Original Article

Comparison of anthropometric indices of obesity in predicting subsequent risk of hyperglycemia among Chinese men and women in Mainland China

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Background: Obesity is a strong risk factor for hyperglycemia. However, the performance of waist-to-height ratio (WHtR), waist-to-hip ratio (WHR), waist circumference (WC) and body mass index (BMI) in predicting hyperglycemia was inconclusive; and ethnic differences may exist in the associations. Objective: The objective was to compare WHtR, WC, WHR and BMI in predicting hyperglycemia among Chinese adults and identify optimal cut-off points. Design: A community-based prospective cohort study was conducted during 2004-2007 in Nanjing China. WHtR, WC, WHR, BMI, fasting capillary blood glucose, covariates and potential confounders were assessed at baseline and third year of follow-up. Results: The overall cumulative incidence of hyperglycemia was 8.6% (8.0% in men, 9.0% in women). Relative risks across quartiles of WHtR, WHR, WC and BMI were 1.00, 1.33, 1.67, 3.40; 1.00, 2.38, 2.53, 3.87; 1.00, 1.29, 1.75, 2.90; and 1.00, 1.45, 1.49, 2.41 in men, and 1.00, 1.24, 1.99, 2.87; 1.00, 1.14, 2.28, 2.66; 1.00, 1.32, 1.80, 3.14; and 1.00, 1.39, 1.50, 2.08 in women, respectively. *p* for trend was <0.01 for each marker and gender. Adjustment for potential confounders did not change such dose-response relationships materially. ROC analysis indicated that WHtR had the best sum of sensitivity and specificity compared to the other measures .Optimal cut-offs for WHtR, WHR, WC and BMI were 0.51, 0.92, 85 and 24 for men, while 0.55, 0.86, 82 and 25 for women, respectively. Conclusion: WHtR, WHR, WC and BMI were positively associated with subsequent hyperglycemia. WHtR and WC best predicted hyperglycemia among Chinese adults.

Key Words: body mass index, waist circumference, waist-to-hip ratio, waist-to-height ratio, hyperglycemia

INTRODUCTION

Obesity is a substantial risk factor for type 2 diabetes and its complications, including hyperinsulinemia, insulin resistance, dyslipidemia, and cardiovascular diseases, and that different body fat patterning, for example, abdominal adiposity or overall obesity, may have different impacts on the risk of type 2 diabetes.[1-5] Of the methods used to measure body fat and its distributions, anthropometric measurements play an important role in clinical practice.[6-11] Body mass index (BMI) is most widely used to measure total adiposity, while waist-to-height ratio (WHtR), waist-to-hip ratio (WHR) or waist circumference (WC) is a surrogate marker for abdominal adiposity.

Two of the major gaps in the current related literature include: first, it remains controversial regarding what anthropometric measures perform the best in assessing obesity related health risks, and which one and what optimal cut-off points should be used in clinical settings. In addition, the related ethnic differences in these need be better understood. Some studies showed WC as a better indicator of abdominal obesity and a better predictor for diabetes than other anthropometric variables,[12-15] whereas others demonstrated that WHR as the best predictive anthropometric indicator for development of type 2 diabetes (T2D).[16,17] Recently, a few studies have shown WHtR as the best predictor for T2D.[18-21] Moreover, it has been suggested that the predictive power of anthropometric indices is population-dependent,[22] and varies across ethnic groups.[23]

Our study was designed to help fill these major gaps based on data collected from a large community-based cohort of adults in China. We compared the predictive performance of baseline WHtR, WC, WHR, and BMI in predicting subsequent hyperglycemia risk and estimated the related optimal cut-off points, respectively.

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MATERIALS AND METHODS

Study design and sample

This community-based cohort study was conducted between 2004 and 2007 in Nanjing City, one of the largest cities in east China. It has a population of more than 5.9 million within 13 administrative units, eleven urban districts and 2 rural counties in 2004. According to the proportion of regular residents in urban and rural areas, a multi-stage random sampling method was applied. First, we randomly selected three urban districts and one rural county. Then, one community in each chosen district/ county was randomly selected. This resulted in a total number of 4, 3 urban and 1 rural, communities.

