometric measurements have been used as surrogate measurements of obesity and have more practical value in both clinical practice and for large-scale epidemiological studies. Body mass index (BMI) is the most widely used and a simple measure of body size, and is frequently used to estimate the prevalence of obesity within a population. It is now established that central adiposity shows stronger associations with cardiovascular disease risk and type 2 diabetes mellitus than overall adiposity in general population (5, 25). Thus, measurements of waist circumference (WC) and waist to hip ratio (WHR) have been viewed as alternatives to BMI and are regularly used in the clinical and research settings. WC has been shown to be the best simple measure of both intra-abdominal fat mass and total fat (8, 17), but it was reported (13) that the metabolic risk between people of similar WC with different heights is different. Recent epidemiological studies (10, 14) have shown that waist

Corresponding author: Dr. Lu-Lu Chen, Department of Endocrinology, Union Hospital, 1277 Jiefang Avenue, Wuhan 430022, Hubei, P.R. China. Tel: +86-27-85801744, Fax: +86-27-85356365, E-mail: hongyzn_wu2003@yahoo.com.cn
Received: November 22, 2006; Revised: January 25, 2007; Accepted: March 15, 2007.

to height ratio (WHtR) is an effective abdominal obesity index in predicting the risk of diabetes and coronary heart disease in the general population. Its predicting power is better than WC and WHR. However, few studies have examined the feasibility and effectiveness of WHtR as an abdominal obesity index in predicting the cardiovascular risk factors in Chinese adults with type 2 diabetes mellitus. The aim of this study was to compare the four indices in relation to cardiovascular risk factors in Chinese adults with newly diagnosed type 2 diabetes mellitus to determine which would be the best.

Materials and Methods

Patients

The study group was composed of patients who were newly diagnosed with type 2 diabetes at the Diabetic Clinic of Union Hospital (a teaching hospital of Tongji Medical School, Huazhong Technology Univerity in Wuhan City, Hubei, China). This clinic provides treatment to approximately 15% of the diabetic population of Wuhan and its surrounding areas of central south of China, including both rural and urban area. Type 2 diabetes was diagnosed using the ADA (1997) criteria (fasting glucose ≥ 7.0 mM or postload glucose ≥ 11.1 mM)[1]. Patients with any of the following criteria were excluded: age < 40, diabetes history, or diabetic complications such as coronary artery disease, peripheral arterial disease or previous stroke, for the reason that a previous diagnosis of diabetes or macrovascular complications could have induced a modification of life style or specific therapeutic interventions interfering with the assessed parameters of adiposity. No patient had previously received insulin or oral hypoglycemic drugs or diuretics therapy that would also influence weight. Four hundred and forty-eight Chinese patients were recruited from January 2003 to March 2006. Further exclusion of the patients lacking complete anthropometrical data left 411 patients for the analysis. In general, the subjects had a middle-to-high education level. All the patients had signed informed consent.

Measurements

Participants were seen after a 12-h fast. The interviewers were trained to measure weight and height according to the World Health Organisation (WHO, 1987) standards[2]. Height and weight were measured after the removal of shoes and with the patients wearing light clothing. BMI was calculated as weight (kg)/[height (m)]^2. Both WC and hip circumference were measured to the nearest 0.1 cm in triplicate with a flexible tape before the average value was calculated. WC was measured at the mid-point between the distal border of the ribs and the top of the iliac crest with subjects standing at the end of a normal expiration. Hip circumference was measured at the widest point over the buttocks. The ratio of waist to hip (WHR) and waist to height (WHtR) was calculated. Obesity was defined as a BMI value ≥ 25 kg/m^2 according to the Asia Pacific criteria[3] or WC ≥ 85 cm for men and ≥ 80 cm for women (19, 28) or WHR ≥ 0.9 for men and ≥ 0.85 (1) for women or WHtR ≥ 0.5 in either sex (10, 16).

Sitting blood pressure was measured twice, and the mean reading was used. Participants were classified as hypertensive if they were on treatment for hypertension, had a mean systolic reading (SBP) ≥ 140 mmHg or a mean diastolic reading (DBP) ≥ 90 mmHg.

