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Identifying the insulin resistance index in nondiabetic Chinese subjects

Xiu Tuo, MD[a,c,d], Jing Yuan, MD[a,c], Xu-Hong Wang, MD[b,c], Zhong Xin, MD, PhD[a,c,*]

Abstract

In the present study, the performance of anthropometric parameters, lipid and glucose indexes, and the combination of anthropometric parameters with the TyG (triglycerides × fasting plasma glucose) metabolic index, was compared in detecting insulin resistance (IR) to evaluate the optimal cut-off points in nondiabetic Chinese individuals. A total of 1067 nondiabetics underwent oral glucose tolerance test, blood lipid, and fasting insulin measurements. The clinical usefulness of various parameters— body mass index (BMI), waist circumference (WC), TyG, triglycerides/ high density lipoprotein cholesterol ratio, and TyG with adiposity status (TyG-BMI [TyG × BMI] and TyG-WC)—was analyzed to identify IR. Spearman correlation and receiver-operating characteristic curve analyses were used to compare the predictive efficacy of different indicators. All indicators showed a positive correlation with IR in both normal glucose and all subjects. However, the correlation between BMI and homeostasis model assessment of IR index was higher than other indicators as assessed by Spearman correlation test ($P < .05$). Furthermore, BMI and TyG-BMI were better indicators than others as determined by comparing the area under the receiver-operating characteristics curves ($P < .05$) in detecting IR. BMI is a simple and accurate measure for detecting IR in Chinese subjects. The 27 kg/m^2 threshold was the optimal BMI cut-off point for detecting IR in both normal glucose and all glucose categories subjects.

Abbreviations: BMI = body mass index, FPG = fasting plasma glucose, HDL-C = high density lipoprotein cholesterol, HOMA-IR = homeostasis model assessment of insulin resistance index, IR = insulin resistance, T2DM = type 2 diabetes, TG = triglycerides, TyG = TG × FPG, TyG-BMI = TyG × BMI, TyG-WC = TyG × WC, TyH = TG/HDL-C, WC = waist circumference.

Keywords: anthropometric measurement, BMI, cut-off points, HOMA-IR, insulin resistance

1. Introduction

Insulin resistance (IR) involves decreased hepatic, muscle, and adipose tissue sensitivities to insulin. IR is a critical pathophysiological factor in the development of type 2 diabetes (T2DM) and a major characteristic of metabolic syndrome (MS).[1] It is also related to several metabolic disorders, such as high blood pressure, dyslipidemia, atherosclerosis, and cardiovascular diseases.[2] The epidemic of diabetes is increasing, and the cost of treating diabetes and its complications is a major concern worldwide, especially China.[3] Thus, early detection and control of IR before the manifestation of clinical disease should be important aspects for general practitioners in terms of prophylaxis and treatment.

The gold standard for assessing IR is the euglycemic-hyperinsulinemic clamp.[4] However, it cannot be performed in daily practice because of ethical concerns, high cost, and complexity. Thus, the homeostasis model assessment of insulin resistance index (HOMA-IR) (calculated based on the measurement of fasting glucose and insulin levels) was developed and highly correlated with the insulin euglycemic–hyperinsulinemic clamp.[5] Nonetheless, the measurement of insulin has yet to be standardized and is not included in a routine health examination. Therefore, a simple marker of IR is an urgent requisite in routine general practice.

Previous studies also proposed that the IR state was significantly associated with adiposity, dyslipidemia, and liver enzymes.[6] For example, body mass index (BMI) and waist circumference (WC) are simple anthropometric parameters and commonly adopted as indicators of obesity and IR. Dyslipidemia is also a major risk factor for atherosclerosis and IR. Some studies suggested that the product of triglycerides (TG) and glucose in plasma (TyG), and TG/ high density lipoprotein cholesterol (HDL-C) are effective in detecting IR.[1] Furthermore, the visceral adiposity index and the lipid accumulation product, based on the anthropometric BMI, WC, and metabolic TG and HDL-C parameters, also serve as markers for IR.[7] However, a consensus

Editor: Daryle Wane.