After informed consent was obtained, all registered residents aged 35 years or more in the 4 selected communities were invited to participate in the baseline survey in July 2004. Those diagnosed with cancer, diabetes, or hyperglycemia at baseline were excluded from this study, resulting in 3727 men and women eligible for the follow-up survey in July 2007.

At baseline, questionnaires were interviewer-administrated to collect information regarding the participants' diabetic status, family history of diabetes, general socio-demographic information such as age, gender, area of residence, education, occupation, physical activity, dietary intake, and cigarette smoking. In the follow-up, participants were administered a face-to-face interview by the same trained health professionals to collect similar information as at baseline. In addition, the portable blood glucose meters (ONETOUCH SureStep, Johnson & Johnson Medical (China) Ltd., Shanghai, China) were used to test fasting capillary blood glucose concentration for participants at baseline and the third-year follow-up. In total, 3031 subjects completed the follow-up survey (follow-up rate=81.3%).

This study was approved by the academic and ethical committee of Nanjing Municipal Center for Disease Control and Prevention (CDC) in accordance with the internationally agreed ethical principles for medical research involving human subjects (World Medical Association Declaration of Helsinki).

Diagnosis of hyperglycemia

Hyperglycemia was defined using the 1999 WHO criteria,[24] i.e., fasting capillary blood glucose concentration ≥7.0 mmol/L or diagnosed having diabetes.

Anthropometric measures

In the baseline and follow-up surveys, body weight, height, WC and hip circumference were measured by trained health-care professionals at designated general practitioners (GP) clinics. Participants, wearing light indoor clothing and without shoes, had their weight measured to the nearest 0.1 kilograms using a beam balance scale, and height measured to the nearest 0.01 meter using a stadiometer (Wuxi Weight Factory, Wuxi, Jiangsu, China). Using a non-elastic flexible tape, WC was measured to the nearest 0.1 centimeter at the midpoint between costal inferior and iliac crest, while hip circumference was measured as the longest girth of the hip. Each of these anthropometric variables was measured twice and the means of the two readings for each were used in our analysis. We calculated WHtR [waist (cm)/height (cm)], WHR [waist (cm)/hip (cm)] and BMI [weight (kg)/height squared (m^2)] for each participant.

Other main covariates

Information on other main covariates and potential confounders were collected at baseline and the follow-up. (1) Age: participants were classified as young adults (35-49 yrs), middle-aged (50-64 yrs) and the elderly (≥65 yrs). (2) Educational attainment: 0-6 yrs, 7-12 yrs and ≥13 yrs. (3) Smoking status: a) current smoker: smoked at least one cigarette per day continuously for at least one year, or smoked at least eighteen packs in total each year; b) ex-smoker: previously smoked, but subsequently quit smoking for more than one year; and c) non-smokers: those who did not meet the criteria for either current smokers or ex-smokers. (4) Alcohol consumption: They were classified as 'regular drinkers' (those who drank alcohol at least 2 times per week on average, for at least 1 year), 'non- regular drinkers' (those who drank but could not meet the criterion of regular drinkers), and non-drinkers. (5) Physical activity and sedentary behaviors: assessed using the validated Chinese version of International Physical Activity Questionnaire (IPAQ),[25] participants were categorized as: had ≥150 minutes/week, and <150 minutes/week, according to the time they were engaged in moderate intensity physical activity. They were also classified as: had ≥1 hour/day, and <1 hour/day regarding their television viewing time. And (6) Intakes of meat and vegetables (g/day): each was dichotomized into 'high' and 'low' using its related median value (cut-off points: 343 g/day for vegetables intake, and 22 g/day for meat consumption).

