Optimal Cutoff Values for Overweight: Using Body Mass Index to Predict Incidence of Hypertension in 18- to 65-Year-Old Chinese Adults

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Abstract

Studies aimed at identifying BMI cutoffs representing increased disease risk for Asians are typically based on cross-sectional studies. This study determines an optimal BMI cutoff for overweight that represents elevated incidence of hypertension in Chinese adults with data from the China Health and Nutrition Survey 2000–2004 prospective cohort. Cumulative incidence was calculated by dividing new cases of hypertension over the study period by the total at-risk population, aged 18–65 years, in 2000. Sex-specific receiver operating characteristic curves were used to assess the sensitivity and specificity of BMI as a predictor of hypertension incidence. Four-year cumulative incidences of hypertension (13% for women and 19% for men) were related \( P < 0.005 \) to the increase in BMI. The crude area under the curves (AUC) were 0.62 (95% CI: 0.59–0.65) and 0.62 (95% CI: 0.58–0.65) for men and women, respectively; the age-adjusted AUC were 0.68 (95% CI: 0.65–0.70) and 0.71 (95% CI: 0.68–0.74) for men and women, respectively. A BMI of 23.5 kg/m\(^2\) for women and 22.5 kg/m\(^2\) for men provided the highest sensitivity and specificity (60%). The finding was consistent in different age groups. A BMI level of 25 kg/m\(^2\) provided lower sensitivities (36% for women and 29% for men) with higher specificities (80% for women and 85% for men). Our study supported the hypothesis that the BMI cutoff to define overweight should be lower in Chinese than that in Western populations. J. Nutr. 138: 1377–1382, 2008.

Introduction

Increased prevalence, attributable death, and economic burdens of overweight and noncommunicable diseases are emerging problems in China and other Asian countries (1–4). Although BMI cutoffs of 25 and 30 kg/m\(^2\) for overweight and obesity, respectively, have been widely used among Western populations and recommended by the WHO as international criteria for body fatness at the population level, controversy remains regarding the optimal BMI cutoffs for Asians (6–8).

Most of the work that serves as a background for these debates used cross-sectional samples and a \( P \)-value < 0.05 or non-overlapping 95% CI as a decision rule (6–8). Because \( P \)-values and 95% CI widths are driven by both magnitude of effect and sample size (9), findings will vary by sample size, BMI distributions, and prevalence of risk factors. A BMI cutoff of 23 kg/m\(^2\) has been proposed by some authors who used sensitivity, specificity, and receiver operating characteristic (ROC) \(^6\) curve analysis (10–14). Because these studies were based on cross-sectional samples, we are not certain that the exposure to a higher BMI had preceded the hypertension outcome (15). We used an ROC curve analysis to determine an optimal BMI cutoff for overweight that represents elevated incidence of hypertension in Chinese adults.

Subjects and Methods

Subjects. The China Health and Nutrition Survey (CHNS) is an ongoing study established in the late 1980s in 9 provinces that vary substantially in geography, economic development, public resources, and health indicators. A detailed description of the study design and data collection procedures has been presented elsewhere (16,17). Data sets and questionnaires may be downloaded from the CHNS Web sites (http://www.cpc.unc.edu/china). For this analysis, we used data from the CHNS conducted in 2000 and 2004, because these 2 surveys had the most comparable study sample, questionnaires, protocol, and equipment in measuring blood pressure, weight, height, and waist circumference. Of the 6162 participants who were 18- to 65- year-old men, nonpregnant or nonlactating women in 2000, and who were involved in both surveys, 5543 (90%) had complete and plausible measurements of blood pressure and other anthropometric measurements (e.g. 4-y changes in height <10 cm and in BMI <10 kg/m\(^2\); a baseline BMI of 15–40 kg/m\(^2\), waist circumference of 45–150 cm, waist:hip ratio of 0.6–1.3, and hip circumference of 55–155 cm; or the difference between systolic and diastolic blood pressure <10 mm Hg). Of the 5543 participants, 4492

\( ^1 \) Supported by the Vietnam Educational Foundation and NIH (R01-HD30880, DK066350, and R01-HD38700).