XT and JY These authors contributed equally to this paper.

This study was supported by the Expert Promotion Program of Beijing Health Systems (2015-3-017) to XZ.

The data that support the findings of this study are available from the corresponding author upon reasonable request.

The study was conducted with approval from the Ethics Committee of Beijing Tongren Hospital, Capital Medical University. Informed written consent was obtained from all participants included in this study.

The authors have no conflicts of interest to disclose.

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How to cite this article: Tuo X, Yuan J, Wang XH, Xin Z. Identifying the insulin resistance index in nondiabetic Chinese subjects. Medicine 2020;99:5(e19023).

Received: 24 August 2019 / Received in final form: 22 November 2019 / Accepted: 6 January 2020

http://dx.doi.org/10.1097/MD.0000000000019023

on the robust and optimal has not yet been established. Thus, in the present study, we compared the performance of anthropometric parameters, lipid and glucose indexes, and combination of anthropometric parameters and metabolic indexes in detecting IR and evaluated the optimal cut-off points in nondiabetic Chinese individuals.

2. Methods

2.1. Ethics statement

The Ethics Committee of Beijing Tongren Hospital, Capital Medical University, approved the present study (number: TRECKY2014-010). Written informed consent was obtained from each participant.

2.2. Study population

Individuals were selected from a cross-sectional, population-based study (the Diabetes and Other Chronic Disease Survey), conducted in Mizidian, a rural satellite town of Beijing, with a permanent resident population of 23,000 inhabitants. In 2014, 3200 registered permanent residents with community health records, aged ≥20 years, were invited to participate in the study by the Center for Disease Control and Prevention of Tongzhou district, Beijing. All subjects underwent baseline examinations, including anthropometric and blood pressure measurements, and an inquiry about diabetes and hypertension history. Among these, 2967 individuals had no history of diabetes. One-half of the individuals were randomly selected to undergo oral glucose tolerance test (OGTT). Finally, a total of 1209 (81.5%) subjects agreed to partake in OGTT, HbA1c, and fasting insulin measurements. After excluding the subjects with:

(1) Newly diagnosed T2DM mellitus according to OGTT (123 subjects) and
(2) Those with missing data for HOMA-IR index (19 subjects), 1067 subjects were eligible for the analysis.

The results of the fasting plasma glucose (FPG) and 2-hour post-load glucose (2h-PG) test were categorized according to the American Diabetes Association criteria. FPG < 110 mg/dL (6.1 mmol/L) and 2hour-PG < 140 mg/dL (7.8 mmol/L) were defined as normal glucose. The diagnosis of IGT was based on serum glucose concentration 2-h PG ≥140 mg/dL (7.8 mmol/L) but < 200 mg/dL (11.1 mmol/L). FPG levels ≥ 110 mg/dL (6.1 mmol/L) but <126 mg/dL (7.0 mmol/L) were classified as impaired fasting glucose (IFG).[8]

2.3. Anthropometric measurements

The body weight (kg) and height (cm) of the participants were recorded. The height was measured with a stadiometer to the nearest 0.5 cm, while the body weight was measured on a calibrated balance scale. The BMI was calculated by dividing the weight in kilograms by the square of the height in meters. WC and hip circumference were obtained using a cloth tape. The WC was defined as the midpoint between the peak of the iliac crest and the nadir of the costal margin in the midaxillary line. The hip circumference was measured at the level of the greater femoral trochanters.[9]

2.4. Laboratory measurements

Blood samples were collected after overnight fasting for the determination of the plasma glucose and HbA1c levels. The OGTT was performed between 08:00 and 10:00 a.m. These specimens were analyzed within 24 hours.