Statistical analysis

We conducted a set of analyses stratified by gender. Data were double-entered and cleaned with EpiData 3.0 (The Epidata Association, Odense, Denmark), and managed and analyzed using SPSS 13.0 (SPSS Inc., Chicago, IL, USA). First, we calculated cumulative incidence rates of hyperglycemia according to baseline quartile of WHtR, WHR, WC and BMI, separately. Then, using Cox proportional hazards models, we examined the association between cumulative incidence rates of hyperglycemia and different obesity indices. Three models were introduced: model 1 was a univariate analysis with each obesity measure as the single predictor; model 2 adjusted for participants' age, residence area and educational attainment; model 3 further adjusted for family history of diabetes, cigarette smoking, alcohol drinking, television viewing, physical activity, vegetable intake, meat intake, and self-reported hypertension in addition to the covariates included in model 2.

Next, using receiver operator characteristic (ROC) curve analysis, we compared the predictive power of baseline WHtR, WHR, WC, and BMI on risk of developing hyperglycemia.[26,27] ROC curve is a graphic representation of the relation between sensitivity and specificity for a diagnostic test. With the area under the curve (AUC), it provides a simple tool for comparing the predictive power of different tests or measures, which can assist with the choice of one test over the others. A perfect test will have an AUC of 1.0, and an AUC=0.5 means the test performs no better than chance. ROC curves are drawn by plotting the sensitivity (true positive rate) against the false-positive rate (1–specificity) for several measures or choices. The measure with a ROC curve that is closest to the upper left corner has the highest sensitivity and specificity and, thus, is the best measure. Sensitivity and specificity of the anthropometric measurements were calculated at all possible cut-off points to find the optimal cut-off value, which yielded maximum sum for sensitivity and specificity.

RESULTS

Table 1 shows the characteristics of our study participants. Compared to men, women tended to have higher WHtR and BMI, but less WHR and WC. Participants with hyperglycemia had higher WHtR, WHR, WC and BMI, but less moderate physical activity than those without hyperglycemia. We tested selection bias, but there were no significant demographic differences between participants who could and those could not complete the follow-up survey.

Over the 3-year follow-up, the cumulative incidence rate of hyperglycemia was 8.6% (260/3031), 8.0% (111/1384) in men and 9.0% (149/1647) in women. Table 2 presented the relative risks (RRs) for men and women with different anthropometric indicators to develop hyperglycemia, separately. Cox regression analysis found that increased WHtR, WHR, WC or BMI at baseline predicted elevated risk of hyperglycemia. For men, the RRs were 1.00, 1.33, 1.67, 3.40 (p for trend <0.01) across quartiles of WHtR, 1.00, 2.38, 2.53, 3.87 (p for trend <0.01) across quartiles of WHR, 1.00, 1.29, 1.75, 2.90 (p for trend <0.01) across quartiles of WC, and 1.00, 1.45, 1.49, 2.41 (p for trend <0.01) across quartiles of BMI, while for women, the RRs were 1.00, 1.24, 1.99, 2.87 (p for trend <0.01) across quartiles of WHtR, 1.00, 1.14, 2.28, 2.66 (p for trend <0.01) across quartiles of WHR, 1.00, 1.32, 1.80, 3.14 (p for trend <0.01) across quartiles of WC, and 1.00, 1.39, 1.50, 2.08 (p for trend <0.01) across quartiles of BMI. Adjustment for potential confounders did not change the dose-response relationship between WHtR, WHR, WC and hyperglycemia materially, but did attenuate the association of BMI with hyperglycemia to be non-significant.

Figures 1 a) and b) displayed the AUCs of various anthropometric indices yielded from ROC analysis, WHtR (AUC=0.65 for men and 0.63 for women) and WC (0.64 for men and 0.63 for women) performed the best in predicting hyperglycemia, followed by WHR (0.63 for men and 0.63 for women) and BMI (0.59 for men and 0.57 for women). Table 3 presented the results of our ROC analysis, regarding optimal cut-off values of various anthropometric indices. The optimal cut-off values to predict hyperglycemia were 0.51, 0.92, 85, 24 in men and 0.55, 0.86, 82, 25 in women for WHtR, WHR, WC and BMI in this study, respectively. With the corresponding cut-offs, the largest sum of sensitivity (true positive rate) and specificity (true negative rate) was produced for each anthropometric measurement, 130%, 121%, 122%, 115% in men and 124%, 123%, 123%, 113% in women for WHtR, WHR, WC and BMI.

