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Abdominal obesity and the prevalence of diabetes and intermediate hyperglycaemia in Chinese adults

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Abstract

Objective: To assess the association of indicators of general and abdominal obesity with the prevalence of type 2 diabetes (T2DM) and intermediate hyperglycaemia (IHG) in the Chinese population.
Methods: We used data of 50 905 adults aged 18–79 years in the 2002 China National Nutrition and Health Survey. Recommended Chinese cut-off values were used for BMI (24 kg/m^2) and waist circumference (WC; 85 cm in men, 80 cm in women). Optimal cut-offs for waist:height ratio (WHtR) were determined from analyses of receiver-operating characteristic (ROC) curves.
Results: The prevalence of T2DM and IHG was 2·6 % and 1·9 % respectively. ROC curve analyses indicated 0·5 as the optimal cut-off value for WHtR in both sexes. High BMI, WC and WHtR were all associated with the prevalence of glucose tolerance abnormalities, with the highest prevalence ratio (PR) for high WHtR (men: PR = 2·85, 95 % CI 2·54, 3·21; women: PR = 3·10, 95 % CI 2·74, 3·51). When combining BMI and WHtR, in men either a high BMI or a high WHtR alone was associated with increased risk. Among women, a high BMI without a concomitant high WHtR was not associated with increased glucose tolerance abnormalities risk, whereas a high WHtR was associated with risk irrespective of BMI.
Conclusions: Among the Chinese adult population measures of central obesity are better predictors of glucose tolerance abnormalities prevalence than BMI. A WHtR cut-off point of 0·5 for both men and women can be considered as optimum for predicting (pre-) diabetes and may be a useful tool for screening and health education.

Keywords
Obesity
China
Body mass index
Waist circumference
Waist:height ratio
Type 2 diabetes
Abdominal adiposity
Intermediate hyperglycaemia
Glucose tolerance abnormalities

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With the rapid development of the Chinese economy and society, lifestyle and dietary patterns have changed considerably during the past decades. There is now a double burden of disease, posed by traditional health problems at one end of the spectrum and escalating non-communicable diseases at the other. Recently, the 2002 China National Nutrition and Health Survey (CNNHS)[(1)] showed that the prevalence of overweight in Chinese adults now amounts to 22·8 % and the prevalence of obesity to 7·1 %. The estimated total number of overweight people in China is now about 200 million, and over 60 million Chinese are obese.

Previously, the InterASIA study estimated the prevalence of diabetes in China to be 5·2 % (equivalent to 12·7 million individuals) among men and 5·8 % (13·3 million) among women aged 35–74 years[(2)]. Data from the 2002 CNNHS indicate that there currently are more than 20 million subjects with diabetes in China, and nearly another 20 million people with intermediate hyperglycaemia (IHG) or pre-diabetes[(3)].

As obesity is the main risk factor for diabetes, it is essential to assess the strength of the obesity–diabetes association in the Chinese population and also to provide an estimate of the proportion of diabetes that can be prevented by avoiding overweight and abdominal obesity. Anthropometric indices such as BMI and waist circumference (WC) remain the most commonly used tools for assessing body composition because of their simplicity and low cost, and provide sensitive methods for the estimation of total and central adiposity in different population groups[(4)].

In 1998, the WHO presented international definitions for overweight (i.e. BMI $\geq$ 25 kg/m^2) and central adiposity (i.e. WC $\geq$ 94 cm for men, $\geq$80 cm for women)[(5)]. As it is now well established that the Asian population accumulates fat mass at lower body weight compared with Caucasians[(6)], the Working Group on Obesity in China has recommended the optimal range of healthy weight and appropriate cut-off points of BMI and WC specifically

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for Chinese adults. In these recommendations overweight is defined as BMI $\geq$ 24 kg/m^2 and the suggested WC cut-offs are 85 cm for men and 80 cm for women[7].

Recently, several authors suggested the use of waist: height ratio (WHtR) as an indicator of abdominal obesity, to enable adjustment for variations in body frame size[8–10]. It was argued that WHtR is not only more sensitive than BMI, but also a boundary value of 0·5 can be applied in all age groups, in men as well as women in different ethnic groups, thus circumventing the problem of group-specific WC cut-off points[8]. Studies showed that WHtR was a better indicator of cardiovascular and all-cause mortality in comparison with BMI or waist:hip ratio[9,10].

To what extent general and abdominal obesity currently account for the prevalence of (pre-) diabetes in China needs to be established. The aim of the present study was therefore to assess the strength of the association of BMI, WC and WHtR with the prevalence of diabetes and IHG in the general Chinese population. Special attention was paid to the optimum predictive levels of WHtR in order to recommend cut-off values for diabetes prevention and health education in China.