\(^2\) Author disclosures: N. T. Tuan, L. S. Adair, K. He, and B. M. Popkin, no conflicts of interest.

\(^6\) Abbreviations used: AUC, area under the curve; CHNS, China Health and Nutrition Survey; ROC, receiver operating characteristic.

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(81%) with normal blood pressure in 2000 were included in our longitudinal sample. We only included 18- to 65-y-old adults, including nonpregnant and nonlactating women because a teenager, an older person, or a pregnant or lactating woman requires different BMI cutoffs (5). The exclusion of participants with extreme or implausible values of anthropometric measures or blood pressure helped to increase our estimate precision without changing the overall results.

**Results**

At baseline, mean systolic and diastolic blood pressures were higher among men compared with women (~3 mm Hg; P < 0.05). Women had a higher mean BMI and prevalence of overweight compared with men. The proportions of Chinese men who were smokers (63%) and alcohol drinkers (65%) were much higher than those of women (4 and 10%, respectively) (Table 1).

Although the Chinese adults had a low mean BMI (a mean of 22.6 kg/m²; 95% CI: 22.5–22.7), 4-y cumulative incidences of hypertension in women were 12.7% (95% CI: 11.3–14.0) and 18.7% (95% CI: 17.1–20.4) in men. In general, approximately one-fourth of the hypertensive new cases in the Chinese population are attributed to a BMI of 23 kg/m² or higher. In addition, a higher population attributable risk was found in women and young participants. Crude incidence of hypertension among men was higher than that of women at almost all BMI levels (e.g. 21–22.9, 23–24.9, and 25–29.9; P < 0.05). There was a decline in hypertension incidence at the BMI of 30–40 kg/m² in men. The estimate, however, might not reflect a real trend of BMI and hypertension association because of a small number of participants that lead to less precise estimate in the BMI group (Fig. 1A). The adjusted incidence of hypertension in men (in a hypothesized population at age 40 y) was significantly higher than that of women at all BMI levels (Fig. 1B).

The AUC for the prediction of hypertension by BMI (~0.62) was significantly higher than what would be expected by chance, which indicated that BMI predicts hypertension. The AUC values were higher in younger compared with older participants (Table 2). Compared with the maximum value of AUC (1.0 for perfect prediction), these AUC values suggested that other risk factors also contributed to the prediction of hypertension.

Controlling for age and other potential confounding factors, the AUC increased significantly to ~0.70, without reducing estimated precision.

In this cohort, BMI levels of 23.5 kg/m² for women and of 22.5 kg/m² for men provided the shortest distance on the ROC curves.