DISCUSSION

In this community-based cohort of Chinese men and women over a 3-year follow-up, we found that increased values of all four anthropometric indices (WHtR, WHR, WC, or BMI), indicators of elevated adiposity, led to increased risk of developing hyperglycemia. The associations were consistent and strong. This provided further evidence for the impact of obesity on the risk for hyperglycemia.[1-5] we also found that WHtR and WC were the best predictors of hyperglycemia (in men, WHtR > WC > WHR> BMI; and in women WHtR = WC = WHR > BMI)

Table 1. Selected baseline characteristics by gender and the third-year follow-up fasting blood glucose status of Chinese men and women in Nanjing City, China†

Characteristics	Men and women	By Gender		By fasting blood glucose status at 3rd year follow-up ‡	
		Men	Women	Hyperglycemia	Non-hyperglycemia
No. of participants	3031	1384	1647	260	2771
Age (years)	54.3±12.3	54.4±12.4	54.1±12.3	57.9±11.3	53.9±12.3**
Urban area (%)	71.80%	67.10%	75.8%**	80.00%	71.1%**
Educational level (13+yrs)	6.60%	8.70%	4.8%**	2.30%	7.0%**
Family history of diabetes (positive, %)	3.60%	2.80%	4.3%*	6.50%	3.4%**
Current smoker (%)	29.60%	60.80%	3.3%**	27.70%	29.80%
Alcohol drinker (%)	12.70%	26.60%	1.1%**	13.80%	12.60%
Viewing television time≥1 hr/day	80.60%	82.86%	78.7%**	75.80%	81.0%*
Moderate physical activity time ≥150 m/wk	27.00%	29.80%	24.6%**	17.70%	27.9%**
Vegetables intake (g)	54.4±36.4	56.0±39.9	53.0±33.0	50.3±28.0	54.7±37.0
Meat intake (g)	5.9±6.4	6.6±6.9	5.2±5.8**	5.8±6.1	5.8±6.4
WHtR	0.51±0.07	0.50±0.06	0.52±0.07**	0.54±0.07	0.51±0.06**
WHR	0.87±0.07	0.89±0.06	0.86±0.07**	0.89±0.08	0.87±0.07**
WC (cm)	81.9±10.5	82.9±10.2	81.1±10.5**	86.5±10.8	81.5±10.3**
BMI (kg/m^2)	23.7±3.4	23.5±3.2	23.9±3.6**	24.6±3.8	23.6±3.3**
Self-reported hypertension (%)	19.00%	18.60%	19.20%	33.90%	17.5%**

† Continuous variables are presented as Mean ± SD, while categorical variables as percentages.
‡ Hyperglycemia was defined as fasting capillary blood glucose concentration ≥ 7.0mmol/L according to the WHO criterion.
* p <0.05, ** p < 0.01, the difference between men and women, and between participants with and without hyperglycemia was significant.

Table 2. Relative risks (RRs) and 95% CIs for hyperglycemia according to quartiles of baseline anthropometric measures among Chinese men and women in Nanjing City, China*†

