

Report on Childhood Obesity in China (2) Verification of BMI Classification Reference for Overweight and Obesity in Chinese Children and Adolescents¹

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Objective To verify Working Group for Obesity in China (WGOC) recommended body mass index (BMI) classification reference for overweight and obesity in Chinese children and adolescents using the data of 2002 China Nationwide Nutrition and Health Survey. **Methods** Pediatric metabolic syndrome (MetS) and abnormality of each risk factor for MetS were defined using the criteria for US adolescents. Definition of hyper-TC, LDL, and dyslipidemia in adults was applied as well. The average level and abnormality rate of the metabolic indicators were described by BMI percentiles and compared with general linear model analysis. Receiver operating characteristic analysis was used to summarize the potential of BMI to discriminate between the presence and absence of the abnormality of these indicators. **Results** There was neither significantly increasing nor significantly decreasing trend of biochemical parameter levels in low BMI percentile range (<65th). Slight increasing trend from the 75th and a significant increase were found when BMI \geq 85th percentile. In general, the prevalence of the examined risk factors varied slightly when BMI percentile < 75th, and substantial increases were consistently seen when BMI percentile \geq 75th. As an indicator of hyper-TG, hypertension and MetS, the sensitivity and specificity were equal at the point of BMI < 75th percentile, and the Youden's index of risk factors also reached peak point before 75th percentile except for MetS. When the BMI percentile was used as the screening indicator of MetS, Youden's index reached peak point at 85th percentile, just the point in the ROC graph that was nearest to the upper left corner. **Conclusion** The BMI classification reference for overweight and obesity recommended by WGOC is rational to predict and prevent health risks in Chinese children and adolescents. Lower screening cut-off points, such as 83th percentile or 80th percentile, should not be excluded when they are considered as overweight criteria in future intervention or prevention studies.

Key words: BMI classification; Verification; Child; China; Obese

INTRODUCTION

Body mass index (BMI) is generally accepted as a valid indirect measure of adipose tissue in both children and adolescents. Currently, the two most widely used international classification references for overweight and obesity of children and adolescents are the WHO/NCHS- and IOTF-recommended references. They are suitable for research and monitoring and evaluating changes in populations, because the cut-off points provide a standard benchmark against which all population groups can be compared with the trends assessed. However, as indicated by Lobstein^[1], in terms of defining groups at special risk of health problems due to excess

weight, the cut-off points may need to be adjusted for local factors, because there are differences in body composition across different ethnic groups^[2]. Several studies have found that differences exist between Chinese children and children of other ethnic origins^[3-4].

The Working Group for Obesity in China (WGOC) organized by International Life Science Institute Focal Point in China conducted an analysis on BMI of children and adolescents aged 7-18 years in 2002. The age-, sex-specific BMI 85th and 95th percentiles were developed respectively by using B-Spline curve to adjust the curves passing through a BMI of 24 kg/m² and 28 kg/m² (the cut-off points used for Chinese adults to define overweight and

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obesity, respectively) at 18 years of age, and a new BMI classification reference was recommended by WGO in 2003^[5-6].

The primary purpose to define overweight and obesity cut-off points is to provide a tool for predicting obesity-related health risks and prevention of chronic diseases in children and its extension into their adult life. So, disease risk-based evidence has been applied to some extent in the verification of the cut-off points for overweight and obesity of Chinese children and adolescents aged 7-18 years^[7-8]. The purpose of this study was to further verify the rationality of the WGO-recommended BMI classification reference using the data of 2002 China Nationwide Nutrition and Health Survey (2002 CNHNS).

SUBJECTS AND METHODS

2002 CNHNS is a nationally representative cross-sectional survey covering 31 provinces, autonomous regions and municipalities directly under the Central Government (Hong Kong, Macao and Taiwan are not included). Multi-step cluster sampling was adopted; 71 971 households were chosen from 132 counties/districts/cities (22 from each category: large, medium-sized and small cities, rural areas 1, 2, 3, 4 from highly to least developed).

