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Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity and metabolic syndrome

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ABSTRACT

Objective: This study aimed to evaluate the diagnostic value of Waist-to-Height Ratio in early detection of obesity and metabolic syndrome in Chinese children and adolescents.

Method: A cross-sectional study was conducted in six cities in China in 2010 with 16,914 children and adolescents aged 7–17 years. Participants were randomly divided into the training and testing sets. Diagnostic values were estimated using sensitivity, specificity and areas under receiver operating characteristic curves.

Results: The coefficients of variation of Waist-to-Height Ratio among age groups were lower than that of body mass index and waist circumstance. The area under receiver operating characteristic curve of Waist-to-Height Ratio was 0.968 in boys and 0.949 in girls for general obesity evaluation, and 0.983 in boys and 0.984 in girls for central obesity. The optimal cut-offs of Waist-to-Height Ratio were 0.47 in boys and 0.45 in girls in the training set and validated in the testing set. For metabolic syndrome evaluation, the sensitivity and specificity were 0.858 and 0.825 in boys, 0.864 and 0.812 in girls under the suggested cut-offs.

Conclusion: Waist-to-Height Ratio was a simple, effective and practical tool for mass screening childhood obesity and metabolic syndrome in China. It will have potential values in public health practice.

Introduction

The continuous rise in the obesity rate, considered as a serious global health issue, has posed a heavy burden on both the health care system and individuals nowadays (Murray et al., 2012; Yang et al., 2013; Zhao et al., 2008). Childhood obesity is particularly worrisome. More attention should be paid to this problem because of the various adverse effects in childhood (Ebbeling et al., 2002) as well as the continued long-term impacts in adulthood (Dietz, 1998). Previous studies have shown that the long-term effects of childhood obesity and obesity-related complications increased incidence of cardiovascular diseases (CVDs) (Morrison et al., 2007) and diabetes (Morrison et al., 2008) in adulthood. Early detection and intervention are urgently needed for both primary and secondary prevention of obesity and obesity-related complications.

Body mass index (BMI) and waist circumstance (WC) are effective indices for childhood obesity diagnosis. However, they are not ideal tools for mass screening because they are age-dependent indices and the diagnostic references are age-specific. (Cole et al., 2000; Ma et al., 2010). These age-specific cut-offs will reduce the practicability in mass screening and are not suitable for self-regulation by non-professionals.

The common interval of the BMI and WC cut-offs is one year (Cole et al., 2000; Ji, 2005). However, considering the fast rate at which children grow, the U.S. Centers for Disease Control and Prevention has recommended half-year intervals and monthly interval for more accurate assessment (Kuczmarski et al., 2002). Accuracy and practicability requirements cannot be met at the same time using age-depended indices.

Waist-to-Height Ratio (WHtR) is age-independent and has been shown to be effective. It can be suitable for fast and mass screening for obesity and metabolic syndrome, especially in children and adolescents (Ashwell and Hsieh, 2005; Ashwell et al., 1996; Browning et al., 2010). WHtR, the ratio of WC to height, can be considered as a synchronized-adjusted index for WC. Although WC has been shown to be closely correlated to abdominal fat deposits (Balkau et al., 2007; Janssen et al.,

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2004), it is reasonable to doubt its accuracy of evaluations in relatively tall and relatively short individuals with similar WC. Recent studies (Hsieh and Yoshinaga, 1999; Schneider et al., 2011) revealed that shorter people had a higher risk of metabolic syndrome and other related diseases with a similar WC. These findings indicated that height modification of WC was reasonable and it should be taken into account in evaluations of obesity.

Previous studies have shown that the WHtR is closely correlated with obesity and related diseases in adults, such as CVD (Ashwell et al., 2012; Browning et al., 2010; Gelber et al., 2008; Hsieh and Muto, 2005), type 2 diabetes (Browning et al., 2010; Jayawardana et al., 2013; Xu et al., 2013), and metabolic syndrome (Hsieh and Muto, 2006). Significant diagnostic values of metabolic related diseases of WHtR have been reported in obese children and adolescents (Campagnolo et al., 2011; Chen et al., 2012; Kruger et al., 2013; Kuba et al., 2013).

However, few large-scale population-based studies have investigated the role of WHtR in mass screening for childhood obesity and metabolic syndrome. The purpose of the current study, which covers a large sample of children and adolescents in China, was to assess the effectiveness and the practicality of WHtR as a mass screening tool for childhood obesity and metabolic syndrome, and to identify the ideal cut-offs for children and adolescents in China.

Methods

Study design and population

A cross-sectional study of metabolic syndrome in children and adolescents aged 7–17 years was conducted in 2010 from six geographically representative areas in China (Shanghai and Hangzhou for eastern China, Beijing and Tianjin for northern and central China, Chongqing and Nanning for western and southern China). Considering the representative of age, gender and socio-economic status, school-based cluster sampling was performed in these cities. Participants who had cancer, chronic diseases of the heart, liver, lung or kidney, or other serious diseases were excluded.