Plasma glucose was determined by the glucose oxidase method. The levels of TG, high-density lipoprotein (HDL) cholesterol, and low-density lipoprotein (LDL) cholesterol were analyzed by enzymatic methods on a Hitachi 7600 analyzer using an enzymatic assay. HbA1c was measured using high-performance liquid chromatography (Variant, Bio-Rad, Hercules, CA). Serum insulin levels were measured using the ADVIA Centaur Immunoassay System (Siemens Medical Solutions Diagnostics). IR was calculated using the homeostasis model by Matthews et al. as follows: fasting serum insulin (μU/mL) × fasting serum glucose (FPG, mmol/L) / 22.5.[5] The subjects whose HOMA-IR index values exceeded the 75th percentile of the population were considered to have IR.[7] TyH (TG/HDL-C [triglycerides/ high density lipoprotein cholesterol ratio]) index: TG (mmol/L) / HDL-C (mmol/L); TyG index: TG (mmol/L) × FPG (mmol/L). TyG-BMI: TyG index × BMI. TyG-WC: TyG index × WC.[7]

2.5. Statistical analysis

Spearman correlation was employed to assess the associations between the indices and HOMA-IR. It is a nonparametric indicator that measures the degree and direction of the association between the 2 variables, expressed by the rank correlation coefficient r (the r-value is between -1 and 1); positive values indicate positive correlation and negative values indicate a negative correlation. The comparison of the 2 correlation coefficients was performed following Fisher Z transformation method, which is represented as the following formula:

$$Z = \left(\frac{1}{2}\ln\frac{1+r_1}{1-r_1} - \frac{1}{2}\ln\frac{1+r_2}{1-r_2}\right)/\sqrt{\frac{1}{n_1-3} + \frac{1}{n_2-3}}$$

where r_1 and r_2 indicate the 2 correlation coefficients; n_1 and n_2 indicate the corresponding sample sizes in 2 independent samples.

The area under the receiver-operating characteristics curves (AUC) was calculated for each index of IR and homeostasis model results using receiver-operating characteristic (ROC) curves. The ROC curves were constructed by plotting the sensitivity (true-positive rate) against the false-positive rate (1-specificity) for several measures or choices. The ROC curve analyses and the respective AUC were used to compare the association of the IR index with the homeostasis model. The difference in the areas under the 2 ROC curves was used to calculate the generalized Z statistics as follows:

$$Z = \frac{A_1 - A_2}{\sqrt{[SE(A_1)]^2[SE(A_2)]^2 - 2r[SE(A_1)][SE(A_2)]}}$$

Where A_i and $SE(A_i)$ $(i=1,2)$ indicate the observed area and estimated standard error of A_i; r represents the estimated correlation between A_1 and A_2. This quantity Z still obeys the normal distribution, and hence, we could judge the significance based on its critical point with normal distribution.[10] The ROC curves were also used to calculate the sensitivity, specificity, and Youden index, defined as "sensitivity + specificity-1". The Youden index showed the ratio after the misdiagnosis, and the missed diagnosis rates were deducted; a large ratio is preferred (0–1). These parameters determined the optimal values for each index of IR and the results of the homeostasis model.

Table 1

Characteristics of participants according to their glucose homeostasis category and presence of insulin resistance.