Fasting body weight, height, waist circumference, and blood pressure of the subjects were measured following the standardized procedures. Fasting blood samples were collected for the measurements of biochemical parameters including blood glucose and lipid profiles.

The information on weight and height measurements of 44 880 children aged 7-18 years, blood glucose and lipid profiles of 8480 children aged 7-18 years, waist circumference and blood pressure of 1160 children aged 15-18 years were available for this study.

The following definitions were used:

(1) Pediatric metabolic syndrome (MetS)^[9]. Analogous to Adult Treatment Panel (ATP III), ≥ 3 of following 5 parameters:

- Hyper-TG: fasting triglycerides ≥ 1.1 mmol/L
- Low HDL: HDL < 1.3 mmol/L, except in boys aged 15 to 18 years, in whom the cut-point is < 1.17 mmol/L
- Hyperglycemia: fasting glucose ≥ 6.1 mmol/L
- Central obesity: waist circumference > 75 th percentile for age and gender
- Hyper-SBP: systolic blood pressure > 90 th percentile for gender, age, and height; Hyper-DBP: diastolic blood pressure > 90 th percentile for gender, age, and height;

Hypertension: with hyper-SBP or hyper-DBP, or both^[10]

(2) Diabetes mellitus: fasting blood glucose ≥ 7.0 mmol/L^[11]

The following parameters for adults were applied in this analysis, as there is no reference for children^[12]:

(1) Hyper-TC: blood cholesterol ≥ 5.72 mmol/L

(2) High LDL: LDL > 3.64 mmol/L

(3) Dyslipidemia: with any one of hyper-TC, hyper-TG or low HDL

The mean and standard deviation of each variable were analyzed using age- and sex- specific percentiles to reduce the potential differences due to maturation. To compare the differences in blood glucose, blood pressure, and lipid levels of children with different BMI percentiles relative to the one at the lowest BMI (< 25 th percentile), a general linear model factorial analysis was conducted with Tukey post-hoc comparisons as the data did not exhibit bivariate normal distribution; sensitivity and specificity were calculated at all BMI percentiles. Sensitivity was the proportion of overweight children with risk factor, while specificity was the proportion of non-risk children with normal weight. Youden's Index was calculated using the standard formula (sensitivity+specificity-1). Receiver operating characteristic (ROC) analysis was used to assess the performance of high BMI to detect increased risk of cardiovascular disease risk factors and determine optimal cut-off points. ROC plots were obtained by graphing the sensitivity values against 1-specificity for all available thresholds. ROC analysis, as described by Zweig and Campbell^[13], was used to summarize the potential of BMI to discriminate between the presence and absence of illnesses. The range of values 0.7-0.8 for the area under the ROC curve was considered to represent reasonable diagnostic discrimination, and values > 0.8 were considered to represent good diagnostic discrimination. All statistical analyses were performed by SAS software (version 8.2), and statistical significance was adjudged to be at the 0.05 level.

RESULTS

The characteristics of the subjects are shown in Table 1. The number of boys and girls from urban areas of China was 967 and 889, respectively, while that from rural areas was 3761 and 3244, respectively.

The distribution of blood pressure, fasting blood glucose, and lipid profiles by BMI percentiles is shown in Table 2. There was neither apparent increasing nor decreasing trends of biochemical parameters at

TABLE 1

Characteristics of Subjects

| Age (Years) | Urban | | Rural | |
|----------------|-------|-------|-------|-------|
| | Boys | Girls | Boys | Girls |
| 7- | 70 | 65 | 357 | 283 |
| 8- | 85 | 70 | 390 | 324 |
| 9- | 84 | 95 | 413 | 388 |
| 10- | 90 | 100 | 453 | 363 |
| 11- | 120 | 83 | 427 | 432 |
| 12- | 115 | 111 | 521 | 396 |
| 13- | 92 | 89 | 418 | 405 |
| 14- | 93 | 81 | 344 | 316 |
| 15- | 87 | 74 | 249 | 187 |
| 16- | 78 | 70 | 126 | 102 |
| 17- | 53 | 51 | 63 | 48 |
| Total | 967 | 889 | 3761 | 3244 |

