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Original Article

Heterogeneity of body mass index, waist circumference, and waist-to-hip ratio in predicting obesity-related metabolic disorders for Taiwanese aged 35–64 y

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SUMMARY

Background & aims: Obesity-related metabolic disorders such as hypertension, diabetes mellitus, hypercholesterolemia, hypertriglyceridemia, and hyperuricemia are major risk factors for cardiovascular disease. The aim was to compare body mass index, waist circumference, and waist-to-hip ratio as predictors of these metabolic disorders.

Methods: We evaluated 1625 men and 1779 women, aged 35–64 y who participated in the 2001 National Health Interview Survey and 2002 Taiwan Three High Prevalence Survey. Their anthropometric measurements were analyzed as predictors of metabolic disorders using empirical receiver-operating characteristic curves and logistic regression models.

Results: Overall, waist circumference performed well as a predictor of metabolic disorders. Body mass index was the best predictor for men who smoked, whereas waist circumference and waist-to-hip ratio were better alternatives for non-smoking men and women. Anthropometric measures had higher predictabilities for those aged 35–44 y but relatively weak associations with diabetes mellitus for men aged 45–64 y and hypercholesterolemia for men and women.

Conclusions: The associations between anthropometric measures and the metabolic disorders varied with comorbidity, gender, age groups, and smoking status. Waist-to-hip ratio was the best predictor for diabetes mellitus, especially for participants aged 45–64 y. The anthropometric measures did not predict hypercholesterolemia well.

1. Introduction

Obesity has become a major public health problem in developed and developing countries. It is closely associated with diabetes mellitus and cardiovascular diseases such as ischemic heart disease and stroke, as well as major risk factors for metabolic disorders, including high blood pressure (HBP), diabetes, hypercholesterolemia (H-Chol), hypertriglyceridemia (H-TG), and hyperuricemia (H-UA).[1–3] Making use of these associations, simple obesity indexes such as body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and other related indices such as waist-to-height ratio (WHtR) and waist-to-stature ratio (WSR) may serve as predictors of cardiovascular disease and these metabolic disorders. Although the World Health Organization has recommended classifications of body weight based on BMI,[4] the anthropometric measurements BMI, WC, and WHR are essentially different in body fat distributions as indexes of overall and central adiposity. Body fat reference measurement determined by dual-energy X-ray absorptiometry has shown that BMI and WC conform better with the screening outcomes than does WHR,[5] and the obesity indices may in some cases predict the abnormal metabolic risk factors more adequately than the percentage of body fat.[6] Various studies across gender, age, and ethnic groups also indicate that BMI, WC, and WHR may have heterogeneous associations with cardiovascular disease and metabolic disorders and thus play different roles as preferable disease predictors.[1–4]

For assessing the risk of insulin resistance and type 2 diabetes, WC consistently has higher predictive ability, although the

Non-standard abbreviations: AUC, area under curve; BMI, body mass index; HBP, high blood pressure; HC, hip circumference; H-Chol, hypercholesterolemia; H-TG, hypertriglyceridemia; H-UA, hyperuricemia; ROC, receiver-operating characteristic; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; WSR, waist-to-stature ratio.

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superiority of BMI and WHR may differ among ethnic groups.[3,7,8] A worldwide large-scale case–control study of participants from 52 countries showed that WHR has a significantly stronger association than BMI with the development of myocardial infarction.[1] As for the associations with other cardiovascular risk factors, WC has been recommended as a standard component of risk evaluation in routine clinical practice, whereas BMI and WHR as predictors may differ among gender and ethnic groups.[9–12] Independent studies of different ethnic groups have also demonstrated evidence of the superiority of other obesity indices such as WHtR and WSR than BMI or WHR.[12–14] However, the three anthropometric measurements as predictors of cardiovascular disease risk factors and health status of the elderly may differ from those of the middle-aged adult population.[15,16]

Although comparisons of BMI, WC, and WHR as predictors of cardiovascular disease and its risk factors have been studied thoroughly in the several publications, differences in their predictabilities for individual metabolic disorders, especially age and gender interactions, remain unclear. The objective of this study was to investigate how well BMI, WC, and WHR serve as predictors of selected metabolic disorders for different subpopulations of Taiwanese residents aged 35–64 y. In the following study hypothesis testing, the null hypothesis was that BMI, WC, and WHR have the same predictability for the specific metabolic disorder of the studied subpopulation vs. the alternative that there are heterogeneities among the three anthropometric measures.

