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Association of central adiposity with prediabetes and decreased insulin sensitivity in rural Chinese normal-weight and overweight women

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Abstract

This study investigated whether high central adiposity was associated with prediabetes and decreased insulin sensitivity (IS) in both normal-weight (body mass index [BMI] <23 kg/m^2) and overweight (BMI ≥23 kg/m^2) rural Chinese women. Adipose variables measured by dual-energy x-ray absorptiometry (percentage body fat, percentage lower-body fat [%LF], and percentage trunk fat [%TF]) and general adipose variables (BMI and waist circumference) were used for examining the association of adiposity with prediabetes among 4071 rural Chinese women aged 20 to 60 years. Furthermore, the association of adiposity with IS was tested in both normal- and overweight women with normal glucose tolerance. BMI was highly correlated with percentage body fat and waist circumference, but was weakly correlated with %LF and %TF. Both high %TF (top quartile of %TF) and low %LF (lower 3 quartiles of %LF) were associated with higher prevalence of prediabetes in both normal- and overweight women. Compared with normal-weight women in low %TF, the odds of prediabetes were similarly increased for women with high %TF regardless of whether they were overweight (odds ratio [95% confidence interval] = 1.6 [1.3-2.0]) or not (odds ratio [95% confidence interval] = 1.5 [1.2-2.0]). Similarly, among 3280 women with normal glucose tolerance, high %TF was associated with increased fasting insulin, 2-hour oral glucose tolerance test insulin, and homeostasis model assessment of insulin resistance regardless of weight status (normal or overweight). Among relatively lean, rural Chinese women, high %TF was associated with increased odds of prediabetes and lower IS regardless of weight status (normal or overweight).

1. Introduction

Many studies indicated that individuals with prediabetes have higher lifetime risks of developing type 2 diabetes mellitus or cardiovascular disease (CVD) [1,2]. Furthermore, preventive interventions are able to prevent diabetes or CVD development from prediabetes in non-Asian [3-6] and Asian populations [7]. It is thus very crucial to explore the potential risk factors for prediabetes. Obesity is a serious public health problem worldwide. Obesity increases the risks of metabolic syndrome (MS), type 2 diabetes mellitus, hypertension, dyslipidemia, and CVD [8-12]. A key link between obesity and metabolic diseases may be that obesity increases insulin resistance (IR) [13], particularly when adiposity is centrally located. Visceral fat accumulation increased the risk of MS, homeostasis model assessment (HOMA)–IR, and insulin concentrations in Japanese men with prediabetes [14]. Even in 20 normal-weight (body mass index [BMI] <25 kg/m^2) Japanese individuals with normal glucose tolerance (NGT), increased visceral fat was associated with IR [15]. It is noted that Asian women have higher amounts of visceral fat than

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whites for a given BMI [16,17]. Such ethnic differences in fat distribution warrant further investigation because the relationships between adiposity and IR observed in non-Asian populations may or may not apply to Asians.

To date, there are a few published studies on MS in Chinese populations [12,18]; but none of them has evaluated total and central adiposity in relation to prediabetes or insulin sensitivity (IS). To our knowledge, only one study explored the relationship of central adiposity with IS in Asian populations with BMI less than 25 kg/m^2 and NGT [15]. This is the first study that simultaneously evaluated surrogate adiposity measurements (BMI and waist circumference [WC]) and direct adiposity measures derived from dual-energy x-ray absorptiometry (DEXA) in relation to prediabetes or IS in both normal-weight (BMI <23 kg/m^2) and overweight (BMI ≥23 kg/m^2) rural Chinese women.

The primary aim of this cross-sectional study was to examine whether adiposity, particularly central adiposity, was independently associated with prediabetes and decreased IS among both normal-weight (BMI <23 kg/m^2) and overweight (BMI ≥23 kg/m^2) women. The second aim focused on whether DEXA measures of adiposity could better predict the risk assessment of prediabetes and IS than BMI and WC.

2. Research design and methods

2.1. Study population

The study population was described in detail elsewhere [19]. Briefly, this study was conducted in Anhui Province, China, from September 1998 to May 2000. The study population was derived from a large, community-based twin study to examine environmental and genetic risk factors of chronic diseases. Twins were chosen based on the following criteria: (1) age at least 6 years; (2) both twins were available for the survey; (3) both twins (or parents/guardians of children) consented to participate in the survey; (4) no history of stroke or cardiovascular, renal, hepatic, or malignant diseases; and (5) not breastfeeding or pregnant. Written informed consent was obtained from each subject or parents/guardians of children before any data collection. This study was reviewed and approved by the Institutional Review Boards of Children's Memorial Hospital and the Biomedical Institute of Anhui Medical University.