Biochemical Analyses

Levels of fasting plasma glucose (FPG), serum triglyceridemia (TG), cholesterol, and high-density lipoprotein cholesterol (HDL-C) were measured by enzymatic methods with an autoanalyzer (Hitachi 7170A, Tokyo, Japan) and manufacture's reagent kits. Dyslipidemia was defined as self-reported current treatment with TG-lowering or HDL-C-raising medication or having one or more of the following: TG ≥ 1.7 mM, HDL-C ≤ 0.9 mM for men and ≤ 1.0 mM for women. Glycosylated hemoglobin (HbA1c) was measured by liquid chromatographic methodology using DiaSTAT(tm) (Bio-Rad Laboratories, Hercules, CA, USA).

Statistical Analysis

Partial correlation analysis was performed between cardiovascular risk factors and anthropometric indices after adjusting for age as a continuous variable. Comparison between genders was performed using Student's *t*-tests. Chi square test was used to compare the prevalence of cardiovascular risk factors with BMI, WC, WHR and WHtR as indices of obesity. Logistic regression models were applied to calculate odds ratios

[1] Report of the expert committee on the diagnosis and classification of diabetes mellitus. Diabetes Care 20:1183-1197, 1997.

[2] Measuring obesity-classification and description of anthropometric data. Report on a WHO consultation of the epidemiology of obesity, Warsaw, 21-23. October, 1987.

[3] The Asia-Pacific Perspective: Redefining Obesity and its Treatment. World Health Organization, Western Pacific Region. Geneva: World Health Organization, 2000.

Table 1. Clinical and metabolic characteristics

Variables	Male (n =198)	Female (n = 213)
Age (yr)	53.9 ± 8.3	54.5 ± 8.5
Weight (kg)	72.4 ± 10.0	61.4 ± 8.9*
Height (cm)	169.6 ± 5.6	157.6 ± 4.9*
BMI (kg/m^2)	25.1 ± 2.9	24.7 ± 3.2
BMI ≥ 23	149 (75.3%)	146 (68.5%)
BMI ≥ 25	97 (49.0 %)	113 (53.1%)
WC (cm)	90.6 ± 8.1	85.0 ± 8.3*
WC ≥ 85/80 cm	144 (72.7%)	157 (73.7%)
WHtR	0.53 ± 0.05	0.54 ± 0.06
WHtR ≥ 0.5	147 (74.2%)	155 (72.8%)
WHR	0.92 ± 0.05	0.87 ± 0.06*
WHR ≥ 0.9/0.85 1	20 (60.6%)	130 (61.0%)
FPG (mM)	8.11 ± 1.64	7.79 ± 2.06
HbA1C (%)	8.65 ± 2.64	8.44 ± 2.39
SBP (mmHg)	131.4 ± 19.8	131.6 ± 16.0
DBP (mmHg)	82.3 ± 13.0	79.2 ± 9.9*
BP ≥ 140/90 mmHg	77 (38.9%)	82 (38.5%)
TG (mM)	2.21 ± 1.19	2.03 ± 1.39
TG ≥ 1.7 mM	90 (45.5%)	86 (40.4%)
HDL-C (mM)	1.22 ± 0.40	1.21 ± 0.60
HDL-C ≤ 0.9/1.0 mM	44 (22.2%)	61 (28.6%)

Data are presented as means ± SD or n (%). *$P < 0.05$ for comparison between male and female groups.

Table 2. Distribution of obesity indices among newly diagnosed type 2 diabetics

	Percentile, Male				Percentile, Female			
	25th	50th	75th	90th	25th	50th	75th	90th
BMI (kg/m^2)	23.0	24.9	26.9	28.7	22.2	24.7	26.9	28.7
WC (cm)	84.4	90.3	95.6	100.5	79.5	85.2	91.0	95.0
WHtR	0.50	0.53	0.57	0.60	0.49	0.54	0.58	0.61
WHR	0.89	0.92	0.96	0.98	0.84	0.87	0.92	0.95

(OR) for the presence of cardiovascular risk factors (dependent variables) after adjustment for age, obesity indices treated as categorical variables using the selected cut-off points were considered as independent variables. To further evaluate the accuracy of obesity indices for assessment of at least one metabolic risk, we calculated sensitivity and specificity of obesity indices using receiver operating characteristic (ROC) curves. The area under the ROC curve (AUC) provides a single measure of overall accuracy that is not dependent upon a particular threshold. AUC for the ROC curves and comparison of ROC curves were performed using MedCalc (MedCalc Software, Mariakerke, Belgium). Other statistical analyses were performed with SPSS 13.0. The level of significance for all statistical tests of hypotheses was set at $P < 0.05$. TG values were transformed to the natural logarithm to normalize skewed distribution for statistical testing; however, actual values are displayed.