Subjects and methods

Sample design and study population

For study sampling for the 2002 CNNHS, the method of multi-step cluster sampling was adopted[11]. Finally, 71 971 households were randomly selected to represent the national data. All family members above 2 years old were invited for the measurement of fasting blood glucose, and finally data on fasting blood glucose were available on a total of 98 509 subjects[3].

We restricted the analyses to subjects aged 18–79 years, including 51 970 men and women. We excluded 507 pregnant or lactating women. Also, a total of 558 subjects were excluded because of missing information on height, weight or WC measurement. Our final study population included 23 980 men and 26 925 women.

Anthropometric measurements

Body weight was measured in the morning with a balance-beam scale while the subjects were wearing lightweight clothing and without shoes. Height was measured using a standard steel strip stadiometer in barefoot subjects. Height was measured to the nearest 0·1 cm, and weight to the nearest 0·1 kg. BMI was calculated as [weight (kg)]/[height (m)]^2. WC was measured halfway between the costal border and the iliac crest at the end of exhalation. WHtR was calculated as [WC (cm)]/[height (cm)].

Laboratory methods

Fasting blood glucose levels were measured by trained technicians and an oral glucose tolerance test (OGTT) was undertaken in subjects whose fasting glucose was $\geq$5·5 mmol/l. For interpretation of the fasting and 2 h OGTT glucose levels, criteria from the WHO Expert Committee on Diabetes Mellitus (1999 criteria)[12] were used. Subjects were classified as having type 2 diabetes mellitus (T2DM), impaired glucose tolerance (IGT) or impaired fasting glucose (IFG). Prevalence rates of IFG or IGT, together referred to as IHG[13], generally mirror those of T2DM. We use the term 'glucose tolerance abnormalities' to refer to the combined groups of subjects with T2DM, IGT and IFG.

Quality control of anthropometric and blood measurements

Body weight, height and waist circumference were all measured in the fasting state by trained investigators, and duplicate measurements in subgroups showed high reproducibility. Glucose was measured in plasma, with heparin lithium added to the tube to avoid glycolysis by red blood cells. All fasting glucose samples were measured within 4 h of blood sampling. Every tenth sample was measured twice (correlation coefficient of duplicate measurements was 0·98); at the same time, one reference sample, one quality control sample and one blind sample were measured before every thirtieth sample.

Statistical analyses

Characteristics of the study subjects according to diabetes status were compared by Student's t test and the χ^2 test for continuous and categorical variables, respectively.

Receiver-operating characteristic (ROC) curve analysis was performed to determine cut-off values to minimize the total number of misclassifications and evaluate the general performance of BMI, WC and WHtR in diagnosing glucose tolerance abnormalities. The area under the curve (AUC) was used to reflect the overall accuracy of the diagnostic test derived from a ROC curve analysis. The AUC can take values between 0 and 1, where 1 is a perfect screening test and 0·5 is a test equal to chance. The distance in the ROC curves was calculated according to the equation[14]: $[(1-\text{sensitivity})^2 + (1-\text{specificity})^2]^{1/2}$. Youden's index was calculated according to the equation: sensitivity + specificity − 1. The optimal cut-off value for WHtR was based on the shortest distance and the highest value of the Youden's index.

The prevalence ratio (PR) has been recommended to communicate potentially causal association in cross-sectional studies. This is useful as at higher rates of disease prevalence, the OR tends to overestimate the PR[15,16]. Adjusted PR and their 95 % CI were calculated by using the PROC GENMOD procedure[17]. We adjusted for any potentially confounding effects of lifestyle and socio-economic factors in the log-binomial regression models. All analyses were conducted with the use of the SAS statistical software package version 9·1 (SAS Institute Inc., Cary, NC, USA).

Results

Characteristics of the study population are presented in Table 1. Persons who lived in the urban areas were on average older, more highly educated, less likely to be smokers (in men) and had higher mean BMI, WC and WHtR.

The prevalence of T2DM (either newly diagnosed using fasting and post-load glucose levels or treated) and IHG increased with age, and was higher in urban than in rural areas. The overall prevalence of T2DM amounted to 2·6% and IHG was present in 1·9% of the subjects (Table 2).