Eligible twins were invited to a central office to complete a questionnaire interview, oral glucose tolerance testing (OGTT), DEXA scan, and physical examination including anthropometric measures. Subjects were included in this analysis if they met the following criteria: (1) women aged 20 to 60 years; (2) completion of both OGTT and DEXA scan; (3) absence of *diabetes* (defined as 2-hour [2H] OGTT ≥11.1 mmol/L or fasting glucose ≥7.0 mmol/L) and other severe diseases (stroke or cardiovascular, renal, hepatic, or malignant diseases); (4) did not previously or currently smoke cigarettes; and (5) BMI was equal to or greater than 18.5 kg/m^2.

2.2. Anthropometric and DEXA measures of adiposity

Body mass, standing height, and WC were measured according to standard protocols. Body fat was measured using DEXA (GE Lunar Prodigy, Waukesha, WI) according to the standard operating protocol. Body mass index was calculated as the ratio of body mass (in kilograms) divided by the square of height (in meters). Percentage body fat (%BF) was calculated as 100 times fat mass divided by whole-body mass. Percentage truncal to total fat (%TF) was calculated as 100 times truncal fat mass divided by whole-body fat mass. Percentage lower-body to total fat (%LF) was calculated as whole-body fat mass minus head, 2 upper extremities, and truncal fat mass, and then divided by whole-body fat mass and times 100.

2.3. Plasma insulin and glucose assays and HOMA-IR calculation

Plasma glucose concentrations were measured by the glucose oxidase method with an automated biochemical analyzer (Model 7020; Hitachi, Tokyo, Japan). Plasma insulin concentrations were determined with electrochemiluminescence immunoassay (Model 2010; Roche, Basel, Switzerland), for which insulin mean coefficients of variation of intra- and interassays were 2.0% and 5.96%, respectively. The HOMA-IR, a marker of IS, was calculated as fasting insulin concentration (in milliunits per liter) times fasting glucose concentration (in millimoles per liter) divided by 22.5 [20,21].

2.4. Definition of NGT, impaired fasting glucose, impaired glucose tolerance, and prediabetes

Normal glucose tolerance was defined as fasting glucose less than 5.6 mmol/L and 2H-OGTT glucose less than 7.8 mmol/L [22]. *Prediabetes* was defined as impaired fasting glucose (fasting glucose, 5.6~7.0 mmol/L) [22] and/or impaired glucose tolerance (2H-OGTT glucose, 7.8~11.1 mmol/L) [23].

2.5. Statistical analysis

For descriptive statistics, discrete and continuous variables were expressed as frequencies and percentages, and means and standard deviations, respectively. t tests and χ^2 tests were used to investigate differences in means and prevalence of continuous and categorical variables, respectively, among women with NGT and prediabetes. Plasma insulin concentrations at fasting and 2H-OGTT were transformed to the natural log (ln) scale because they had skewed distributions. Because BMI of at least 23 kg/m^2 is the World Health Organization definition of overweight for Chinese adults and WC of at least 80 cm increases the risk of MS in Asian women [24], the cut points of BMI of at least 23 kg/m^2 and WC of at least 80 cm were used to define binary categories of high BMI and high WC, respectively.

High %LF and *high %TF* were defined as the upper quartile of each, whereas the bottom 3 quartiles of each were defined as *low*. The binary variables of BMI, WC, %LF, and %TF were used in further analyses.

We conducted the analysis in the following sequential steps to examine if central adiposity was independently associated with prediabetes and decreased IS in normal- and overweight women. First, we used LOESS smoothing to plot %BF, %TF, %LF, and WC against BMI to examine their correlations. We then plotted the prevalence of prediabetes against BMI, stratified by low vs high %TF and %LF, respectively, to examine whether high %TF or %LF was associated with the prevalence of prediabetes for a given BMI. Furthermore, we used logistic regression to examine how the odds of prediabetes compared in 4 groups of women defined by the combination of their BMI (normal or overweight) and central adiposity (low or high %TF).