### Table 1 Characteristics of 18- to 65-y-old, normotensive participants in 2000

<table>
<thead>
<tr>
<th></th>
<th>Women, n = 2415</th>
<th></th>
<th>Men, n = 2077</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>95% CI</td>
<td>Estimate</td>
<td>95% CI</td>
</tr>
<tr>
<td>Age, y</td>
<td>42.5</td>
<td>(42.1–42.9)</td>
<td>41.5*</td>
<td>(41.0–41.9)</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>111.7</td>
<td>(111.2–112.1)</td>
<td>115.2*</td>
<td>(114.7–115.7)</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>73.0</td>
<td>(72.7–73.4)</td>
<td>75.5*</td>
<td>(75.2–75.8)</td>
</tr>
<tr>
<td>BMI</td>
<td>22.8</td>
<td>(22.6–22.9)</td>
<td>22.4*</td>
<td>(22.3–22.5)</td>
</tr>
<tr>
<td>15–18.5 kg/m², %</td>
<td>6.0</td>
<td>(5.1–7.0)</td>
<td>6.0</td>
<td>(5.0–7.0)</td>
</tr>
<tr>
<td>23–40 kg/m², %</td>
<td>44.0</td>
<td>(42.0–46.0)</td>
<td>38.1*</td>
<td>(36.0–40.2)</td>
</tr>
<tr>
<td>25–40 kg/m², %</td>
<td>21.7</td>
<td>(20.0–23.3)</td>
<td>17.5*</td>
<td>(15.9–19.2)</td>
</tr>
<tr>
<td>Ever smoked cigarettes, %</td>
<td>3.6</td>
<td>62.9* (60.8–65.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol drinker, %</td>
<td>10.2</td>
<td>(8.9–11.4)</td>
<td>64.7*</td>
<td>(62.6–66.8)</td>
</tr>
<tr>
<td>Urban resident, %</td>
<td>32.4</td>
<td>(30.6–34.3)</td>
<td>32.2</td>
<td>(30.2–34.2)</td>
</tr>
</tbody>
</table>

1 Values are means or percentages with 95% CI, n = 4,492 (excluded participants with implausible anthropometric indices, e.g. BMI <15 or >40 kg/m²). *Different from women, P < 0.05; 2-tail independent t test for continuous variables or chi-square test for categorized variables.
The optimal BMI cutoff for ages 41–65 y was slightly higher compared with that for age 18–40 y. A BMI cutoff of 25 provided lower sensitivities (26–37%) and higher specificities (76–86%) compared with the optimal BMI cutoffs (Table 2). ROC curves and optimal BMI levels for various age groups are presented for all subjects (Fig. 2A), women (Fig. 2B), and men (Fig. 2C).

Discussion
To our knowledge, we are the first to use ROC curve analyses to identify an optimal BMI cutoff for incident hypertension in an Asian sample. Our findings show a strong positive association between BMI and incidence of hypertension and suggest an optimal BMI cutoff of ~23.0 kg/m² to define overweight in 18- to 65-y-old Chinese adults.

The significant trend of increased risk of hypertension with increased BMI is similar to results from cross-sectional studies in Asian populations (12,13,19–22). This longitudinal analysis of hypertension incidence confirms a dose-response relationship. Using the CHNS 2000–2004 cohort, Li et al. (23) also found higher hypertension incidence with higher BMI and waist circumference levels. Although both studies were based on data from the same cohort, they differ in focus. Our focus was on establishing optimal BMI cutoffs, whereas theirs was on comparing hypertension incidence or risk ratios among several BMI and waist circumference groups (23).

Our study suggests an optimal BMI cutoff of <25 kg/m² for 18- to 65-y-old Chinese men and women. We found a slight increase in the BMI cutoffs (~0.5 kg/m²) among older compared with younger participants. There are several explanations for the lower optimal BMI cutoff for Asians compared with that of Westerners. First, Asian ethnicities tend to have a higher total body fat (24,25) as well as a greater amount of abdominal and visceral fat (26,27) at a given BMI compared with other races and ethnicities. Increased visceral fat mass leads to increased blood pressure via several mechanisms such as leptin resistance, insulin resistance, and inflammation (28,29). Second, race/ethnic groups often differ in socioeconomic status, cultural factors, food habits, physical activity levels, and lifestyles (30,31). Third, different ethnicities may have different combinations of genes associated with hypertension and gene-environment interactions that lead to the variation in blood pressure (28,32–35). Finally, there is also speculation that insults during fetal development and infancy might have also resulted in the elevated risks. However, there is great debate about these relationships and their subsequent effects (36–40).

Our findings were consistent with results from large-scale cross-sectional studies in Chinese and Indian populations (10,13,21,41). In those studies, a BMI cutoff of 22–24 kg/m² was associated with increased prevalence of hypertension. (corresponding to a sensitivity and specificity of ~60%). The optimal BMI cutoff for ages 41–65 y was slightly higher compared with that for age 18–40 y. A BMI cutoff of 25 provided lower sensitivities (26–37%) and higher specificities (76–86%) compared with the optimal BMI cutoffs (Table 2). ROC curves and optimal BMI levels for various age groups are presented for all subjects (Fig. 2A), women (Fig. 2B), and men (Fig. 2C).