Results

Characteristics of the Study Population

Subjects' characteristics regarding age, body composition and metabolic risk profile are given in Table 1. According to the BMI cut-off of 25 kg/m^2, 97 males (49.0%) and 113 females (53.1%) were obese, whereas the prevalence of central obesity was 74.2% in men and 72.8% in women using the WHtR cut-off of 0.5. The distribution of BMI, WC, WHR and WHtR were normal. Table 2 shows the 25th, 50th, 75th, 90th percentile values of the four obesity indexes for men and women. Anthropometric indices for women were

Table 3. Partial correlation coefficients between obesity measurements and cardiovascular risk factors

Variables	Male				Female			
	BMI	WC	WHtR	WHR	BMI	WC	WHtR	WHR
SBP	0.16*	0.22**	0.27**	0.09	0.12	0.16*	0.18**	0.09
DBP	0.22**	0.23**	0.24**	0.11	0.25**	0.25**	0.25**	0.10*
lgTG	0.23**	0.31**	0.35**	0.09	0.29**	0.33**	0.35**	0.14*
HDL-C	-0.07	-0.15*	-0.18**	-0.10	-0.09	-0.23**	-0.28**	-0.07
HbA1c	-0.15*	-0.20**	-0.22**	-0.11	-0.24**	-0.25**	-0.26**	-0.21**
FPG	-0.16*	-0.16*	-0.19**	-0.12	-0.22**	-0.24**	-0.23**	-0.18**

Adjusted for age. $*P < 0.05$, $**P < 0.01$

Table 4. Prevalence of cardiovascular risk factors according to BMI, WC, WHR and WHtR

Variables	Male			Female		
	Hypertention n (%)	High -TG n (%)	Low-HDL-C n (%)	Hypertentionn n (%)	High-TG n (%)	Low-HDL-C n (%)
BMI ≥ 25kg/m^2	45(46.4)	52(53.6)	26(23.2)	51(45.1)	54(47.8)	38(33.6)
BMI < 25 kg/m^2	32(31.7)	38(37.6)	18(20.9)	31(31.0)	32(32.0)	23(23.0)
P value	0.034	0.024	0.224	0.034	0.019	0.087
WC ≥ 85/80 cm	63(43.8)	73(50.7)	37(25.7)	69(43.9)	73(46.5)	51(32.5)
WC < 85/80 cm	14(25.9)	17(31.5)	7(13.0)	13(23.2)	13(23.2)	10(17.9)
P value	0.022	0.016	0.055	0.006	0.002	0.038
WHtR ≥ 0.5	65(44.2)	76(51.7)	38(25.9)	72(46.5)	75(48.4)	55(35.5)
WHtR < 0.5	12(23.5)	14(27.5)	6(11.8)	10(17.2)	11(19.0)	6(10.3)
P value	0.009	0.003	0.037	< 0.001	< 0.001	< 0.001
WHR ≥ 0.9/0.85	55(45.8)	62(51.7)	30(25.0)	56(43.1)	56(43.1)	41(31.5)
WHR < 0.9/0.85	22(28.2)	28(35.9)	14(17.9)	26(31.3)	30(36.1)	20(24.1)
P value	0.013	0.029	0.244	0.086	0.315	0.241

always lower than those for men for height, weight, WC and WHR, except for WHtR and BMI for which the gender ratio was closest to 1. The prevalences of hypertension, high TG and low HDL-C were 38.9%, 45.5%, 22.2% in men and 38.5%, 40.4%, 28.6% in women, respectively. Sex differences in metabolic risk factors were observed only for DBP (with lower values in women).

Correlation between Obesity Measurements and Cardiovascular Risk Factors

Table 3 shows the age-adjusted partial correlation coefficients between anthropometric indices and cardiovascular risk factors. WHtR had the highest coefficients for all the risk factors in both sexes, followed by WC. The correlations between WHR and both of blood pressure and lipidemia were weakest. HbA1c and FPG showed a significant inverse correlation with WHtR, WC and BMI. None of the four indices of adiposity showed a significant correlation with TC and LDL-C (data not shown).