Second, we explored the associations of central adiposity with IS among women with NGT. We plotted HOMA-IR against BMI stratified by low vs high %TF and %LF, respectively, to examine if high %TF and/or high %LF was associated with IS for a given BMI. Furthermore, we used multiple linear regression to examine how mean levels of ln(fasting insulin), HOMA-IR, 2H-OGTT ln(insulin), and 2H-OGTT glucose prediabetes compared in 4 groups of women defined by the combination of their BMI (normal or overweight) and central adiposity (low or high %TF).

All regression models described above were adjusted for age (continuous variable), age^2, education (primary school, middle school, or greater than middle school vs illiterate), occupation (farmer vs not farmer), previous alcohol use (yes vs no), and current alcohol use (yes vs no). For all analyses, twins were treated as individual observations rather than twin pairs. To account for the correlation of within-twin pair measures, we calculated robust estimates of variances with generalized estimating equations using SAS procedure GENMOD (SAS Institute, Cary, NC) [25]. We also repeated the analyses mentioned above, using only one randomly selected subject per family.

3. Results

3.1. Population characteristics by prediabetes status

Four thousand seventy-one women (3280 with NGT and 791 with prediabetes) were included in this study. The distributions of important variables by prediabetes status were shown in Table 1. Women with prediabetes were older; had higher %BF, WC, %TF, ln(fasting insulin), fasting glucose, HOMA-IR, 2H-OGTT ln(insulin), and 2H-OGTT glucose; and had lower %LF than those with NGT. Women with prediabetes had slightly less education and were slightly more likely to be farmers. Prevalence of alcohol use was low and not different between the 2 groups.

Table 1
The general characteristics among 4071 Chinese women twins aged 20 to 60 years by NGT and prediabetes

Variables	NGT (n = 3280)	Prediabetes[a] (n = 791)	*P*
	Mean ± SD		
Age, y	31.7 ± 7.5	33.7 ± 8.6	<.0001
Height, m	1.5 ± 0.1	1.5 ± 0.1	.0920
Weight, kg	52.5 ± 6.9	53.4 ± 7.5	.0014
BMI, kg/m^2	22.2 ± 2.5	22.7 ± 2.8	<.0001
Whole-body fat, kg	13.9 ± 4.7	14.6 ± 5.2	.0002
%Whole-body fat[b]	25.9 ± 6.0	26.8 ± 6.3	.0002
Truncal fat, kg	7.0 ± 2.7	7.6 ± 3.0	<.0001
%TF[c]	49.8 ± 4.4	50.9 ± 4.3	<.0001
Lower-body fat, kg	4.5 ± 1.4	4.6 ± 1.4	.0981
%LF[d]	33.3 ± 5.0	32.3 ± 4.9	<.0001
WC, cm	72.2 ± 7.3	74.3 ± 8.1	<.0001
Fasting insulin, mU/L	6.7 ± 6.2	7.6 ± 9.1	.0097
Fasting glucose, mmol/L	4.4 ± 0.6	5.7 ± 0.8	<.0001
HOMA-1[e]	1.3 ± 1.2	1.9 ± 2.5	<.0001
2H-OGTT insulin, mU/L	24.2 ± 23.3	28.1 ± 26.9	.0001
2H-OGTT glucose, mmol/L	5.2 ± 1.1	7.0 ± 1.9	<.0001
	n (%)		
Education			
Illiterate	1256 (38.3)	343 (43.4)	.0050
Primary school	1067 (32.5)	265 (33.5)	
Middle school	745 (22.7)	140 (17.7)	
Higher middle school	212 (6.5)	43 (5.4)	
Farmer	2505 (76.4)	639 (80.8)	.0080
Previous alcohol use	36 (1.1)	12 (1.5)	.3270
Current alcohol use	79 (2.4)	23 (2.9)	.4200

P value was generated by *t* test for continuous variables and χ^2 test for categorical variables.

[a] Prediabetes: fasting glucose of 5.6 to 7.0 mmol/L and/or 2H-OGTT glucose of 7.8 to 11.1 mmol/L.

[b] %Whole-body fat = 100 × (whole-body fat) ÷ weight.

[c] %Truncal fat = 100 × (truncal fat) ÷ whole-body fat.

[d] %Lower-body fat = 100 × (whole-body fat − truncal fat − upper extremities fat − head fat) ÷ whole-body fat.