	Normal Glucose		IGT		IFG		IFG+IGT	
	Insulin resistance		Insulin resistance		Insulin resistance		Insulin resistance	
	Without	With	Without	With	Without	With	Without	With
n (%)	621	188	66	37	69	18	44	24
Sex (M/F)	223/398	49/139	22/44	10/27	29/40	5/13	14/30	9/15
Age, yr	55.78 ± 7.06	54.74 ± 7.65	57.67 ± 6.01	55.81 ± 6.55	57.43 ± 4.78	54.56 ± 7.91*	57.36 ± 6.83	55.38 ± 6.82
WC (cm)	89.68 ± 8.89	96.91 ± 10.98*	94.15 ± 8.98	99.05 ± 9.13*	90.77 ± 8.43	94.83 ± 6.89*	95.05 ± 9.37	98.33 ± 7.10
BMI	25.50 ± 3.21	28.72 ± 3.54*	26.23 ± 2.75	29.59 ± 3.76	25.76 ± 2.84	27.93 ± 2.70	27.64 ± 4.73	28.33 ± 3.61
SBP (mm Hg)	130.58 ± 18.41	132.99 ± 18.00	136.60 ± 19.57	138.66 ± 20.06	136.2 ± 18.51	130.87 ± 14.03	136.71 ± 18.63	132.402 ± 22.99
DBP (mm Hg)	76.92 ± 10.95	78.82 ± 10.15*	78.40 ± 10.69	81.89 ± 10.41	80.15 ± 12.01	78.78 ± 10.54	80.56 ± 12.45	77.50 ± 9.30
FBG (mmol/L)	5.32 ± 0.38	5.41 ± 0.37*	5.54 ± 0.35	5.61 ± 0.42	6.43 ± 0.25	6.35 ± 0.22	6.42 ± 0.25	6.41 ± 0.24
2-h BG (mmol/L)	5.63 ± 1.13	5.80 ± 1.09	8.82 ± 0.83	8.79 ± 0.88	6.14 ± 1.09	6.43 ± 0.85	9.04 ± 0.86	9.18 ± 0.93
HbA1c (%)	5.67 ± 0.32	5.80 ± 0.34*	5.84 ± 0.45	5.92 ± 0.36	6.08 ± 0.45	6.03 ± 0.19	6.23 ± 0.48	6.38 ± 0.49
CHO (mmol/L)	4.98 ± 0.91	5.08 ± 0.96	5.16 ± 1.21	5.11 ± 0.87	5.17 ± 0.91	5.47 ± 1.93	5.02 ± 0.95	5.29 ± 0.93
TG (mmol/L)	1.27 (0.92–1.85)	1.80 (1.20–2.62)*	1.46 (0.82–2.01)	2.16 (1.48–3.35)*	1.29 (0.92–1.89)	2.10 (1.61–3.75)	1.89 (1.11–2.57)	2.37 (1.39–3.12)
HDL-C (mmol/L)	1.39 ± 0.34	1.25 ± 0.41*	1.39 ± 0.50	1.37 ± 0.75	1.46 ± 0.39	1.14 ± 0.30*	1.29 ± 0.27	1.37 ± 0.92
LDL-C (mmol/L)	3.02 ± 0.78	3.09 ± 0.78	3.21 ± 1.17	3.11 ± 0.75	3.05 ± 0.68	3.15 ± 0.89	3.00 ± 0.81	3.33 ± 0.75
Insulin (U/mL)	38.15 (25.77–50.81)	85.39 (74.39–103.95)*	43.08 (28.92–53.75)	87.00 (81.49–103.35)	38.99 (27.30–48.75)	84.57 (66.15–103.50)*	38.53 (25.00–48.16)	76.36 (67.58–106.43)*
TyG	6.72 (4.85–9.78)	9.66 (6.54–14.42)*	8.36 (4.53–11.15)	11.67 (8.23–19.79)*	8.19 (5.84–12.48)	13.53 (10.15–23.30)*	12.00 (7.40–16.87)	14.88 (8.88–19.70)
TyH	0.96 (0.62–1.46)	1.48 (0.87–2.30)*	0.93 (0.55–1.75)	1.98 (0.88–3.14)*	0.94 (0.59–1.74)	2.08 (1.16–3.86)*	1.53 (0.83–2.00)	2.07 (2.12–3.30)
TyG-WC	113.75 (80.91–168.77)	179.45 (119.91–260.13)*	133.53 (78.43–190.19)	226.72 (134.23–310.82)*	117.92 (81.15–183.25)	197.58 (143.50–353.48)*	171.39 (114.09–240.3)	226.95 (134.23–311.09)
TyG-BMI	32.40 (22.47–47.80)	53.55 (34.25–77.04)*	37.37 (21.77–55.61)	67.26 (41.16–96.27)*	32.48 (23.10–50.57)	59.52 (43.52–102.55)*	47.12 (33.82–64.86)	64.93 (38.45–81.87)
HOMA-IR	8.26 (5.61–11.06)	18.96 (16.69–24.00)*	10.15 (6.76–12.28)	20.69 (17.91–24.22)*	8.93 (6.57–11.37)	21.31 (17.06–24.91)*	8.67 (6.27–11.69)	18.9 (17.35–25.10)*

Values are means (SD), median (range), or n (%). Compared by unpaired *t* test or Chi-square test.