Prevalence of Cardiovascular Risk Factors According to BMI, WC, WHR and WHtR

Table 4 shows the prevalence of cardiovascular risk factors according to the four obesity indices, respectively. An increased WHtR was significantly associated with all 3 risk factors (hypertension, high TG and low HDL-C) in both sexes (all $P < 0.01$, except for low HDL-C $P < 0.05$). An increased WC was also significantly associated with all 3 risk factors (in men, all $P < 0.05$, except for low HDL-C $P > 0.05$; in women, all $P < 0.01$, except for low HDL-C $P < 0.05$). BMI was only significantly associated with hypertension and high TG in both sexes (all $P < 0.05$), whereas an increased WHR was only significantly associated with hypertension and high TG in men (all $P < 0.05$).

Table 5. Adjusted odds ratios and 95% confidence intervals for the presence of hypertension and dyslipidaemia according to the obesity status

	Male			Female		
Variables	Hypertention	High -TG	Low-HDL-C	Hypertentionn	High-TG	Low-HDL-C
WHtR ≥ 0.5	2.56(1.24,5.29)	2.87(1.43,5.78)	2.59(1.03,6.59)	3.75(1.75,8.05)	3.21(1.52,6.79)	3.62(1.43,9.21)
WC ≥ 85/80 cm	2.30(1.14,4.64)	2.16(1.11,4.21)	2.47(1.02,6.01)	2.59(1.29,5.20)	2.95(1.46,5.96)	2.26(1.04,4.88)
BMI ≥ 25 kg/m^2	1.96(1.08,3.52)	1.83(1.03,3.24)	0.69(0.34,1.36)	1.86(1.051,3.29)	2.25(1.25,4.04)	2.00(1.05,3.78)
WHR ≥ 0.9/0.85	2.21(1.19,4.09)	1.86(1.03,3.35)	1.38(0.68,2.81)	1.66(0.93,2.96)	1.12(0.63,1.98)	1.31(0.68,2.53)

Adjusted for age.

Table 6. Area under the receiver operating characteristic curve for anthropometric indices as a predictor of at least one cardiovascular risks factor

	Male			Female		
	Cut-off	AUC	95%CI	Cut-off	AUC	95%CI
BMI	24.5	0.587	0.515, 0.657	24.9	0.663	0.595, 0.726
WC	83	0.658	0.588, 0.724	81	0.716	0.651, 0.776
WHR	0.89	0.616	0.545, 0.684	0.86	0.687	0.620, 0.749
WHtR	0.51	0.690	0.621, 0.754	0.50	0.754	0.690, 0.810

AUC = Area under the receiver operating characteristic curve. 95% CI, 95% confidence interval.

Table 7. Difference test of the areas under the ROC curves for each anthropometric index

	Male			Female		
	WC	WHR	WHtR	WC	WHR	WHtR
BMI	$P = 0.087$	$P = 0.572$	$P = 0.016$	$P = 0.100$	$P = 0.603$	$P = 0.002$
WC	~	$P = 0.277$	$P = 0.057$	~	$P = 0.348$	$P = 0.014$
WHR		~	$P = 0.040$		~	$P = 0.035$

Multivariate Logistic Regression Analysis

Table 5 shows adjusted ORs and 95% confidence intervals (CIs) of the 4 obesity indices for the presence of cardiovascular risk factors. Subjects above the selected cut-offs had higher risk for hypertension and dyslipidaemia. Both men and women with WHtR ≥ 0.5 had the highest ORs for hypertension, high TG and low HDL-C.

Accuracy of Obesity Indices for Assessment of One or More Risks Using ROC Curve Analysis

Tables 6 and 7 display the AUC for each anthropometric index as a predictor of at least one risk factor (hypertension, high TG or low HDL-C) and comparison of the AUC. One hundred and forty-three males (72.2%) and 150 females (70.4%) had at least one risk factor. The AUC for WHtR was the largest in both sexes, although the difference between WHtR and WC is marginal in men ($P = 0.057$). The differences of AUC between BMI and WC and between WC and WHR were not significant. The optimal cut-off values in men and women were 24.5 and 24.9 kg/m^2 for BMI, 83 and 81 cm for WC, 0.89 and 0.86 for WHR, 0.51 and 0.50 for WHtR, respectively. The ROC curves of the four anthropometric indices in relation to one or more risk factors in men and women are given in Figures 1 and 2.