[e] Homeostasis model assessment–1 = fast insulin × fast glucose ÷ 22.5, where the unit of fasting glucose and fasting insulin is millimole per liter and microunit per liter, respectively.

3.2. Associations of central and lower adiposity with prediabetes

Seventeen percent of 2739 women with normal weight (BMI <23 kg/m^2) had prediabetes compared with 23% of 1332 overweight women (data not shown). Sixteen percent of normal-weight women vs 43% of overweight women had high %TF (data not shown). Fig. 1A plotted the means of %BF, %TF, %LF, and WC against BMI in 4071 women. Overall, BMI was positively associated with %BF, %TF, and WC and was negatively associated with %LF. However, BMI was more highly correlated with %BF (correlation coefficient r = 0.75) and WC (r = 0.77), but was weakly correlated with %TF (r = 0.43) and %LF (r = −0.41) in this population. The correlations of WC and %TF with %BF (correlation coefficient r = 0.67 for WC and 0.47 for %TF) were similar to those of %TF and WC with BMI.

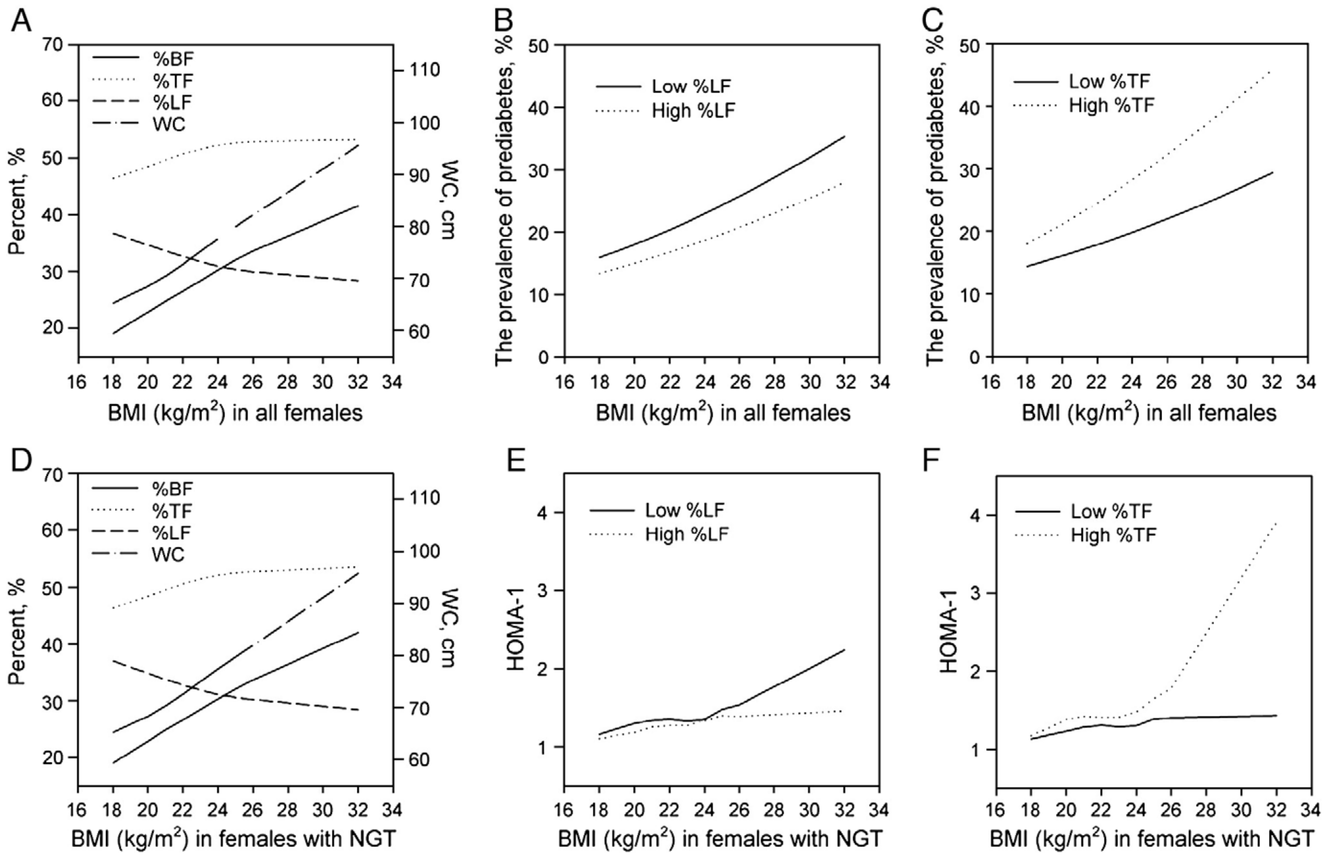

Fig. 1. Percentage body fat, %TF, %LF, and WC plotted against BMI among 4071 women (A) and 3280 women with NGT (D); prevalence of prediabetes plotted against BMI stratified by %LF (B) and %TF (C) among all women; and HOMA-1 plotted against BMI stratified by %LF (E) and %TF (F) among women with NGT.

Fig. 1B shows that, for a given BMI, women who had high %LF had lower prevalence of prediabetes. Conversely, women with high %TF had higher prevalence of prediabetes for a given BMI (Fig. 1C). Furthermore, the linear correlation coefficients of BMI and prediabetes among women with low and high %LF were similar (0.011 and 0.010, respectively); those among women with low and high %TF were also similar (0.010 and 0.007, respectively). Table 2 shows that, compared with normal-weight women with low %TF, the odds of prediabetes in normal-weight

Table 2
Relative odds of prediabetes[a] by BMI and central adiposity (%TF and WC) groups among 4071 Chinese women twins aged 20 to 60 years