Variables	Quartiles of baseline values	Participants with hyperglycemia at 3rd year follow-up (% and n/N)[a]	RR (95%CI)		
			Model 1‡	Model 2§	Model 3¶
Men					
WHtR	< 0.45 (ref)	4.34% (15/346)	1	1	1
	0.45-0.50	5.78% (20/346)	1.33 (0.68, 2.60)	1.20 (0.61, 2.36)	1.19 (0.60, 2.35)
	0.50-0.53	7.23% (25/346)	1.67 (0.88, 3.16)	1.35 (0.70, 2.61)	1.37 (0.70, 2.68)
	≥ 0.53	14.74% (51/346)	3.40 (1.91, 6.05)	2.56 (1.40, 4.71)	2.50 (1.34, 4.67)
WHR	< 0.86 (ref)	3.26% (11/337)	1	1	1
	0.86-0.89	7.76% (27/348)	2.38 (1.18, 4.79)	2.19 (1.08, 4.43)	2.14 (1.06, 4.34)
	0.89-0.93	8.26% (29/351)	2.53 (1.26, 5.07)	2.43 (1.21, 4.88)	2.41 (1.20, 4.83)
	≥ 0.93	12.64% (44/348)	3.87 (2.00, 7.50)	3.41 (1.75, 6.64)	3.34 (1.71, 6.52)
WC (cm)	< 75 (ref)	4.58% (16/349)	1	1	1
	75-83	5.92% (20/338)	1.29 (0.67, 2.49)	1.15 (0.59, 2.24)	1.13 (0.57, 2.22)
	83-90	8.04% (27/336)	1.75 (0.94, 3.25)	1.43 (0.74, 2.74)	1.40 (0.72, 2.72)
	≥ 90	13.30% (48/361)	2.90 (1.65, 5.11)	2.15 (1.16, 3.99)	2.04 (1.08, 3.86)
BMI (kg/m^2)	< 21.26 (ref)	5.04% (17/337)	1	1	1
	21.26-23.38	7.32% (26/355)	1.45 (0.79, 2.68)	1.39 (0.75, 2.51)	1.31 (0.70, 2.45)
	23.38-25.53	7.51% (26/346)	1.49 (0.81, 2.75)	1.35 (0.72, 2.54)	1.31 (0.70, 2.47)
	≥ 25.53	12.14% (42/346)	2.41 (1.37, 4.23)	1.96 (1.08, 3.56)	1.80 (0.98, 3.30)
Women					
WHtR	< 0.47 (ref)	5.10% (21/412)	1	1	1
	0.47-0.51	6.33% (26/411)	1.24 (0.70, 2.21)	1.14 (0.64, 2.03)	1.13 (0.63, 2.03)
	0.51-0.56	10.14% (42/414)	1.99 (1.18, 3.36)	1.67 (0.98, 2.85)	1.63 (0.94, 2.82)
	≥ 0.56	14.63% (60/410)	2.87 (1.75, 4.72)	2.17 (1.28, 3.69)	2.00 (1.16, 3.46)
WHR	< 0.82 (ref)	5.11% (21/411)	1	1	1
	0.82-0.86	5.84% (24/411)	1.14 (0.64, 2.05)	1.05 (0.58, 1.88)	1.00 (0.56, 1.81)
	0.86-0.90	11.62% (48/413)	2.28 (1.36, 3.80)	1.95 (1.16, 3.28)	1.85 (1.10, 3.13)
	≥ 0.90	13.59% (56/412)	2.66 (1.61, 4.39)	2.07 (1.23, 3.47)	1.82 (1.08, 3.08)
WC (cm)	< 74 (ref)	4.96% (20/403)	1	1	1
	74-81	6.54% (27/413)	1.32 (0.74, 2.35)	1.28 (0.72, 2.29)	1.37 (0.76, 2.47)
	81-88	8.94% (37/414)	1.80 (1.05, 3.10)	1.65 (0.95, 2.86)	1.70 (0.97, 2.99)
	≥ 88	15.59% (65/417)	3.14 (1.90, 5.19)	2.62 (1.55, 4.43)	2.54 (1.47, 4.39)
BMI (kg/m^2)	< 21.23 (ref)	6.07% (25/412)	1	1	1
	21.23-23.44	8.42% (33/392)	1.39 (0.83, 2.33)	1.40 (0.83, 2.37)	1.32 (0.78, 2.24)
	23.44-25.96	9.07% (39/430)	1.50 (0.91, 2.47)	1.43 (0.86, 2.38)	1.33 (0.79, 2.23)
	≥ 25.96	12.59% (52/413)	2.08 (1.29, 3.34)	1.83 (1.12, 3.00)	1.59 (0.95, 2.64)

* All the tests for trends across the quintiles were significant, $p<0.01$.
† Hyperglycemia was defined as fasting capillary blood glucose concentration ≥ 7.0mmol/L according to the WHO criterion.
‡ Model 1: unadjusted Cox model.
§ Model 2: adjusted for age, residence area, and educational attainment.
¶ Model 3: adjusted for variables in model 2 + baseline measures of family history of diabetes, cigarette smoking, alcohol drinking, TV viewing, PA, vegetables intake, meat intake, and self-reported hypertension.

according to AUCs. The optimal cut-offs we estimated were consistent to those available ones recommended for Chinese men and women by others.[3,21,28,29] Considering these results and the simplicity for use in the clinical setting and/or at home by patients, we recommend the use of WC.