Discussion

Diabetic patients tend to have an android pattern of fat distribution, with accumulation of fat in the abdomen regardless of sex (22). Increased intra-abdominal adipose tissue has been suggested to contribute both to the development of type 2 diabetes (7) and to the increased risk of cardiovascular events

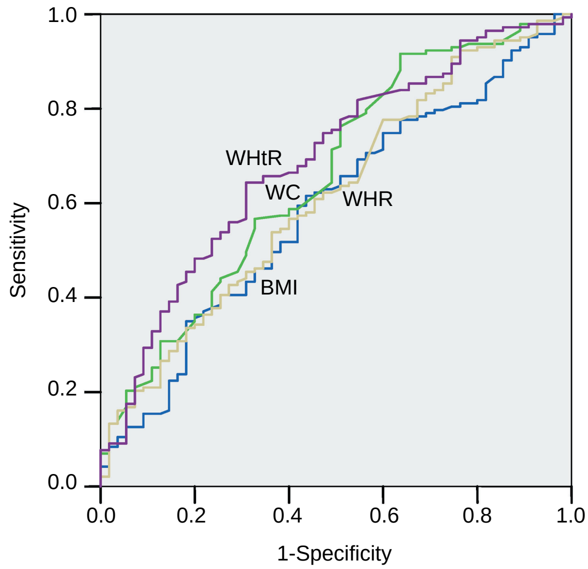

Fig. 1. ROC curves for one or more risk factors in men.

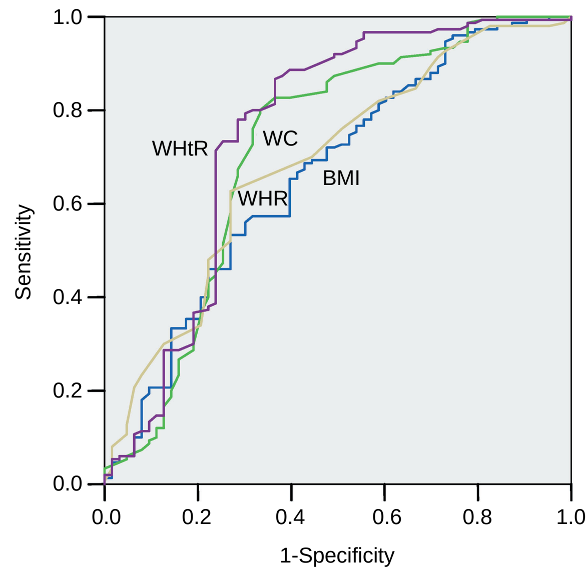

Fig. 2. ROC curves for one or more risk factors in women.

(25). WC could be a better predictor of visceral adipose tissue mass (15) and total body fat (27) when compared to WHR. Moreover, the improvement of cardiovascular risk factors observed during a weight loss program is correlated to the reduction of WC, but not of WHR (9). This suggests that the association between WC and cardiovascular risk factors was also stronger than that of WHR. Therefore, various organizations have proposed WC to assess central obesity. However, differences in cutoff values between men and women and among various ethnic groups (21) may limit its usefulness around the world. Even within the same population, people with identical WC but different heights were observed to have dissimilar risk for hyperglycemia, hypertension and fatty liver (13). For a given WC a short person will obviously look more centrally obese than a taller person. Therefore, height is an important parameter that should not be ignored before adopting an obesity index. WHtR which takes into account differences in height may make up the deficiency and may best predict the risks of cardiovascular disease.

The correlation between WHtR and cardiovascular disease risk factors have been studied extensively worldwide in general population. Various studies (10, 14, 24) have confirmed that WHtR have the potential to be globally applicable to different ethnic populations and to children as well as adults and has the highest predictive value for the detection of cardiovascular disease risk factors. Though type 2 diabetes mellitus is tightly correlated with cardiovascular disease, few studies report the association of WHtR with cardiovascular disease risk factors in Chinese population with type 2 diabetes. A previous diagnosis of diabetes mellitus could induce a modification of life style or specific therapeutic interventions which will interfere with the assessed parameters of adiposity. To avoid this interference, the subjects enrolled were those newly diagnosed of type 2 diabetics with no acute or chronic complications. In this population, there were no significant differences between sexes for distribution of WHtR and BMI while the means and quartiles of WC and WHR for females were significantly different from that of the males. Additionally, the values of height for men were significantly higher than that of women. We speculated that the differences of WC between sexes and ethnicity may be partly caused by height.