Adiposity		Total n	Prediabetes (%)	Joint association[b]		Stratified by BMI[c]	
				OR (95% CI)	*P*	OR (95% CI)	*P*
BMI	%TF[d]						
<23	Low	2295	377 (16.4)	1.0	–	1.0	–
	High	444	107 (24.1)	1.5 (1.2-2.0)	.0012	1.5 (1.2-2.0)	.0011
≥ 23	Low	758	159 (21.0)	1.3 (1.0-1.6)	.0198	1.0	–
	High	574	148 (25.8)	1.6 (1.3-2.0)	.0001	1.2 (0.9-1.6)	.1656
BMI	WC						
<23	<80	2656	461 (17.4)	1.0	–	1.0	–
	≥80	83	23 (27.7)	1.5 (0.9-2.6)	.1211	1.5 (0.9-2.5)	.1294
≥ 23	<80	732	142 (19.4)	1.1 (0.9-1.4)	.2986	1.0	–
	≥80	600	165 (27.5)	1.6 (1.3-2.0)	<.0001	1.4 (1.1-1.9)	.0115

Adjusted for age, age^2, previous and current alcohol drinking, education, occupation, and correlations among twin pairs.

[a] Prediabetes was defined as fasting glucose of 5.6 to 7.0 mmol/L and/or 2H-OGTT glucose of 7.8 to 11.1 mmol/L.

[b] Joint associations of BMI and central adiposity (%TF and WC) on the risk of prediabetes.

[c] The associations between central adiposity (%TF and WC) and prediabetes stratified by BMI.

[d] *High %TF* was defined as the highest quartile for the entire study population.

Table 3
Mean fasting insulin, 2H-OGTT insulin, and HOMA-1 by BMI and central adiposity (%TF and WC) groups in 3280 Chinese women aged 20 to 60 years with NGT

Adiposity		n	Fasting ln(insulin)			2H-OGTT ln(insulin)			HOMA-1		
			Mean ± SD	β (SE)	P	Mean ± SD	β (SE)	P	Mean ± SD	β (SE)	P
BMI	%TF[a]										
<23	Low	1882	1.6 ± 0.8	Ref	–	2.8 ± 0.9	Ref	–	1.3 ± 1.2	Ref	–
	High	373	1.7 ± 0.8	0.13 (0.05)	.0045	2.9 ± 0.9	0.12 (0.05)	.0308	1.4 ± 1.0	0.13 (0.06)	.0353
≥23	Low	578	1.6 ± 0.7	Ref	–	2.8 ± 0.9	Ref	–	1.3 ± 1.2	Ref	–
	High	447	1.8 ± 0.8	0.14 (0.05)	.0058	3.0 ± 0.9	0.17 (0.06)	.0059	1.6 ± 1.6	0.24 (0.09)	.0109
BMI	WC										
<23	<80	2195	1.6 ± 0.8	Ref	–	2.8 ± 0.9	Ref	–	1.3 ± 1.2	Ref	–
	≥80	60	1.7 ± 0.7	0.19 (0.09)	.0418	2.9 ± 0.8	0.24 (0.1)	.0235	1.4 ± 1.0	0.14 (0.13)	.2639
≥23	<80	590	1.7 ± 0.8	Ref	–	2.9 ± 1.0	Ref	–	1.4 ± 1.3	Ref	–
	≥80	435	1.7 ± 0.7	0.05 (0.05)	.3429	2.9 ± 0.9	0.04 (0.06)	.5739	1.4 ± 1.5	0.07 (0.09)	.4666