Another important finding of this study is that BMI performed the worst in predicting later risk of developing hyperglycemia, although BMI has been recommended and widely used to classify overall overweight and obesity.[30] Various anthropometric measures tended to measure different aspects of body fat. BMI tends to indicate overall fatness but not body fat distribution, whereas WHtR, WC and WHR assess abdominal adiposity. Overall obesity and central adiposity are associated with some health outcomes differently.[31, 32]

Although the WHO and some other international health organizations have recommended using WC to measure abdominal obesity in predicting risks of developing diabetes and other health conditions,[33,34] it is still inconclusive which anthropometric variable and what cut-off points are more useful in clinical practice.[12-21] The results regarding the performance of WHtR, WC and WHR in predicting risks for hyperglycemia are mixed. Of studies that compared WC and WHR as indicator of central obesity in predicting hyperglycemia, some suggested WC being better than WHR.[12-18] Several recent studies including ours suggest that WHtR performed the best to help predict hyperglycemia.[18-21] Studies in Caucasian populations suggest that WC is a better measure for central obesity than WHR, while in Asian populations such as Japanese and Chinese, WHtR was the best predictor.[18,19,21] To our knowledge, WHtR has not been tested in predicting hyperglycemia or type 2 diabetes in Caucasian populations. The inconsistent findings on the performance of different anthropometric measures in predicting hyperglycemia or diabetes may be, in part, due to ethnic differences in biology including body composition.[22,23]

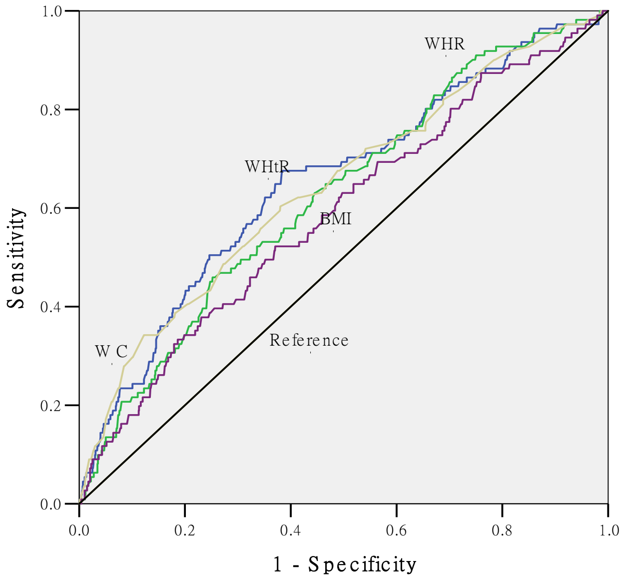

Figure 1 a). Receiver operating characteristic curves for WHtR, WC, WHR and BMI within Chinese men (n=1384). AUC (95%CI) =0.65 (0.60, 0.71) for WHtR, 0.64 (0.59, 0.70) for WC, 0.63 (0.57, 0.68) for WHR, and 0.59 (0.53, 0.65) for BMI.