The present analyses showed that WHtR was the only anthropometric index which was consistently among the best in association with cardiovascular risk factors from four methods of analysis. The results of the partial correlation analysis show that in both sexes after adjustment for age, WHtR, WC and BMI are significantly correlated with SBP, DBP and TG, but only WHtR and WC are inversely correlated with HDL-C. It is interesting to note the relatively high correlation coefficients between WHtR and SBP, DBP, TG and HDL-C among the four anthropometric indexes. WC was comparable to WHtR in partial correlation analysis but was clearly inferior in chi-square and ROC curve analysis. The optimal cut-off values in men and women for assessment of at least one risk factor from our ROC curve analysis were 24.5 and 24.9 kg/m^2 for BMI, 83 and 81 cm for WC, 0.89 and 0.86 for WHR, 0.51 and 0.50 for WHtR, respectively. Obviously these cut-off values were close to the proposed criteria for obesity.

We chose WHtR level of 0.5 for both males and females as the indicator of central obesity because this WHtR cutoff has previously been demonstrated to correlate with adverse health outcomes for an Asian population (10-12, 16, 18). It has also been suggested for use in European (3, 23) and North American subjects (4). Our results showed that although most of the subjects (about 75%) studied had WHtR ≥ 0.5, only about half were obese according to BMI cut-point (≥ 25kg/m^2). This suggests that visceral obesity was more common than overall obesity in this group. Chi-square analysis revealed that in men, all of the abnormal indices were significantly associated with hypertension and high TG but the significance level was $P < 0.01$ only for an increased WHtR. None of the indices was significantly associated with low HDL-C except for an increased WHtR ($P < 0.05$). In women, both elevated WC and WHtR were strongly associated with hypertension, high-TG ($P < 0.01$) but elevated WHtR was more strongly associated with low HDL-C ($P < 0.01$) than elevated WC ($P < 0.05$). This result confirmed that WC was a better anthropometric index than BMI or WHR in relation to cardiovascular disease risk factors, but WHtR was shown to be a preferred index over WC. In addition, the associations of WHtR with cardiovascular disease risk factors for females (all $P < 0.01$) were a little stronger than that for males (for Low-HDL-C, $P < 0.05$). The difference suggested that the risk factors might be slightly different between men and women and that some factors other than central obesity might exist in the diabetic males. Logistic regression analysis also showed WHtR was most related to hypertension, high-TG and low HDL-C in both men and women. These results are consistent with that from the DAI Study (20), although in that study the samples were composed of Caucasian populations living in southern Europe. The subjects enrolled in the present study were from Asian and with relatively low levels of BMI and WC. These findings indicate that WHtR may have the potential to be globally applicable to different ethnic populations for predicting cardiovascular disease risk factors in type 2 diabetes. Our results were partially inconsistent with that of the study by Xiao *et al*. (26) in which the use of BMI, WC, WHR and conicity index (CoI) in combination was more accurate than using them alone in the prediction of trunk fat mass measured by DXA in Chinese males. Although height also entered the calculation of CoI but WHtR was not taken into consideration in that study. Moreover, DXA can not distinguish between visceral and subcutaneous adipose tissue and is less accurate compared with computed tomography or magnetic resonance imaging for the measurement of fat mass. However WHtR has been shown to be a better indicator of intra-abdominal fat measured by computed tomography than BMI, WC or WHR (2), which supports our results.

There was no correlation between both of TC and LDL-C and WHtR which is in line with that TC and LDL-C are not listed in insulin resistance syndrome. Although hyperglycemia is a strong risk factor for cardiovascular disease, our results show that there is a negative correlation between HbA1c and WHtR, BMI and WC. This seems to be contrary to the conclusion that WHtR had good predictive value for diabetes in general population (10, 13), but similar to that of a previous analysis from Chan (6) concerning the association between obesity and glycemia in diabetic patients. We speculated that it is probably due mainly to insulin deficiency in non-obese diabetic patients in the present study because the mean BMI value in WHtR < 0.5 group (22.6 ± 2.2 kg/m^2) was significantly lower than that in WHtR ≥ 0.5 group (25.7 ± 2.9 kg/m^2).