BMI = body mass index, CHO = cholesterol, FPG = fasting plasm glucose, HDL-C = high density lipoprotein cholesterol, HOMA-IR = homeostasis model assessment of insulin resistance index, LDL-C = low density lipoprotein cholesterol, TG = triglycerides, TyG = TG × FPG, TyG-BMI = TyG × BMI, TyG-WC = TyG × WC, TyH = TG /HDL-C, WC = waist circumference.

* *P* value < .05 between subjects with and without insulin resistance within the same category of the glucose metabolic status.

Table 2

Spearman correlation between different indexes and HOMA-IR.

	All subjects		Normal glucose subjects	
	r	*P*	*r*	*P*
BMI	**0.435**	**<.001**$^{*,\#,\triangle}$	**0.445**	**<.001**$^{*,\#\#,\triangle\triangle,\&}$
WC	0.355	<.001	0.348	<.001
TyG	0.347	<.001	0.322	<.001
TyH	0.343	<.001	0.318	<.001
TyG-BMI	0.403	<.001	0.384	<.001
TyG-WC	0.376	<.001	0.352	<.001

BMI = body mass index, HOMA-IR = homeostasis model assessment of insulin resistance index, TyG = TG × FPG, TyG-BMI = TyG × BMI, TyG-WC = TyG × WC, TyH = TG /HDL-C, WC = waist circumference.

* $P < .05$ compare to WC.

$^{\#}$ $P < .05$ compare to TyG.

$^{\triangle}$ $P < .05$ compare to TyH.

$^{\#\#}$ $P < .01$compare to TyG.

$^{\triangle\triangle}$ $P < .01$ compare to TyH.

$^{\&}$ $P < .05$ compare to TyG-WC.

All statistical analyses were conducted using SPSS version 11.5 (SPSS Inc., Chicago, IL) for Windows, MedCalc version 11.4 (http://www.medcalc.be), and the web tool VassarStats (http://www.vassarstats.net/rdiff.html).

3. Results

Table 1 summarizes the characteristics of the cohort. A diagnosis of IFG, IGT, and IFG+IGT was established in 87 (8.2%), 103 (9.7%), and 68 (6.3%) individuals, respectively. IR was determined by HOMA-IR index values that exceeded the 75th percentile of the population. It was identified in 267 subjects, including 188, 18, 37, and 24 subjects in the normal glucose, IFG, IGT, and IFG+IGT groups, respectively. The clinical and biochemical characteristics of the participants are summarized, showing that subjects with IR had high insulin levels and high WC, BMI, TyG, TyH, TyG-WC, TyG-BMI, as well as, high fasting glucose and HbA1c levels ($P < .05$) in the normal glucose group.

Table 2 shows the Spearman correlation between different indexes and HOMA-IR. All indicators were positively correlated with HOMA-IR in both normal glucose subjects and all subjects ($P < .001$). In all subjects, a high correlation was established between BMI and HOMA-IR ($r = .435$) than that between other indicators and HOMA-IR (WC, $r = 0.355$; TyG, $r = 0.347$; TyH, $r = 0.343$; TB, $r = 0.403$; TW, $r = 0.376$; $P < .05$ or .01). Also, in the euglycemic subjects, the correlation between BMI and HOMA-IR ($r = 0.445$) was higher than that between other indicators and HOMA-IR (WC, r = 0.348; TyG, r = 0.322; TyH, $r = 0.318$; TyG-BMI, $r = 0.384$; TyG-WC, $r = 0.352$; $P < .05$ or .01). Accordingly, the correlation between BMI and HOMA-IR was higher than that for other indicators.