low range of BMI percentiles (<65th). Slightly increasing trend starting from the 75th BMI percentile and a significant increase after BMI percentile ≥ 85 th were found. Slightly increasing trends of fasting blood glucose and HDL-C were found from the 75th percentile; while significant increment in fasting blood glucose and HDL-C was only found in younger and boys, respectively. The triglyceride levels went up from the 65th or 75th BMI percentile, and significant differences were found when BMI percentile was ≥ 95 th as compared with BMI percentile <25th percentile. The total cholesterol and LDL-C levels in the children started to increase at the 75th BMI percentile, and significant increase started at the 85th percentile in boys and at 95th percentile in girls. The ratio of total HDL cholesterol in children with BMI>85th percentile was significantly higher as well. Both the systolic and diastolic blood pressures of elder children with BMI >55th percentile were significantly higher than those of their counterparts with lowest BMI, steadily increased along with the BMI, and reached over 20 mmHg of the systolic blood pressure and over 10 mmHg of the diastolic blood pressure. Similar trends were found among the elder girls, but the significant increase of the blood pressure started from the 75th BMI percentile, and their increment was less than 10 mmHg.

The prevalence of the examined risk factors varied slightly at BMI percentile<75th, while substantial increases were consistently found at BMI percentile ≥ 75 th. The prevalence of hyper-TG increased

only from 13.2% (<25th) to 15.5% (75th) between the thinnest (<25th) boys aged 7-12 years and those with their BMI percentile between 75th and 85th, but increased to 21.7% of the 85th percentile and then to 27.4% of the 95th percentile (Fig. 1). Compared with the lowest BMI group, the differences in hypertension, hyper-SBP and hyper-DBP were all lower than 10% in the 75th percentile group, but the prevalence of hypertension almost doubled in the boys at BMI percentile>85th and tripled in the boys at BMI percentile>95th; similar trends were also found in girls starting from the 55th percentile (Fig. 2). MetS was found in a few cases when BMI percentile was <75th. The prevalence of MetS reached 22.6% and 33.3% in boys at BMI percentile ≥ 85 th and ≥ 95 th, respectively, while 15.0% and 44.4% in girls at BMI percentile ≥ 85 th and ≥ 95 th, respectively, and only 4% in the low BMI groups (Fig. 3).

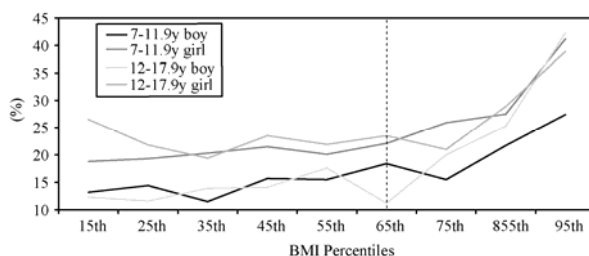


FIG. 1. Prevalence of hyper-triglyceridemia by BMI (percentiles) .

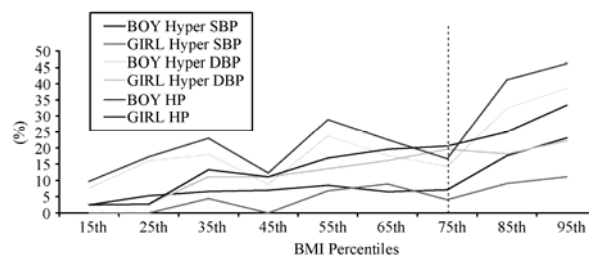


FIG. 2. Prevalence of hypertension by BMI (percentiles).