In conclusion, the present study shows that WHtR, which is cheaper and easier to measure and calculate than BMI, could be a better predictor of abnormalities associated with the metabolic syndrome than WC in Chinese adults affected by type 2 diabetes. The use of WHtR could be an important screening tool to identify cardiovascular disease risk factors in Chinese type 2 diabetic patients.

References

1. Alberti, K.G. and Zimmet, P.Z. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: Diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. *Diabet. Med*. 15: 539 - 553, 1998.
2. Ashwell, M., Lejeune, S. and McPherson, K. Ratio of waist circumference to height may be better indicator of need for weight management. *Br. Med. J*. 312: 377, 1996.
3. Ashwell, M. and Hsieh, S.D. Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health message on obesity. *Int. J. Food Sci. Nutr*. 56: 303-307, 2005.
4. Bertsias, G., Mammas, I., Linardakis, M. and Kafatos, A. Overweight and obesity in relation to cardiovascular disease risk factors among medical students in Crete, Greece. *BMC Public Health* 3: 3, 2003.
5. Bosy-Westphal, A., Geisler, C., Onur, S., Korth, O., Selberg, O., Schrezenmeir, J. and Muller, M.J. Value of body fat mass *vs.* anthropometric obesity indices in the assessment of metabolic risk factors. *Int. J. Obes. (Lond)*. 30: 475-483, 2006.
6. Chan, W.B., Tong, P.C., Chow, C.C., So, W.Y., Ng, M.C. and Ma, R.C. The associations of body mass index, C-peptide and metabolic status in Chinese Type 2 diabetic patients. *Diabet. Med*. 21: 349-353, 2004.
7. Haffner, S.M., Stern, M.P., Hazuda, H.P., Pugh, J. and Patterson, J.K. Do upper-body and centralized adiposity measure different aspects of regional body fat distribution? Relationship to non-insulin-dependent diabetes mellitus, lipids, and lipoproteins. *Diabetes* 36: 43-51, 1987.
8. Han, T.S., McNeill, G., Seidell, J.C. and Lean, M.E. Predicting intraabdominal fatness from anthropometric measures: the influ-