Adjusted for age, age^2, previous and current alcohol drinking, education, occupation and correlations among twin pairs.
[a] *High %TF* was defined as the highest quartile for the entire study population.

women with high %TF (odds ratio [OR] [95% confidence interval {CI}] = 1.5 [1.2-2.0]) were similar to those in overweight women with high %TF (OR [95% CI] = 1.6 [1.3-2.0]). Although similar patterns of association were found for WC, they were not as consistent or significant as those for %TF.

3.3. Associations of central and lower adiposity with IS among women with NGT

Fig. 1D shows that the correlation patterns of BMI with %BF, %TF, %LF, and WC in 3280 women with NGT were similar to those in all women (Fig. 1A). Fig. 1E and F show that, for a given BMI, both low %LF and high %TF were associated with elevated HOMA-IR. The associations were stronger for higher BMI. Table 3 presents the associations of central (high %TF and high WC) adiposity with ln(fasting insulin), HOMA-IR, and 2H-OGTT ln(insulin) among normal- and overweight women with NGT. Compared with women with low %TF, those with high %TF had elevated fasting insulin, HOMA-IR, and 2H-OGTT insulin in both normal- and overweight women. High WC was associated with elevated fasting insulin and 2H-OGTT insulin for normal-weight women; however, the associations were not as strong as those for high %TF.

In addition, the analyses of Tables 2 and 3 were repeated by limiting to only one randomly selected subject per family. The results were very similar to those in the whole sample (data not shown).

4. Discussion

Several important findings were observed in this study. Although this was a relatively lean and low-risk rural Chinese population, 17% of the normal-weight women had prediabetes compared with 23% of overweight women. Remarkably, 16% of normal-weight women had high central adiposity as measured by %TF. Both high %TF and low %LF (lower 3 quartiles of %LF) were associated with higher prevalence of prediabetes in both normal- and overweight women. Similarly, high %TF was associated with increased fasting insulin, 2H-OGTT insulin, and HOMA-IR among normal- or overweight women with NGT.

The prevalence of prediabetes in the Philippines is 31.3% in adults aged at least 20 years [26]. Although the prevalence of prediabetes in Chinese rural women was relatively lower than US and Philippines adults, the prevalence of prediabetes in rural Chinese women with normal weight was higher (17% vs 11%) than that in rural adults of Sri Lanka [27]. Many studies indicated that individuals with prediabetes have higher lifetime risks of developing type 2 diabetes mellitus or CVD [1,2]. Therefore, it is clinically important to investigate the risk factors for prediabetes in the normal-weight population. Our data demonstrated that high %TF was independently associated with increased risk of prediabetes after accounting for BMI and other covariates. Consistently, both central adiposity (%TF) and low %LF were associated with lower IS in both normal- and overweight women with NGT; but these associations were stronger for overweight women. Most importantly, we found that normal-weight women with high %TF had 50% greater odds of prediabetes compared with normal-weight women without high %TF. The relative odds of prediabetes in normal-weight women with high %TF were similar to those in overweight women with high %TF. Similar to our study, Yu et al [28] found that abdominal obesity was associated with higher risks of metabolic abnormalities than higher BMI and that central obesity conferred a greater risk of diabetes than obesity defined by BMI. However, their study population (aged 50-70 years) was older than ours; and they did not specifically focus on the association of central obesity with prediabetes among normal- and overweight individuals.