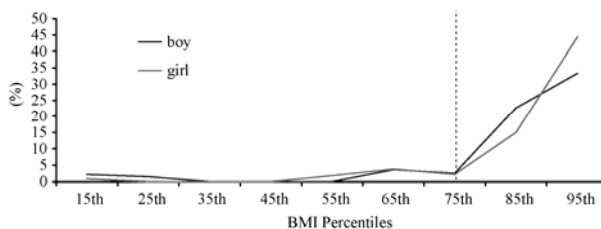


FIG. 3. Prevalence of MetS by BMI percentiles.

TABLE 2
Distribution of Biochemical Indicators by BMI Percentile¹

| | BMI Percentiles (Boys) | | | | | | | | | | BMI Percentiles (Girls) | | | | | | | | | |
|--------------------------|------------------------|--------|-------|-------|--------|--------|--------|--------|--------|--|-------------------------|-------|-------|-------|--------|-------|--------|--------|--------|--|
| | <25th | 25th- | 35th- | 45th- | 55th- | 65th- | 75th- | 85th- | 95th- | | <25th | 25th- | 35th- | 45th- | 55th- | 65th- | 75th- | 85th- | 95th- | |
| 7-12 years | | | | | | | | | | | | | | | | | | | | |
| BMI (kg/m ²) | 14.3 | 15.3* | 15.8* | 16.3* | 17.0* | 17.7* | 18.7* | 20.7* | 24.1* | | 13.9 | 14.9* | 15.5* | 16.0* | 16.3* | 17.0* | 18.5* | 20.5* | 23.7* | |
| TBG (mg/dL) | 83.1 | 83.3 | 85.0 | 85.3* | 85.5* | 83.4 | 86.8* | 88.5* | 85.8 | | 82.1 | 81.9 | 83.0 | 82.7 | 82.2 | 83.6 | 84.1 | 84.8 | 86.2 | |
| HDL-C (mg/dL) | 50.0 | 50.6 | 49.9 | 49.7 | 49.9 | 49.8 | 49.7 | 51.1 | 50.9 | | 50.0 | 49.4 | 49.1 | 48.5 | 48.4 | 48.2 | 49.1 | 48.7 | 47.9 | |
| TG (mg/dL) | 71.8 | 71.1 | 68.2 | 73.4 | 73.4 | 76.8 | 71.9 | 77.7 | 84.2* | | 77.0 | 76.1 | 78.0 | 79.7 | 76.7 | 79.8 | 84.1 | 88.2 | 93.9* | |
| TC (mg/dL) | 123.9 | 122.6 | 122.1 | 124.8 | 123.3 | 123.4 | 129.2 | 135.5* | 135.4* | | 124.8 | 125.2 | 124.4 | 122.7 | 122.6 | 122.3 | 128.7 | 132.2 | 137.2* | |
| LDL-C (mg/dL) | 58.3 | 56.6 | 57.6 | 59.1 | 58.2 | 56.9 | 63.8 | 67.5* | 66.2* | | 58.1 | 59.2 | 58.3 | 56.8 | 57.5 | 57.5 | 61.3 | 64.4 | 68.9* | |
| TG:HDL-C | 1.5 | 1.5 | 1.5 | 1.6 | 1.6 | 1.7 | 1.6 | 1.6 | 1.8 | | 1.6 | 1.6 | 1.7 | 1.7 | 1.7 | 1.7 | 1.8 | 1.9 | 2.2* | |
| TC:HDL-C | 2.5 | 2.5 | 2.5 | 2.6 | 2.5 | 2.5 | 2.7 | 2.7* | 2.7 | | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.8 | 3.0* | |