ence of stature. *Int. J. Obes. Relat. Metab. Disord*. 21: 587-593, 1997.
9. Han, T.S., Richmond, P., Avenell, A. and Lean, M.E. Waist circumference reduction and cardiovascular benefits during weight loss in women. *Int. J. Obes. Relat. Metab. Disord*. 21: 127-134, 1997.
10. Ho, S.Y., Lam, T.H. and Janus, E.D. Hong Kong Cardiovascular Risk Factor Prevalence Study Steering Committee. Waist to stature ratio is more strongly associated with cardiovascular risk factors than other simple anthropometric indices. *Ann. Epidemiol*. 13: 683-691, 2003.
11. Hsieh, S.D. and Yoshinaga, H. Abdominal fat distribution and coronary heart disease risk factors in men – waist/height ratio as a simple and useful predictor. *Int. J. Obes*. 19: 585-589, 1995.
12. Hsieh, S.D. and Yoshinaga, H. Waist/height ratio as a simple and useful predictor of coronary heart disease risk factors in women. *Intern. Med*. 34: 1147-1152, 1995.
13. Hsieh, S.D. and Yoshinaga, H. Do people with similar waist circumference share similar health risks irrespective of height? *Tohoku. J. Exp. Med*. 188: 55-60, 1999.
14. Hsieh, S.D., Yoshinaga, H. and Muto, T. Waist-to-height ratio, a simple and practical index for assessing central fat distribution and metabolic risk in Japanese men and women. *Int. J. Obes. Relat. Metab. Disord.* 27: 610-616, 2003.
15. Jia, W.P., Lu, J.X., Xiang, K.S., Bao, Y.Q., Lu, H.J. and Chen, L. Prediction of abdominal visceral obesity from body mass index, waist circumference and waist-hip ratio in Chinese adults: receiver operating characteristic curves analysis. *Biomed. Environ. Sci.* 16: 206-211, 2003.
16. Ko, G., Chan, J., Cockram, C. and Woo, J. Prediction of hypertension, diabetes, dyslipidemia or albuminuria using simple anthropometric indexes in Hong Kong Chinese. *Int. J. Obes. Relat. Metab. Disord*. 23: 1136-1142, 1999.
17. Lemieux, S., Prud'homme, D., Bouchard, C., Tremblay, A. and Despres, J.P. A single threshold value of waist girth identifies normal weight and overweight subjects with excess visceral adipose tissue. *Am. J. Clin. Nutr*. 64: 685-693, 1996.
18. Lin, W.Y., Lee, L.T., Chen, C.Y., Lo, H., Hsia, H.H., Liu, I.L., Lin, R.S., Shau, W.Y. and Huang, K.C. Optimal cut-off values for obesity: using simple anthropometric indices to predict cardiovascular risk factors in Taiwan. *Int. J. Obes. Relat. Metab. Disord*. 26: 1232-1238, 2002.
19. Lu, B., Yang, Y., Song, X., Dong, X., Zhang, Z., Zhou, L., Li, Y., Zhao, N., Zhu, X. and Hu, R. An evaluation of the International Diabetes Federation definition of metabolic syndrome in Chinese patients older than 30 years and diagnosed with type 2 diabetes mellitus. *Metabolism* 55: 1088-1096, 2006
20. Mannucci, E., Alegiani, S.S., Monami, M., Sarli, E. and Avogaro, A. DAI (Diabetes and Informatics) Study Group. Indexes of abdominal adiposity in patients with type 2 diabetes. *J. Endocrinol. Invest.* 27: 535-540, 2004.
21. Molarius, A., Seidell, J.C., Sans, S., Tuomilehto, J. and Kuulasmaa, K. Varying sensitivity of waist action levels to identify subjects with overweight or obesity in 19 populations of the WHO MONICA *Project. J. Clin. Epidemiol.* 52: 1213-1224, 1999.
22. Resnick, H.E. and Howard, B.V. Diabetes and cardiovascular disease. *Annu. Rev. Med*. 53: 245 -267, 2002.
23. Sargeant, L.A., Bennett, F.I., Forrester, T.E., Cooper, R.S. and Wilks, R.J. Predicting incident diabetes in Jamaica: the role of anthropometry. *Obes. Res.* 10: 792 - 798, 2002.
24. Sayeed, M.A., Mahtab, H., Latif, Z.A., Khanam, P.A., Ahsan, K.A. and Banu, A. Waist-to-height ratio is a better obesity index than body mass index and waist-to-hip ratio for predicting diabetes, hypertension and lipidemia. *Bangladesh. Med. Res. Counc. Bull*. 29: 1-10, 2003.
25. Thomas, G.N., Ho, S.Y., Lam, K.S., Janus, E.D., Hedley, A.J. and Lam, T.H. Hong Kong Cardiovascular Risk Factor Prevalence Study Steering Committee. Impact of Obesity and Body Fat Distribution on Cardiovascular Risk Factors in Hong Kong Chinese. *Obes. Res*. 12: 1805-1813, 2004.
26. Xiao, S.M., Lei, S.F., Chen, X.D., Liu, M.Y., Jian, W.X., Xu, H., Tan, L.J., Deng, F.Y., Yang, Y.J., Wang, Y.B., Sun, X., Jiang, C., Guo, Y.F., Guo, J.J., Li, Y.N., Jiang, H., Zhu, X.Z. and Deng, H.W. Correlation and prediction of trunk fat mass with four anthropometric indices in Chinese males. *Br. J. Nutr*. 96: 949-955, 2006.
27. Yang, F., Lv, J.H., Lei, S.F., Chen, X.D., Liu, M.Y., Jian, W.X., Xu, H., Tan, L.J., Deng, F.Y., Yang, Y.J., Wang, Y.B., Sun, X., Xiao, S.M., Jiang, C., Guo, Y.F., Guo, J.J., Li, Y.N., Zhu, X.Z., Papasian, C.J. and Deng, H.W. Receiver-operating characteristic analyses of body mass index, waist circumference and waist-to-hip ratio for obesity: Screening in young adults in central south of China. *Clin. Nutr*. 25: 1030-1039, 2006.
28. Zhou, B.F. Co-operative Meta Analysis Group of the Working Group on Obesity in China. Predictive values of body mass index and waist circumference for risk factors of certain related diseases in Chinese adults—study on optimal cut-off points of body mass index and waist circumference in Chinese adults. *Biomed. Environ. Sci.* 15: 83-96, 2002.