As expected BMI, WHtR and WC were all significantly inter-correlated in both sexes (BMI *v.* WC: men $r=0{\cdot}86$, women $r=0{\cdot}84$; BMI *v.* WHtR: men $r=0{\cdot}86$, women $r=0{\cdot}82$; WC *v.* WHtR: men $r=0{\cdot}95$, women $r=0{\cdot}96$; all $P<0{\cdot}0001$). For the diagnosis of glucose tolerance abnormalities, the AUC of the ROC curves ranged from 0·70 to 0·75 (Table 3). In general, the AUC for BMI was lower than that for WC or WHtR. The AUC of WC and WHtR were higher in women than in men. Additional analysis for the diagnosis of T2DM only showed similar results (data not shown).

Expressed per 1 SD increment in obesity index, the adjusted PR were higher for WHtR and WC than for BMI in both men and women (Table 3). We also calculated the population-attributable risk (PAR) comparing the highest *v.* the lowest quintile of each index. The PAR for the highest BMI quintile was 44% for men and 49% for women. For WC and WHtR, the PAR values observed were about 56% for men and 57–58% for women.

Because there are no generally accepted reference values to define abdominal obesity by WHtR, the influence of different WHtR cut-offs on the test characteristics was investigated (Table 4). WHtR thresholds of 0·50 in men and 0·52 in women had the largest AUC and the shortest distance in the ROC curve. The highest Youden's index was found for the cut-off value of 0·50 in both men and women.

Regardless of the cut-off points used, BMI, WC and WHtR were all significantly associated with the prevalence of glucose tolerance abnormalities in both sexes (Table 5). In women the PR were higher for WC and WHtR than for BMI. For men this difference between obesity indices was less clear. The highest PR was observed for WHtR ≥ 0·5 in both men and women.

Adjusted PR was highest with both higher BMI and higher WHtR in either sex, suggesting that measurement of both parameters could much improve the predictive power (Table 6). However, high BMI without concomitant high WHtR was not associated with increased prevalence of glucose tolerance abnormalities in women, whereas in men both high BMI and high WHtR alone were associated with a moderate increased risk.

Table 1 Characteristics of the study population by age, sex and area: adults aged 18–79 years in the 2002 China National Nutrition and Health Survey

	Urban		Rural	
	Men	Women	Men	Women
n	8320	9794	15 660	17 131
Age (years)				
Mean	48·0*	47·0*	44·6	44·0
SD	15·2	14·5	14·1	13·5
Education (years)				
Mean	10·4*	9·2*	8·1	6·3
SD	3·5	4·1	3·3	3·9
Smoker (%)	50·4*	3·9	57·3	2·9
BMI (kg/m^2)				
Mean	24·1	24·0	22·5	23·0
SD	3·6	3·8	3·2	3·6
WC (cm)				
Mean	84·3*	78·4*	78·0	75·4
SD	10·5	10·3	9·8	9·9
WHtR				
Mean	0·50*	0·50*	0·47	0·49
SD	0·06	0·07	0·06	0·06

WC, waist circumference; WHtR, waist:height ratio.
*Mean values were significantly different from those of the same sex in the rural area: $P<0{\cdot}0001$.

Discussion

The proportions of men and women with T2DM and obesity have increased throughout Asia[18], and the present nationwide survey shows that the prevalence of T2DM in

Table 2 Prevalence of diabetes (T2DM) and intermediate hyperglycaemia (IHG) in the study population: adults aged 18–79 years in the 2002 China National Nutrition and Health Survey

		Urban			Rural			National†		
	Age group (years)	Men	Women	Men + women‡	Men	Women	Men + women‡	Men	Women	Men + women‡
T2DM	Total§	4·53	4·32	4·45	1·70	1·97	1·83	2·54	2·66	2·60
	18–44	2·30	1·67	1·95	1·12	0·86	0·98	1·48	1·10	1·27
	45–59	8·20	7·44	7·78	2·33	3·55	2·96	3·93	4·63	4·29
	≥60	13·28	12·92	13·13	3·94	4·88	4·41	6·47	7·06	6·77
IHG	Total§	2·97	2·53	2·70	1·89	1·45	1·56	2·21	1·77	1·90
	18–44	2·12	1·01	1·50	1·49	0·85	1·14	1·68	0·90	1·25
	45–59	3·59	2·78	3·15	2·51	2·30	2·39	2·80	2·43	2·60
	≥60	4·00	4·87	4·43	3·13	2·97	3·05	3·37	3·49	3·42

†Adjusted for area (urban/rural).
‡Adjusted for sex.
§Adjusted for age.