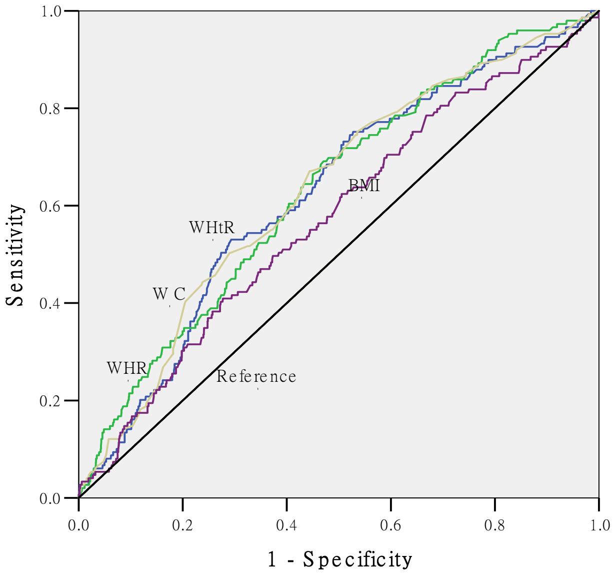

Figure 1 b). Receiver operating characteristic curves for WHtR, WC, WHR and BMI within Chinese women (n=1647). AUC (95%CI) = 0.63 (0.58, 0.67) for WHtR, 0.63 (0.59, 0.68) for WC, 0.63 (0.59, 0.68) for WHR, and 0.57 (0.53, 0.62) for BMI.

Figure 1. The measure with a ROC curve that is closest to the upper left corner has the highest sensitivity and specificity and, thus, is the best measure. Sensitivity and specificity of the anthropometric measurements were calculated at all possible cut-off points to find the optimal cut-off value, which yielded maximum sum for sensitivity and specificity from the ROC curves.

Noteworthy is that the differences in related findings from various studies may also be due to differences in study design, sample and other study methods such as assessments. For example, of the above mentioned four previous studies conducted in Asian populations examining the relationship between WHtR and hyperglycemia, one was a hospital-based cross-sectional study that enrolled subjects of routine health checkup government employees in Japan;[19] the Taiwanese study was also a hospital-based cross-sectional study;[18] one was a community-based cross-sectional study in Guangdong, Mainland China;[21] and another was a population-based follow-up study from Iran.[20] Our study was a community-based follow-up study. Nevertheless, overall these five studies consistently suggested that WHtR might be the best anthropometric index to predict the risk of hyperglycemia.

Most of the optimal cut-offs for WHtR, WC, WHR and BMI we estimated based on data collected from Chinese adults in Nanjing, Mainland China, were higher than those corresponding figures proposed by Lin WY *et al.* for Chinese adults in Taiwan.[18] This may be due to several factors. Our study participants were older (average age was 54) than theirs (average age was 37); second, our data were from a community-based prospective study, whereas theirs were from a hospital based cross-sectional survey. These cut-off points suggested for the Chinese population are quite different from those recommended for Western populations, in particular, regarding WC and BMI.[7,12] However, the optimal cut-offs for 4 anthropometric variables were similar to those previously recom mended for Chinese adults in Mainland China.[3,21,28,29] This might be explained by that all these 5 studies were.

Table 3. The optimal cut-off values, sensitivities and specificities for four various anthropometric measures helping predict hyperglycemia among Chinese men and women in Nanjing city, China

	Based on optimal cut-off value in this study with ROC curves				Based on selected recommended cut-off value*			
	WHtR	WHR	WC (cm)	BMI (kg/m2)	WHtR	WHR	WC (cm)	BMI (kg/m2)
Men								
Cut-off value	0.51	0.92	85	24	0.5	0.9	85	24
Sensitivity (%)	68%	46%	60%	52%	68%	59%	60%	52%
Specificity (%)	62%	75%	62%	63%	56%	58%	62%	63%
Sum of sensitivity & specificity (%)	130%	121%	122%	115%	124%	117%	122%	115%
Women								
Cut-off value	0.55	0.86	82	25	0.5	0.85	80	24
Sensitivity (%)	53%	69%	67%	41%	76%	72%	75%	53%
Specificity (%)	71%	54%	56%	72%	45%	49%	47%	56%
Sum of sensitivity & specificity (%)	124%	123%	123%	113%	121%	121%	122%	109%

*recommended cutoffs for adult Chinese population: WHtR by Guangdong Provincial Cooperation Group for Diabetes Epidemiological Study, China; WHR by Wang WJ *et al.*; WC by Zhai Y *et al.*; and BMI by Cooperative Meta-analysis Group of China Obesity Task Force.

community-based designed and their participants were with the similar mean age and within the same cultural, economic and conventional settings. Furthermore, each of the sums of sensitivity and specificity was greater than the corresponding recommended value for Chinese adults,[3,21,28,29] suggesting that the optimal cut-offs used in this study might perform better than the recommended values in predicting subsequent hyperglycemia.