The AUC was also calculated for each index and HOMA-IR using ROC (Table 3 and Fig. 1). All indexes showed a strong correlation with IR in both normal glucose subjects and all subjects ($P < .05$). To examine the significant differences between various indicators, we compared the AUC values (Table 3). In all subjects, BMI and TyG-BMI (TyG × BMI) were similar; however, BMI and TyG-BMI were better indicators than TyG, TyH, and TyG-WC (TyG × WC) as determined by AUC (BMI and TyG-BMI, $P = .127$; BMI and WC, BMI and TyG, BMI and TyH, BMI and TyG-WC, TyG-BMI and TyG, TyG-BMI and TyH, TyG-BMI and TyG-WC, $P < .05$; WC and TyG, $P = .366$; WC and TyH, $P = .391$; WC and TyG-WC, $P = .955$; TyG and TyH, $P = .853$). Nonetheless, TyG-BMI and WC did not exhibit a significant difference ($P = .508$). In normal glucose subjects, the variables of interest also showed a similar tendency, but TyG-WC was better than TyG and TyH ($P < .05$). These findings demonstrated that the performance of BMI and TyG-BMI in detecting IR in euglycemic subjects was higher than other indicators, according to the AUCs. However, BMI is more accessible in the clinical setting than TyG-BMI.

In addition, we assessed the optimal cut-off points of BMI for identifying IR. Table 4 shows the sensitivity, specificity, and Youden index for the BMI in normal glucose and all subjects. In both groups, 27 kg/m^2 is the optimal BMI cut-off in terms of Youden index, and its sensitivity and specificity were 0.683 and 0.712 for normal and 0.685 and 0.689 for all subjects, respectively.

4. Discussion

IR is a crucial pathophysiological factor in the development of T2DM, and a core characteristic of MS. Thus, early detection and control of IR before the manifestation of the clinical disease should be important aspects of prophylaxis. In this study, we used 2 methods to evaluate the most accurate detection indicator associated with IR. Herein, irrespective of the methods, BMI was

Table 3

AUC of different indexes in detecting IR.

	All subjects			Normal glucose subjects		
	AUC	95% CI	*P*	AUC	95% CI	*P*
BMI	**0.747**	**0.720 -0.773**	**<.05**$^{*,\#,\triangle,\&}$	**0.759**	**0.728–0.788**	**<.05**$^{*,\#,\triangle,\&}$
WC	0.701	0.672–0.728	<.05	0.708	0.675–0.739	<.05
TyG	0.678	0.649 -0.706	<.05	0.673	0.639–0.705	<.05
TyH	0.68	0.651–0.708	<.05	0.678	0.644–0.710	<.05
TyG-BMI	**0.715**	**0.687–0.742**	**<.05**$^{\#,\triangle,\&}$	**0.712**	**0.679–0.743**	**<.05**$^{\#,\triangle,\&}$
TyG-WC	0.699	0.671–0.727	<.05	0.694	0.661–0.726	<.05$^{\#,\triangle}$

AUC = area under the receiver-operating characteristics curves, BMI = body mass index, CI = confidence interval, TyG = TG × FPG, TyG-BMI = TyG × BMI, TyG-WC = TyG × WC, TyH = TG /HDL-C, WC = waist circumference.

* $P < .05$ compare to WC.

$^{\#}$ $P < .05$ compare to TyG.

$^{\triangle}$ $P < .05$ compare to TyH.

$^{\&}$ $P < .05$ compare to TyG-WC.