Table 3 Associations between BMI, WC and WHtR and prevalence of glucose tolerance abnormalities, analysed by area under the receiver-operating characteristic curves (AUC), prevalence ratio (PR) and population-attributable risk (PAR): adults aged 18–79 years in the 2002 China National Nutrition and Health Survey

Indicator		AUC	SE	95 % CI	Adjusted PR†	95 % CI	PAR‡ (%)
BMI	Men	0·705	0·007	0·692, 0·719	1·607*	1·535, 1·682	44·2
	Women	0·700	0·007	0·687, 0·713	1·546*	1·482, 1·613	49·3
WC	Men	0·730	0·007	0·717, 0·743	1·677*	1·600, 1·757	56·1
	Women	0·754	0·006	0·742, 0·766	1·733*	1·658, 1·811	58·1
WHtR	Men	0·737	0·006	0·724, 0·749	1·675*	1·598, 1·756	56·2
	Women	0·753	0·006	0·741, 0·765	1·679*	1·606, 1·756	56·9

WC, waist circumference; WHtR, waist:height ratio.
*PR increased significantly per 1 SD increment in obesity index: $P < 0{\cdot}0001$.
†Adjusted by area, education years, smoking and age.
‡PAR comparing fifth with first quintile categories.

Table 4 Test characteristics of WHtR predicting prevalence of glucose tolerance abnormalities: adults aged 18–79 years in the 2002 China National Nutrition and Health Survey

	WHtR	Sensitivity (%)	Specificity (%)	AUC	95 % CI	Distance in ROC curve	Youden's Index
Men	0·48	55·7	80·2	0·682	0·669, 0·694	0·485	0·359
	0·50	66·3	70·1	0·692	0·678, 0·706	0·451	0·364
	0·52	75·7	58·3	0·682	0·667, 0·697	0·483	0·340
	0·54	83·7	43·8	0·653	0·637, 0·670	0·585	0·275
Women	0·48	48·8	85·9	0·669	0·658, 0·681	0·531	0·347
	0·50	60·7	78·4	0·699	0·687, 0·711	0·448	0·391
	0·52	71·0	67·8	0·705	0·692, 0·719	0·433	0·388
	0·54	79·1	56·3	0·691	0·676, 0·705	0·484	0·354

WHtR, waist:height ratio; AUC, area under the curve; ROC, receiver-operating characteristic.

China is 2·6 % and 1·9 % for IHG. Since historical, nationally representative prevalence data of China are not available, we cannot describe the exact trends of diabetes among the Chinese. Comparing the T2DM prevalence between urban and rural residents however, we found that urban residents had more than twice the prevalence of rural residents, as reported in other Chinese studies as well[2,19]. This suggests that the rate of diabetes will increase in rural communities as they become urbanized.

Data from cohort studies in Western countries have shown that BMI is strongly associated with increased risk of developing diabetes[20,21] and such association has also been shown in other ethnic groups, including a cohort of Chinese women[22]. Our results show that BMI is an independent predictor of diabetes after adjustment by age, area, years of education, smoking and physical activity. Diabetes was three times more prevalent in those with a BMI of 24 kg/m^2 or more.

Abdominal obesity, as indicated by WC or waist:hip ratio, is generally more closely correlated with diabetes or glucose levels than general obesity itself in various population groups[21–24]. In the present large Chinese study sample, the AUC of the ROC curve for WC was larger than that for BMI in both sexes and the adjusted prevalence of (pre-) diabetes was three times higher in men and women with WC above the Chinese recommended cut-off values than in those with smaller waist. This confirms the importance of abdominal obesity in the general Chinese population.

However, although WC is closely related with CHD, diabetes or its risk factors, the limits to be used for screening or health education vary across the sexes and ethnic origin. The WHtR has therefore been proposed[25]. In British adults the WHtR was a better indicator of cardiovascular and all-cause mortality than BMI[9]. In Japanese men and women[10], WHtR was more strongly associated with cardiovascular risk factors and metabolic syndrome than waist:hip ratio. Compared with WC and WHtR ratio, WHtR appeared to be a better diabetes predictor in a follow-up of adult men from Tehran[26]. In a previous study in middle-aged Hong Kong Chinese subjects, this ratio was associated with the risk of T2DM, but was not superior to WC alone[27].

Whether WHtR could be an effective predictor of diabetes has not been evaluated in the general Chinese population before. Comparing the adjusted prevalence ratios using various cut-off points in men and women separately, the highest risk ratios were observed for the 0·5 cut-off in both men and women, also in comparison with BMI and WC. Thus, WHtR is a good predictor of glucose tolerance abnormalities among Chinese adults, and a boundary value of 0·5, as proposed[8,28], seems a good choice for both men and women. One of the advantages of the WHtR over WC is the potential to use an overall cut-off value, possibly also in children[29,30].