2. Subjects and methods

2.1. Subjects

The 2001 National Health Interview Survey was an island-wide cross-sectional health survey with non-institutionalized households selected through a multistage proportional-to-population size sampling design. All residents in the chosen households were interviewed. The 2002 Taiwan Three High Prevalence Survey was a follow-up cross-sectional study of the 2001 survey conducted by the Bureau of Health Promotion, Department of Health of Taiwan. Half the primary sampling units of the 2001 National Health Interview Survey was selected and all household members older than 15 y were interviewed. WC and hip circumference (HC) were measured, and participants' fasting blood samples were also drawn. Among these, 1625 men and 1779 women, aged 35–64 y, were evaluated for the associations between their anthropometric measurements and obesity-related metabolic disorders.

2.2. Anthropometric and blood sample measurements

BMI (kg/m^2) was calculated based on self-reported height and weight from the 2001 National Health Interview Survey questionnaire. WC and HC were measured with an anthropometric tape to the nearest 0.1 cm. WC was measured by asking the participant to relax and to bend to the left and right a little bit to show the location of the waist. The position was then held fixed by thumbs, and with the participant then standing erect, the measurement was made by circling the anthropometric tape horizontally on the participant's waist at the designated location. HC was measured at the level of the maximal protrusion of the gluteal muscles. WHR was calculated by dividing WC by HC. Two blood pressure measurements were made 10 s apart, and a third measurement was made if the two were >10 mm Hg apart. Subjects were asked to fast for the 12 h prior to venous blood sample collection, with samples excluded from laboratory analysis if fasting time was <8 h. The blood samples were stored in a refrigerator at −20°C and were sent back by express mail to the research center within 14 d of collection. Fasting plasma glucose, fasting serum uric acid, triacylglycerol, and cholesterol values were measured by technicians at the central laboratory.

2.3. Definitions of the selected metabolic disorders

Hypertension was defined as a systolic blood pressure ≥140 mm Hg, a diastolic blood pressure ≥90 mm Hg, or treatment of previously diagnosed hypertension. Diabetes mellitus was defined as a fasting plasma glucose concentration ≥126 mg/dL or use of insulin or hypoglycemic agents. H-Chol was defined as a serum cholesterol concentration ≥240 mg/dL or use of cholesterol-lowering medication. H-TG was defined as a serum triacylglycerol concentration ≥200 mg/dL. H-UA was defined as a serum uric acid level ≥7.0 mg/dL for men and ≥6.0 mg/dL for women.

2.4. Statistical analysis

The percentages of subjects characterized as having the selected metabolic disorders, smoking status, and age group distributions (35–44 y, 45–54 y, and 55–64 y) stratified by gender were calculated. Mean values of BMI, WC, and WHR were calculated, and differences in gender for the anthropometric measures and the prevalence of metabolic disorders within each of the age groups were examined by the Student t test and Pearson χ^2 test separately. Empirical receiver-operating characteristic (ROC) curves of BMI, WC, and WHR in predicting the metabolic disorders stratified by gender and smoking status were obtained. In addition, multivariate logistic regression models adjusting for gender, age groups, and smoking status were used to analyze the relative contributions of the continuous anthropometric measurements in predicting the metabolic disorders.

Simple logistic models stratified by age and gender were also applied, while controlling for smoking status. Likelihood-ratio differences with and without the corresponding anthropometric measurement in the model were calculated and compared with each other. Each anthropometric measurement was categorized into three subgroups for men and women separately; subjects whose measurement fell between the first and the third quartiles were used as the baseline reference group ($22.0 \le BMI < 26.3$, $80.5 \le WC < 92.0$, $0.85 \le WHR < 0.92$ for men; $20.8 \le BMI < 25.3$, $71.0 \le WC < 83.2$, $0.76 \le WHR < 0.83$ for women). The model parameter estimates were obtained using generalized estimating equations to account for the correlations that might arise from similarities in diet and lifestyles among household members. The statistical analyses were carried out using SAS software (SAS version 9.1. 2002; SAS Institute, Cary NC, USA).

3. Results

3.1. Participant characteristics and prevalence of metabolic disorders

Table 1 summarizes the age distributions, smoking status, mean anthropometric measurements, and prevalence of the metabolic disorders of the participants stratified by gender. The smoking rate for men was substantially higher than that for women in Taiwanese aged 35–64 y, similar to the prevalence of HBP, H-TG, and H-UA. However, gender differences in these disorders were not significant for the older age group of 55–64 y. Men also tended to have higher measurements in WC and WHR than those of women, whereas BMI for the age group 55–64 y was approximately the same. Gender difference in diabetes was not significant, and women tended to have a higher prevalence of H-Chol.