| 12-18 years | | | | | | | | | | | | | | | | | | | | |
| BMI (kg/m ²) | 16.1 | 17.5* | 18.0* | 18.7* | 19.4* | 20.2* | 21.7* | 24.3* | 28.2* | | 16.2 | 17.5* | 18.2* | 18.8* | 19.4* | 20.2* | 21.7* | 24.4* | 28.1* | |
| TBG (mg/dL) | 83.7 | 83.9 | 84.9 | 83.9 | 83.9 | 84.3 | 85.6 | 85.8 | 87.5 | | 82.9 | 83.7 | 82.7 | 84.5 | 84.3 | 82.5 | 83.5 | 85.2 | 83.8 | |
| HDL-C (mg/dL) | 48.5 | 49.6 | 45.1* | 45.7 | 47.9 | 47.0 | 45.2* | 44.7* | 44.2* | | 49.5 | 49.2 | 48.7 | 47.8 | 46.7 | 47.6 | 47.7 | 46.0 | 45.2 | |
| TG (mg/dL) | 70.9 | 68.3 | 71.7 | 77.9 | 72.5 | 66.6 | 75.6 | 82.2 | 94.9* | | 84.6 | 79.0 | 75.1 | 82.9 | 79.9 | 83.4 | 82.0 | 85.1 | 100.3 | |
| TC (mg/dL) | 118.0 | 119.5 | 112.7 | 113.3 | 119.4 | 118.4 | 117.8 | 125.8 | 133.3 | | 124.6 | 125.4 | 124.8 | 123.7 | 123.5 | 123.7 | 126.4 | 125.7 | 144.7* | |
| LDL-C (mg/dL) | 54.1 | 55.1 | 52.0 | 52.0 | 55.8 | 57.0 | 56.1 | 63.2* | 68.5* | | 57.0 | 59.1 | 59.8 | 57.8 | 59.4 | 58.0 | 61.6 | 61.2 | 77.6* | |
| TG:HDL-C | 1.5 | 1.5 | 1.7 | 1.8 | 1.6 | 1.5 | 1.7 | 2.0* | 2.3* | | 1.8 | 1.7 | 1.6 | 1.9 | 1.8 | 1.8 | 1.8 | 2.0 | 2.3 | |
| TC:HDL-C | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.9* | 3.1* | | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.6 | 2.7 | 2.8* | 3.2* | |
| Waist (%) | 62.5 | 65.1* | 66.1* | 68.6* | 68.4* | 71.1* | 74.9* | 81.3* | 93.0* | | 60.7 | 62.0 | 64.0* | 65.7* | 65.5* | 66.4* | 69.6* | 74.8* | 83.2* | |
| SBP (mmHg) | 104.1 | 108.9* | 109.1 | 107.9 | 114.1* | 111.0* | 114.5* | 118.1* | 120.8* | | 100.7 | 101.7 | 103.9 | 105.3 | 106.4* | 105.3 | 106.5* | 109.7* | 113.7* | |
| DBP (mmHg) | 67.1 | 69.7 | 69.3 | 68.4 | 72.5* | 71.0* | 72.2* | 74.6* | 77.9* | | 66.1 | 66.3 | 68.8 | 69.0 | 68.3 | 68.7 | 70.7* | 72.2* | 73.9* | |