We also examined whether combining BMI and WHtR could improve the predictive power. Interestingly, a high BMI without a concomitant high WHtR was not associated

Table 5 Adjusted prevalence ratios (PR) for different cut-off points of obesity indices according to sex: adults aged 18–79 years in the 2002 China National Nutrition and Health Survey

	Men				Women			
	n	Glucose tolerance abnormalities (%)	Adjusted PR†	95 % CI	*n*	Glucose tolerance abnormalities (%)	Adjusted PR†	95 % CI
BMI (kg/m^2)								
≥24 *v.* <24‡	8541 *v.* 15 439	11·5 *v.* 3·1*	2·780‖	2·482, 3·115	10 398 *v.* 16 527	10·4 *v.* 3·3*	2·268‖	2·041, 2·519
≥25 *v.* <25§	6421 *v.* 17 559	12·5 *v.* 3·8*	2·480‖	2·229, 2·759	7905 *v.* 19 016	11·6 *v.* 3·7*	2·195‖	1·986, 2·426
≥28 *v.* <28‡	2057 *v.* 21 923	14·9 *v.* 5·3*	2·153‖	1·894, 2·446	2986 *v.* 23 939	14·9 *v.* 4·9*	2·146‖	1·921, 2·397
≥30 *v.* <30§	745 *v.* 23 235	16·6 *v.* 5·8*	2·247‖	1·867, 2·704	1318 *v.* 25 607	18·2 *v.* 5·4*	2·356‖	2·051, 2·705
WC (cm)								
≥80 *v.* <80‡					9221 *v.* 17 704	12·6 *v.* 2·6*	3·097‖	2·769, 3·465
≥85 *v.* <85‡	7610 *v.* 16 370	12·3 *v.* 3·2*	2·703‖	2·415, 3·025				
WHtR								
≥0·50 *v.* <0·50	8610 *v.* 15 370	11·9 *v.* 2·8*	2·851‖	2·535, 3·207	11 229 *v.* 15 696	11·4 *v.* 2·2*	3·103‖	2·741, 3·513

WC, waist circumference; WHtR, waist:height ratio.
*Prevalence of glucose tolerance abnormalities significantly different comparing the groups under and over the cut-off point: $P < 0·001$.
†Adjusted by area, education years, smoking and age.
‡Cut-offs for overweight and obesity recommended by the Working Group on Obesity in China[7].
§Cut-offs for overweight and obesity as recommended by WHO[5].
‖PR significantly different comparing the groups under and over the cut-off point: $P < 0·001$.

Table 6 Adjusted prevalence ratios (PR) for glucose tolerance abnormalities for BMI combined with WHtR according to sex: adults aged 18–79 years in the 2002 China National Nutrition and Health Survey

	Men				Women			
	n	Glucose tolerance abnormalities (%)	Adjusted PR†	95 % CI	*n*	Glucose tolerance abnormalities (%)	Adjusted PR†	95 % CI
BMI (kg/m^2) and WHtR								
<24 and <0.5	13 859	2.5	1.000	–	13 811	2.2	1·000	–
<24 and ≥0·5	1580	8·2	2·002*	1·622, 470	2761	9·0	2·339*	1·945, 2·814
≥24 and <0·5	1511	5·8	2·184*	1·722, 2·769	1885	2·7	1·186	0·879, 1·599
≥24 and ≥0·5	7030	12·8	3·481*	3·054, 3·968	8513	12·1	3·429*	2·999, 3·921*

WHtR, waist:height ratio.
*PR significantly different compared with reference category (BMI < 24 kg/m^2 and WHtR < 0.5): $P < 0·001$.
†Adjusted by area, education years, smoking and age.

with increased diabetes prevalence among women. This enforces the importance of the use of an indicator of abdominal obesity rather than overall obesity for predicting diabetes in Chinese women. For men, the impact of BMI and WHtR appeared to be synergistic, with the highest risk observed for the combined presence of high BMI and high WHtR.

About 56% of the prevalence of glucose tolerance abnormalities in the whole Chinese adult population may be preventable if central obesity was eliminated. Although the diabetes rates are still relatively low, this indicates the potential of improvement in the treatment and prevention of obesity in China for the health care burden.

In summary, our results indicate that among the Chinese adult population, measures of central obesity are better predictors of the prevalence of glucose tolerance abnormalities than measures of overall obesity, especially among women. A cut-off value of WHtR $\geq 0{\cdot}5$ for both men and women can be considered an optimum value for a reduced risk of glucose tolerance abnormalities, and may be a useful tool in screening and health education.

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