Our findings indicate that, in addition to BMI, %TF and %LF could further improve risk assessments with regard to prediabetes and IS in this relatively lean, rural Chinese population. Our results are consistent with previous studies among adult men [14,29] and adolescents [30,31]. For example, Weiss et al [30] found that intraabdominal lipid accumulation was closely linked to the development of severe peripheral IR in obese adolescents with prediabetes. Furthermore, previous findings from other groups provide strong evidence that onset of prediabetes or diabetes was highly associated with body adiposity (especially central body adiposity), which leads to reduced IS [15,32-35]. White women develop gynoid (predominantly lower-body) adiposity distribution, which is associated with increased circulating adiponectin levels that can effectively counter the adverse effects of visceral fat mass on IS. For this reason, even obese women can have better IS and lower risk of diabetes than those with lower BMI, but predominant central adiposity [36]. Of particular clinical relevance is our finding that, among women with clinically normal weight (BMI <23 kg/m^2), 16% of them had elevated %TF, which was significantly and independently associated with increased odds of prediabetes and decreased IS. Our finding was very similar to the data reported in 20 Japanese adults with BMI less than 25 kg/m2 and NGT [15]. Despite the stringent criteria for the definition of normal weight that were used in this study, high central adiposity was still related with a higher prevalence of prediabetes and decreased IS in normal-weight women. However, although a significant difference in HOMA-IR between normal-weight women with low and high %TF was observed, this finding needs to confirmed in another study. Although previous studies found that Asians have higher amounts of visceral adipose tissue for a given BMI [16,17], this is the first study to document a substantial proportion of normal-weight women with elevated %TF in a rural Chinese population. Furthermore, this is the first study to demonstrate that this group of women had odds of prediabetes that were similar to those in overweight women with high %TF (the highest-risk group). Thus, in assessing individual risks of prediabetes and decreased IS among rural Chinese women, both BMI and degree of central adiposity need to be considered.

In this study, although similar associations were found for %TF and WC, the associations for WC were not as consistent and significant as for %TF. Furthermore, WC was more highly correlated with BMI (r = 0.77) than %TF (r = 0.50) in this study population. Although Feng et al [12] showed that WC was a good surrogate for abdominal fat among a study sample recruited from the same area, they did not examine %TF; and the study subjects were older (mean age, 45 years) than those in this study (mean age, 32 years). Sierra-Johnson et al [37] also reported that WC was a robust predictor of reduced IS among 256 healthy adults (mean age, 40 years) and that the predictive information provided by adiposity measured using DEXA was approximately equal to that provided by WC. The different observations between our and other groups may result from changes in correlations of WC and %TF with increasing age [38]. Recently, data from Shanghai [39] and Hong Kong [40] indicated that the optimal WC cutoffs were 82 cm for abdominal obesity and 75 cm for mesenteric fat thickness among Chinese women, respectively. In this study, the WC cutoff was 80 cm for central obesity, which is similar. Our data also showed high correlations of WC and %TF with age (data not shown). Therefore, WC may be a better surrogate for central body fat in older adults than in younger adults.

When interpreting our findings, one should be cautious. This is a population-based twin cohort. However, their demographic and clinical characteristics were similar to those of the local general population (data not shown). Furthermore, the results of our analyses were similar whether we included both twins or if we analyzed only one randomly selected twin from each pair. We previously found that lung function in twins did not differ from that in singleton children in the same region where we conducted this twin study [41]. In addition, the findings of this study were consistent with those from similar studies. Thus, we believe that our findings can be generalized to the local rural Chinese women. Our findings remain to be confirmed independently in other populations. This is a population of relatively lean, healthy, and relatively younger-age women. Nevertheless, we found associations between %TF and prediabetes and markers of IS. Such findings raise the possibility that women at high risk of prediabetes or IR can be identified at an early stage and that effective early intervention can be developed. As we continue to follow up this cohort of women, we will be better able to address our findings in predicting the risk of diabetes and MS in the future.

In summary, in this cross-sectional study of relatively lean, rural Chinese women, we found that 16% of normal-weight women vs 45% of overweight women had high %TF; and high %TF was independently associated with increased odds of prediabetes and decreased IS, even after accounting for BMI and other covariates. Of particular clinical importance is that normal-weight women with high %TF had odds of prediabetes that were similar to those in overweight women with high %TF (the highest-risk group). Although similar associations were found for high WC, they were not as consistent or significant as those for high %TF. Our study underscores that when assessing individual risk of prediabetes and decreased IS in rural Chinese women, both BMI and the degree of central adiposity need to be carefully considered.

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