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# Comparison of different anthropometric measures as predictors of diabetes incidence in a Chinese population

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ABSTRACT

*Objective:* We aimed to explore an optimal anthropometric indicator and optimal cut-off points for incident diabetes in Chinese adults.
*Methods:* 61,703 subjects were followed for a median duration of 2 years. Body mass index, waist circumference, waist-to-hip ratio and waist-to-height ratio were collected base on a standard protocol. Receiver Operating Characteristic curve analyses were used to compare the predictive power of baseline BMI, WC, WHpR and WHtR for development of type 2 diabetes.
*Results:* There were 2991 new cases of type 2 diabetes during follow-up. ROC curve analyses indicated that WHtR was the best predictor of type 2 diabetes for male (AUC = 0.633). For female, WHtR and WC had similar predictive ability (AUC = 0.701 and 0.695 respectively) and were superior to BMI. WHpR was the weakest predictor in both genders. The optimal WHtR cut-off values for incidence of type 2 diabetes were similar in both genders (0.53 vs. 0.52). BMI was higher in men (26 kg/m$^2$) than women (24 kg/m$^2$); and so did WC (91 cm in men vs. 85 cm in women).
*Conclusions:* WHtR, and to some degree WC, are the best predictors of type 2 diabetes, followed by BMI then WHpR which is the weakest predictor in the tested adults.


## 1. Introduction

The prevalence of diabetes is high and is increasing over the world, especially in China. A recent survey in China suggested that 92.4 million adults 20 years of age or older (9.7% of the adult population) have diabetes [1]. Obesity has been proved to be an important independent risk factor for type 2 diabetes [2]. Clinical trials have shown that lifestyle intervention, including weight reduction, can benefit individuals at increased risk for type 2 diabetes [3,4], so WHO recommends to develop simple strategies to identify those at risk of diabetes and provide them with early lifestyle interventions [5]. As easy to operate and noninvasive, obesity indicators such as body mass index (BMI), have been proposed and applied in diabetes prevention.

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In the recent years, it has become clear that mainly visceral, rather than subcutaneous fat, is associated with noninfectious chronic disease [6–10]. This finding suggested that measures of central fat distribution such as waist circumference (WC), waist to hip ratio (WHpR), and waist to height ratio (WHtR) may be better than BMI in predicting type 2 diabetes. However, it is not yet established which specific measures of obesity might be most strongly associated with risk of type 2 diabetes [11–13].

From clinical and public prevention point of view, it is practically important to clarify the optimal or more reliable anthropometric indicator for diabetes incidence. To our knowledge, the number of prospective studies about this issue is limited in mainland China. We have therefore compared the predictive ability of BMI with WC, WHpR and WHtR for predicting diabetes incidence based on a prospective study in Chinese adults. On the other hand, the optimal cut-off values of anthropometric measures for definition of obesity were controversial. It often underestimates obesity in Asia using the same criteria as for whites [14,15]. We have also attempted to identify the optimal cut-off values to assess the risk of diabetes.

## 2. Methods

### 2.1. Study population

The data were obtained from health examinations of employees of the Kailuan Company in Tangshan city in the central north of China, which had been reported before [16]. From June 2006 to September 2007, a total of 101,510 employees and retirees underwent the baseline survey. After the baseline survey, all subjects were followed up every year by face-to-face or telephone interview and were invited to a biennial health examination. Between 2007 and 2009, a total of 3802 subjects were lost for follow-up and 955 subjects died. In the present analyses, we selected subjects aged 18–85 years old and free of cardiovascular diseases or diabetes at baseline. We excluded subjects who died during follow-up, who were pregnant during baseline survey, or who had missing one of anthropometric measurements data. We also excluded subjects who had no plasma glucose tests at baseline. This left 48,015 men and 13,688 women for inclusion in this study.

We followed standard protocols in all measurements. The protocol for this study was in accordance with the guidelines of the Helsinki Declaration, and was approved by the Ethics Committee of the Hospital. All participants have given their written informed consent.

### 2.2. Baseline data collection

*Questionnaire*: All data collections were performed by specially trained doctors and nurses. A standardized questionnaire was used for collecting information on subjects' demographic characteristics; family and personnel medical history; and lifestyle, including smoking status, alcohol consumption, physical activity, sleeping time and quality.

*Anthropometric measurements*: Measurements included height, weight, WC, and hip circumference. All subjects were measured standing in light clothing without shoes and hats. Height was measured to the nearest 0.1 cm using a portable stadiometer and weight was measured to the nearest 0.1 kg using calibrated platform scales. WC was measured to the nearest 0.1 cm at the midpoint between the subcostal margin and the margin of the supracrestal plane. Hip circumference was measured to the nearest 0.1 cm at the point of maximum circumference over the buttocks. Body mass index (BMI) was calculated using the formula: weight/height$^2$ (kg/m$^2$). Waist to hip ratio (WHpR) was calculated as WC divided by hip circumference, and waist to height ratio (WHtR) as WC divided by height.

Blood pressure (BP) was measured in the right arm with subjects in a sitting position using a regular mercury sphygmomanometer after resting for 15 min. The three consecutive blood pressure readings were used for mean value of the BP.

*Laboratory test*: Blood samples were obtained from the antecubital vein and transfused into vacuum tubes containing EDTA in the morning after an overnight fasting period. Tubes were centrifuged at $3000 \times g$ for 10 min at 25 °C. An auto analyzer (Hitachi 747; Hitachi, Tokyo, Japan) was used to measure fasting plasma glucose, total cholesterol (TC), triglycerides (TG), HDL and LDL at the central laboratory of Kailuan hospital.

### 2.3. Follow-up data collection

After the baseline survey, all subjects were followed up for development of MI, stroke and type 2 diabetes. Information on the incidence of new events was obtained from the combination of regular 12 months face-to-face or telephone interview and reviews of patients' hospital record and repeated health examinations. Diabetes was defined as the presence of any of the following at follow-up assessment: (1) fasting plasma glucose level $\geq$ 7.0 mmol/L on two occasions [17]; (2) current use of insulin or oral hypoglycemic agents; or (3) a positive response to the question, "Has a doctor ever told you that you have diabetes?"

### 2.4. Statistical analyses

Continuous variables were expressed as the mean $\pm$ SD or median (interquartile range) as appropriate. Differences of baseline characteristics between participants with and without diabetes were tested by Student's *t* test for normally distributed variables and by Mann–Whitney's rank test for variables with a skewed distribution. Categorical data were expressed as frequencies. Differences between participants with and without diabetes were tested by Chi-square test. This study population was stratified into sex-specific quartiles of BMI, WC, WHpR and WHtR. Logistic regression analyses were performed to study the association of baseline anthropometric measures (BMI, WC, WHpR and WHtR) with the incidence of type 2 diabetes. The odds ratios (ORs) were computed for quartiles 2, 3, and 4 as compared with the lowest quartile in different Logistic regression models. Covariates including age, systolic blood pressure (SBP), lg triglyceride, lg HDL-cholesterol, and lg fasting glucose were fitted as continuous variables in the multivariate analyses and smoking, alcohol intake, regular physical exercise, family history of diabetes were fitted as