Some biological mechanisms have been suggested to help explain why WHtR or WC performed better in predicting obesity related health risks than other measures such as BMI. For example, it is suggested that the emergence of visceral fat could be interpreted as a specific marker of systemic lipid over-accumulation, expressed by a parallel rise in circulating triglycerides.[35] The excess lipids may find their way into ectopic sites of lipid storage (e.g., skeletal muscle, liver and pancreatic β cells) where they can cause substantial metabolic disruption,[36,37] thus, compared to hip circumference, body height may impose more influence on the accumulation and/or distribution of body fat, and a large WHtR is a stronger estimator of the visceral adiposity than WC.[38]

To our knowledge, this is the first community-based prospective study to examine the performance of four anthropometric indices in predicting hyperglycemia among men and women within urban and rural areas in Mainland China, where obesity and some related chronic diseases such as T2D, metabolic syndrome and hypertension have been increasing at remarked rates over the past two decades.[39, 40] Our study has several important strengths including its large sample size, prospective study design, good assessment and adjustment for potential confounders and covariates. This study also has some limitations. First, 3 years of follow-up is relatively short. In addition, fasting capillary, but not venous, blood glucose concentration was tested. Long term community-based prospective studies are needed to better understand the complex relationship between body composition being indicated by anthropometric measures and chronic disease and the related ethnic differences.

In conclusion, this study provides good evidence showing that abdominal adiposity measured using WHtR, WC and WHR is a strong risk factor for hyperglycemia. WHtR and WC are good measures of central obesity for predicting the risk of hyperglycemia and they perform better than BMI, and should be used in clinical settings and by the general public for monitoring obesity related health risks.

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AUTHOR DISCLOSURES

None of the authors had a conflict of interest.

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Original Article

Comparison of anthropometric indices of obesity in predicting subsequent risk of hyperglycemia among Chinese men and women in Mainland China

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中国大陆地区成年男女肥胖指数对高血糖症罹患风险的预测

研究背景：肥胖是高血糖症的一个重要危险因素。然而，腰高比(WHtR)、腰臀比(WHR)、腰围(WC)和体质指数(BMI)对高血糖症的预测效用尚未取得一致的研究结论，而且也存在种族差异。研究目的：比较以腰高比、腰臀比、腰围和体质指数预测中国的成人高血糖症的效用，并估计最佳切点值。研究设计：在中国南京于 2004-2007 年间实施的社区为基础的人群队列研究。腰高比、腰臀比、腰围、体质指数、空腹末梢血糖、相关协变量和混杂因素在基线和终点时分别进行了测量。研究结果：总的高血糖症的累计发生率为 8.6%(男性 8.0%，女性 9.0%)。在男性成人中，腰高比、腰臀比、腰围、体质指数预测高血糖症的相对危险度，按 4 等份由低到高分别为 1.00、1.33、1.67、3.40，1.00、2.38、2.53、3.87，1.00、1.29、1.75、2.90，及 1.00、1.45、1.49、2.41；女性成人的相对危险度则为 1.00、1.24、1.99、2.87，1.00、1.14、2.28、2.66，1.00、1.32、1.80、3.14，及 1.00、1.39、1.50、2.08。针对每一个上述变量和性别，p 值都小于 0.05。调整混杂因素并未实质改变这种剂量反应关系。ROC 曲线分析表明腰高比具有最佳的预测高血糖症的灵敏度和特异度。对男性而言，腰高比、腰臀比、腰围、和体质指数的最佳切点值分别为 0.51、0.92、85 和 24；女性则为 0.55、0.86、82 和 25。结论：腰高比、腰臀比、腰围、体质指数都与高血糖症的发生存在正向的联系。针对中国成人的高血糖症，腰高比和腰围的预测效用最好。

关键词：腰高比、腰臀比、腰围、体质指数、高血糖症