To identify the optimal cut-offs of WHtR, participants were randomly divided into the training and testing sets using city-based cluster randomization. The larger subset which included 10,428 participants including participants from Chongqing, Hangzhou and Tianjin was defined as the training set and the remaining 6486 participants, who were from another three cities, were classified as the testing set. The study protocols were approved by the Research Ethics Committees at School of Public Health and Medical Ethics Committees at Children's Hospital, College of Medicine, Zhejiang University. All the participants or their guardians provided written informed consent.

Anthropometric measurements

Anthropometric indices, including weight, height, WC, and blood pressure were measured by well-trained investigators, following a standard protocol. Height and weight were measured with the participants wearing light clothing and without shoes. WC was measured at the midpoint between the iliac crest and lowest rib. Blood pressure was measured in a sitting position with a mercury sphygmomanometer after rest. The anthropometric indices were reported as the average of three repeated measurements. BMI was calculated as the individual's body weight in kilograms divided by the square of his or her height in meters. WHtR was calculated as WC in centimeters divided by the height in centimeters.

Laboratory measurements

Biochemical variables including fasting blood glucose (FBG), triglycerides (TG), total cholesterol (TC), high density lipoprotein (HDL) cholesterol and low density lipoprotein (LDL) cholesterol were measured with blood samples collected after a 12-h overnight fast condition using biochemical auto-analyzers (Hitachi 7060, Tokyo, Japan).

Definitions

General obesity, overweight status, and central obesity were estimated based on the Chinese national reference (Ji, 2005; Ma et al., 2010). Hypertension was defined as systolic blood pressure (SBP) and/or diastolic blood pressure (DBP) ≥90th percentile of age- and gender-specific groups in the current study sample. The criteria we used to diagnose metabolic syndrome were based on the US National Cholesterol Education Program's Adult Treatment Panel III (NCEP ATP III) criteria (Cleeman et al., 2001) and modified by Cook (Cook et al., 2003) for children and adolescents with sample specific reference.

Statistical analysis

The coefficient of variation (CV) was calculated to assess the variation of candidate indices. Z-score, calculated as $Z = (x - \mu) / \sigma$ (where μ and σ denote the mean and standard deviation of age- and gender-specific groups in the current sample) was used to standardize BMI and WC. Receiver operating characteristic (ROC) curve analysis was performed and the areas under ROC curve (AUC) and its 95% confidence interval (CI) were calculated for evaluation. Sensitivity, specificity, and Youden's index were used to evaluate the validity of WHtR.

Statistical significances for continuous variables were assessed using the Student's t test, and for categorical variables were assessed using the Chi-square test. Comparisons of AUCs were based on a non-parametric testing of Mann–Whitney U-statistics (Zhang et al., 2002). All analyses were performed using the SAS for Windows (version 9.2, SAS Institute Inc., Cary, NC, U.S.).

Results

A total of 16,914 participants (8843 boys and 8071 girls), aged 7–17, were recruited for this study. The mean age was 11.7 ± 2.6 years. The prevalence of general obesity and central obesity was 7.6% and 11.9%, respectively, in the training set, and 9.7% and 13.8% in the testing set. Sample characteristics and statistical comparisons between training and testing population are shown in Table 1.

Table 2 shows the mean and standard deviation of BMI, WC and WHtR in children and adolescents by age and gender. The mean values and the percentiles of BMI and WC were increased with the age. The CVs of the mean values of BMI and WC among different age groups were 8.2% and 9.4%, respectively, in boys, and 9.4% and 9.2% in girls, whereas the CV of the WHtR was 2.2% in boys and 1.1% in girls.

Regarding assessment of general and central obesity, AUC and 95% CI in the training population are shown in Table 3. The AUC of general obesity was 0.968 in boys and 0.949 in girls. In the assessment of central obesity, WHtR had the AUC of 0.983 in boys and 0.984 in girls. Table 4 shows the sensitivity, specificity and Youden's index of WHtR in different cut-offs in the training population. The optimal cut-offs, corresponding to the highest value of Youden's index, were 0.47 in boys and 0.45 in girls in general and central obesity evaluation. In the assessment of general obesity, under these cut-offs, the sensitivity, specificity and Youden's index of WHtR were 0.935, 0.888 and 0.823, respectively, in boys and 0.909, 0.853 and 0.763 in girls. In the assessment of central obesity, the sensitivity, specificity and Youden's index of WHtR were 0.943, 0.921, and 0.864, respectively, in boys and 0.963, 0.905 and 0.868 in girls. The diagnostic values of the optimal cut-offs of WHtR were validated in the testing population (Table 5).

Table 6 shows the AUC and 95% CI of WHtR for metabolic syndrome diagnostics. The AUC of WHtR was 0.894 in boys and 0.902 in girls, which was higher than that of BMI (Z-score) (0.884 in boys and 0.870 in girls) and close to that of WC (Z-score) (0.901 in boys and 0.904 in