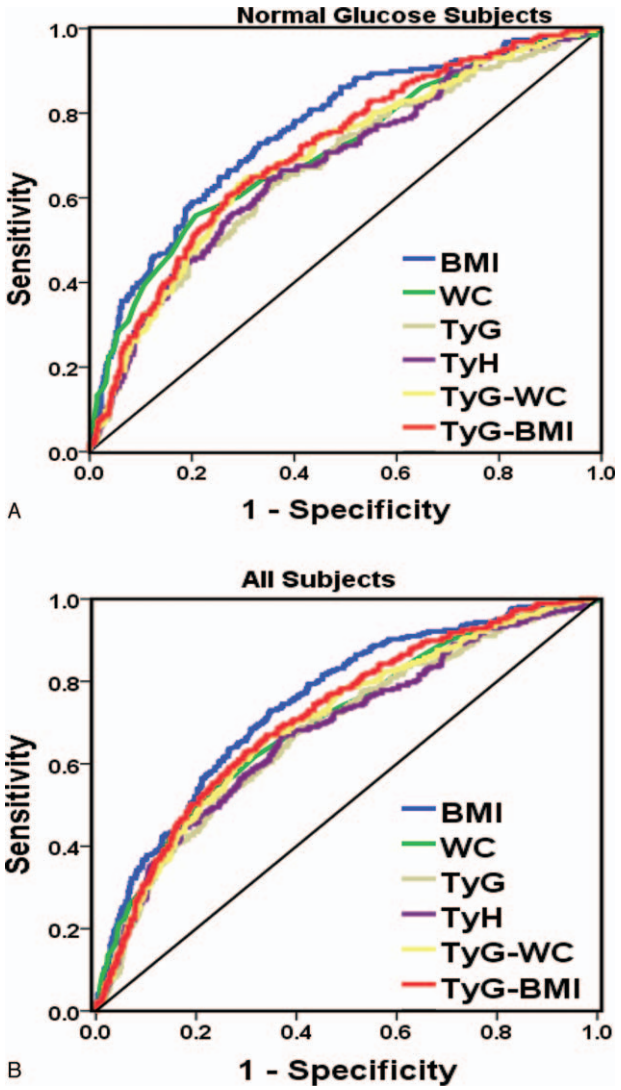

Figure 1. ROC curves of different markers in detecting IR in normal glucose (A) and all subjects (B). BMI = body mass index, ROC = receiver-operating characteristic, TyG = TG × FPG, TyG-BMI = TyG × BMI, TyG-WC = TyG × WC, TyH = TG /HDL-C, WC = waist circumference.

shown to be an efficient surrogate marker for the identification of IR in non-diabetic Chinese people.

Although a myriad of discussions have been conducted, a clear consensus on the most sensitive and specific index for detecting IR is yet lacking. One study from China, which encompasses approximately 56% of China's population varying significantly in terms of geography, economic development, and health status, indicated that TyG is most closely associated with IR; however, the anthropometric parameters were not compared in the study.[2] Another study found TyG-BMI to be efficient.[7] Although the study compared lipid and glucose indexes and the combination of anthropometric parameters and metabolic indexes, the BMI was not compared. In the present study, BMI and TyG-BMI were reliable methods in detecting IR. Moreover, BMI is a simple, accessible, and a noninvasive tool. The study by Gobato et al showed that the BMI was the most effective anthropometric indicator to identify IR;[11] however, the subjects were obese adolescents constituting the small sample size and research variables included only the body composition indicators. Our study was carried out in Mizidian, a rural satellite town of Tongzhou, Beijing. As a typical urban fringe district of Beijing, Tongzhou has undergone dramatic urbanization in the past decade. One result of the transition is the increase in the urban residents and the decrease in the rural population. The overall age-standardized prevalence of IGR (16.0%) in Tongzhou residents was higher than that in the national population (15.0%).[12] In the present study, we fully compared the anthropometric parameters, lipid and glucose indexes, and the combination of anthropometric parameters and metabolic index in nondiabetic individuals aged ≥20 years in this area. We showed that the metabolic indexes mentioned above were not more efficient than only the anthropometric measurement to identify IR. This phenomenon provides a scientific basis for the preventive interventions of diabetes.