Note. ¹General linear model (GLM) factorial analysis with Tukey post-hoc comparisons, * $P < 0.05$ relative to the BMI < 25th percentile. BMI: body mass index; FBG: fasting blood (serum) glucose; HDL-C: high density lipoprotein cholesterol; TG: triglyceride; TC: total cholesterol; LDL-C: low density lipoprotein cholesterol; TG:HDL-C: ratio of triglyceride to HDL cholesterol; TC: HDL-C: ratio of total to HDL cholesterol; Waist: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure.

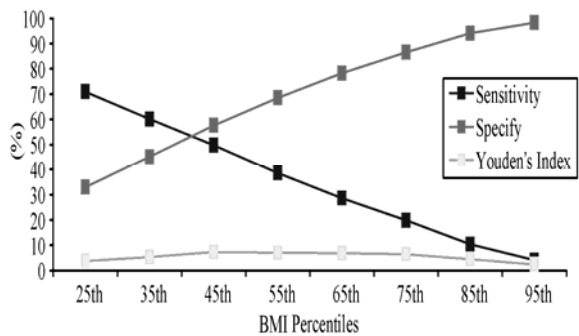


FIG. 4. Sensitivity, specificity, and Youden's index of BMI percentiles as an indicator of risk of hyper-TG.

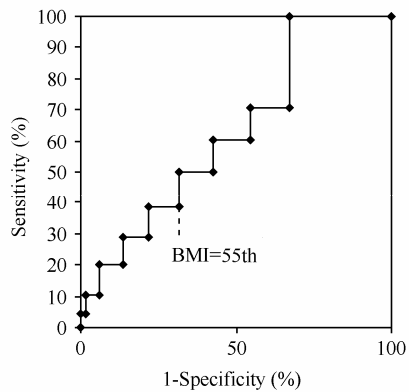


FIG. 7. ROC curve of BMI percentiles as an indicator of risk of hyper-TG.

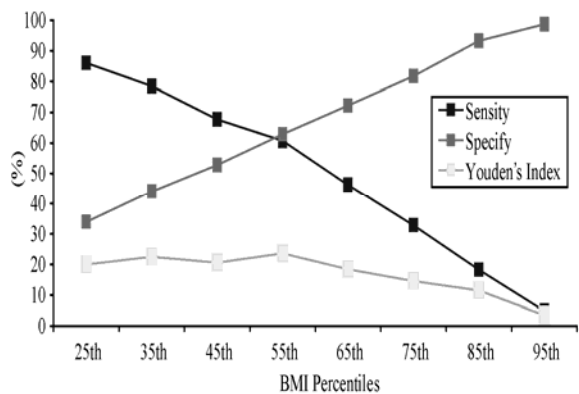


FIG. 5. Sensitivity, specificity and Youden's index of BMI percentiles as an indicator of risk of hypertension.

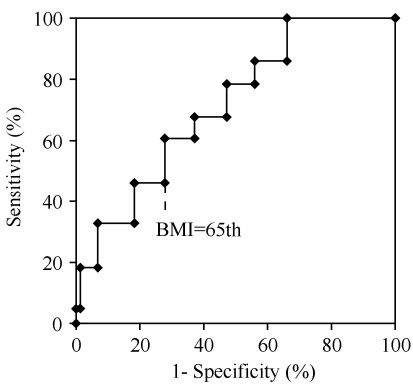


FIG. 8. Sensitivity, specificity and Youden's index of BMI percentiles as an indicator of risk of hypertension.

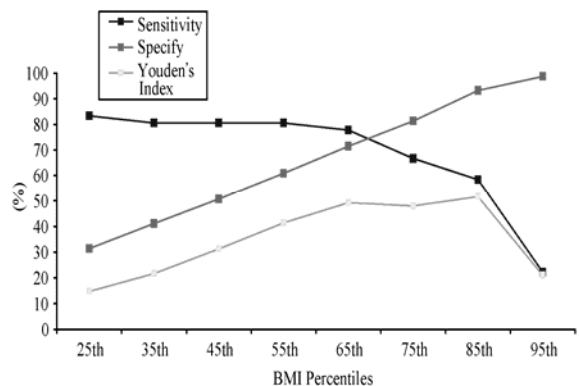


FIG. 6. Sensitivity, specificity and Youden's index of BMI percentiles as an indicator of risk of MetS.

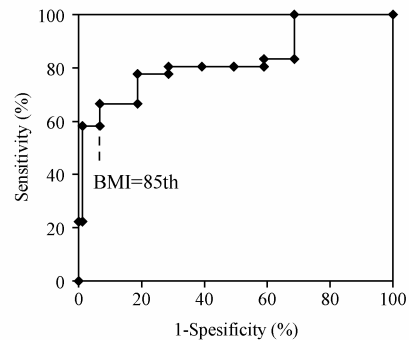


FIG. 9. ROC curve of BMI percentiles as an indicator of risk of MetS.

As an indicator of hyper-TG, hypertension and MetS, the sensitivity and specificity of BMI were equal at the point less than the 75th percentile as observed at the intersection point of the sensitivity and specificity graphs (Figs. 4-6). The Youden's index of risk factors also peaked before 75th percentile (Figs. 4-5) except for MetS (Fig. 6). When BMI percentiles were used as the screening indicator of MetS, the Youden's index peaked at the 85th percentile, just the point in the ROC graph nearest to the upper left corner of the ROC curve (Figs. 7-9). Compared to the area under the ROC curve, a measure of the diagnostic power of a test^[13], the maximum area under the ROC curve for MetS with BMI percentiles was near 0.8 (Fig. 9), presenting the good diagnostic discrimination. The maximum area under the ROC curve for hypertension with BMI percentiles was almost 0.7, representing the reasonable diagnostic discrimination. The areas under the ROC curve for hyper-TG (Fig. 8), hyper-TC and hyper-LDL-C (data not shown) with BMI percentiles were all above 0.5 but less than 0.7.

DISCUSSION

It was reported that differences in body composition exist across adult ethnic groups^[2]. There are differences in 2-3 BMI units between whites and Asian adults with the same body composition^[2,14]; the increased risks related to obesity occur at lower BMIs in Asians, and these populations are predisposed to visceral or abdominal obesity^[7-8,15-17]. Therefore, WHO has suggested that Asia overweight and obesity be defined at BMI ≥ 23 kg/m² and ≥ 25 kg/m², respectively^[18], and WGOC recommended that the BMI cut-off point for overweight be BMI ≥ 24 kg/m² and BMI ≥ 28 kg/m² for obesity for Chinese adults based on the analysis of the data of BMI/waist circumference and its relationship with the risk of hypertension, diabetes mellitus, dyslipidemia, and coronary heart disease risk factor clustering^[6].

Not as in adults whose overweight and obesity cut-off points are always determined by their recent or long term disease risks, the definitions of childhood overweight and obesity are usually based on the distribution of anthropometrics in populations. WGOC-recommended BMI classification reference for overweight and obesity of Chinese children and adolescents is also based on the population distribution of BMI, and can extrapolate from the adult BMI cut-off points into the childhood ones. The major strength of this research lies in the represented samples of Chinese children and adolescents with the measurements of risk factors in childhood.

The results of this study indicate that the

variability of BMI is associated with the prevalence of cardiovascular disease risk factors in Chinese children and adolescents. The obese and overweight groups had a significantly higher level of blood pressures and lipid profile levels, they were also at a higher risk of having metabolic syndrome, hyper-TG and hypertension, suggesting that the WGOC-recommended BMI classification reference for overweight and obesity is rational to predict and prevent health risks in Chinese children and adolescents.

However, we still should consider that this reference might underestimate the prevalence of overweight and obesity in Chinese children. When we look at the distribution curve of the biochemical profiles and prevalence of risk factors according to BMI percentile, the health risk of Chinese children increased remarkably from the 65th or 75th percentile of BMI. As a screening criterion for disease prevention, the sensitivity of overweight when defined as 85th percentile in Chinese children is very low, whereas the specificity of obesity as a screening indicator of all measured cardiovascular risk factors was above 97%; suggesting that some of the children with high adiposity and potential risk of cardiovascular disease may not be screened timely. According to the Bogalusa Heart Study^[19], the sensitivity for all measured risk factors of overweight defined as Quetelet index >95th percentile was 23%-62%, while the specificity ranged 88%-90% as a screening criterion. The possible reason of the underestimated criteria maybe due to the use of B-Spline curve to adjust the curves passing through a BMI of 24 kg/m² and 28 kg/m². Health risk factors start to cluster in Chinese adults from a BMI of 23 kg/m², as is shown by the graph of prevalence in men and women at high risk by BMI^[15].

The limitations of cross-sectional survey design might attenuate our results. However, not as the adults, children are seldom exposed to diet or physical activity regiment and generally do not receive treatment for obesity and related diseases minimizing the confounding factors of the health risk analysis of overweight and obesity.

In conclusion, the WGOC-recommended BMI classification reference for overweight and obesity is rational to predict and prevent health risks in Chinese children and adolescents. Lower screening cut-off points, such as 83rd percentile or 80th percentile, should not be excluded from considering as overweight criteria in future intervention or prevention studies.

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