BMI is speculated to be an indicator of the overall obesity, which is closely associated with IR, but the mechanism is not yet clarified.[13] Increasing evidence indicated that chronic inflammation is a characteristic of obesity and associated with accompanying IR.[14,15] Inflammation inhibits the insulin-signaling activity in adipocytes and hepatocytes through several mechanisms, while muscle insulin action is not sensitive to inflammation.[13] Interestingly, several molecular mechanisms, including ER stress, oxidative stress, dysregulation of lipid homeostasis, mitochondrial dysfunction, and hypoxia, have been proposed.[16] Also, the positive effects of proinflammatory events should be considered in evaluating the impact of inflammation in obesity and T2DM.[17]

The BMI cut-off point of 27 kg/m^2 for detecting IR was evaluated in the total population and normal glucose subjects based on our data. Intriguingly, different BMI cut-off values are recommended for different ethnicities. China Obesity Task Force of the Chinese Ministry of Health has suggested that a BMI of 24

Table 4

Sensitivity, specificity and Youden's index using BMI cut-off points for detecting IR.

	All subjects			Normal glucose subjects		
BMI (kg/m^2)	sensitivity	specificity	Youden's index	sensitivity	specificity	Youden's index
24.0	0.925	0.301	0.226	0.911	0.334	0.245
25.0	0.891	0.425	0.316	0.886	0.456	0.342
26.0	0.794	0.568	0.362	0.777	0.598	0.375
27.0	**0.685**	**0.689**	**0.374**	**0.683**	**0.712**	**0.395**
28.0	0.543	0.791	0.334	0.559	0.811	0.37
29.0	0.431	0.858	0.288	0.45	0.873	0.323

BMI = body mass index, IR = insulin resistance.

to 28 kg/m^2 signifies overweight in the general Chinese population.[18] The organization chose BMI cut-offs based on the prevalence of hypertension, diabetes, dyslipidemia, and clustering of all risk factors. However, the World Health Organization advised to select a lower BMI threshold value of 23 kg/m^2 to detect an increased risk of cardiovascular disease (CVD) for Caucasians, while BMI values ≥ 27.5 kg/m^2 would indicate a higher CVD risk for Asian subgroups.[19–21] In contrast, in a cohort in adults subjects from Malaysia involving 3 major Asian ethnic populations (Malay, Chinese, Indian), Zaher et al showed that the optimal suitable cut-off values of BMI to detect increased CVD risk based on at least 1 CVD risk factor (hypertension or diabetes or dyslipidemia) is 23.5 kg/m^2 in men and 24.9 kg/m^2 in women.[22] Accordingly, authors suggested that these cut-off values should be explored as thresholds to define overweight or obesity category in Asian populations. However, we recommend BMI cut-off points based on the IR situation, which also confer higher CVD risk. Thus, we can set an alert about the practical boundary for early initiating intervention for IR in nondiabetic subjects.

Nevertheless, the present study has some limitations. First, a cross-sectional study cannot reveal the causal correlations between the tested indexes and HOMA-IR, thereby longitudinal studies should be carried out. Second, since the study sample primarily includes the northern regions of China, its applicability to all Chinese population is unknown. Subjects from other regions of China should be selected in the future studies.

5. Conclusion

Taken together, the current data indicate that BMI is a simple and accurate measure for detecting IR in the population. The appropriate BMI cut-off for detecting IR in non-diabetic Chinese subjects is 27 kg/m^2. Physicians can use this body fat anthropometric index to assess their patients IR risk rapidly and easily.

Acknowledgments

The authors thank all the participants and staff involved in the study.

Author contributions

Zhong Xin have contributed to the design of the study, analysis and interpretation of data, and prepared all figures and tables. Xiu Tuo and Jing Yuan drafted a part of manuscript. Zhong Xin, Xiu Tuo, Jing Yuan and Xu-Hong Wang took part in analyzing data.

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