### Table 2

<table>
<thead>
<tr>
<th>Optimal BMI cutoffs</th>
<th>Cutoffs, kg/m²</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>At a BMI of 25 kg/m²</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Both sexes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>All ages</td>
<td>4492</td>
<td>0.61</td>
<td>22.5</td>
<td>0.62</td>
<td>0.56</td>
<td>0.32</td>
</tr>
<tr>
<td>18–40 y</td>
<td>1999</td>
<td>0.64</td>
<td>22.5</td>
<td>0.63</td>
<td>0.61</td>
<td>0.33</td>
</tr>
<tr>
<td>41–65 y</td>
<td>2493</td>
<td>0.59</td>
<td>23</td>
<td>0.56</td>
<td>0.57</td>
<td>0.31</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All ages</td>
<td>2415</td>
<td>0.62</td>
<td>23</td>
<td>0.56</td>
<td>0.85</td>
<td>0.36</td>
</tr>
<tr>
<td>18–40 y</td>
<td>1053</td>
<td>0.64</td>
<td>23</td>
<td>0.59</td>
<td>0.86</td>
<td>0.31</td>
</tr>
<tr>
<td>41–65 y</td>
<td>1362</td>
<td>0.59</td>
<td>23.5</td>
<td>0.57</td>
<td>0.58</td>
<td>0.37</td>
</tr>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All ages</td>
<td>2077</td>
<td>0.62</td>
<td>22.5</td>
<td>0.61</td>
<td>0.59</td>
<td>0.29</td>
</tr>
<tr>
<td>18–40 y</td>
<td>946</td>
<td>0.64</td>
<td>22.5</td>
<td>0.62</td>
<td>0.62</td>
<td>0.34</td>
</tr>
<tr>
<td>41–65 y</td>
<td>1131</td>
<td>0.61</td>
<td>22.5</td>
<td>0.60</td>
<td>0.57</td>
<td>0.26</td>
</tr>
</tbody>
</table>

1 AUC values range from 0.5 (no prediction) to 1.0 (perfect prediction).
diabetes mellitus, dyslipidemia, and cardiovascular diseases. Huxley et al. (14), in a sample of 263,000 participants (73% Asian) from 21 cross-sectional studies in Australia and some Asian countries, also showed an optimal BMI cutoff of \(24 \text{ kg/m}^2\) for Asians.

Our proposed optimal BMI cutoff was lower than those suggested by authors who used total mortality as a study outcome in some Chinese longitudinal samples (42,43). In those samples, a BMI of 24–24.9 kg/m\(^2\) in men, 25–26.9 kg/m\(^2\) in women (42), and 24–27.9 kg/m\(^2\) in both sexes (43) was associated with the lowest mortality rate. There are several potential explanations for the differences. First, at baseline, participants were much older in the studies by Gu et al. (42) (≥40–y; mean age, 56 y) and by Zhou (43) (≥30 y; mean age, 47 y) compared with ours (18–65 y; mean age, 42 y). The inclusion of an older participant would lead to an increase in BMI due to the naturally decreased height and a larger influence of other cardiovascular risks. Thus, the inclusion of an older participant would bias the association between BMI and health outcome toward the null and lead to a higher BMI cutoff. Second, mortality is influenced by factors other than BMI (e.g. diseases and preexisting health conditions, HIV/AIDS, smoking habits, alcohol consumption, other lifestyles factors, accidents, suicides, and health care services) (6,7). Thus, we would see a higher BMI cutoff for an all-cause mortality outcome compared with hypertension or other cardiovascular risk. Third, in the studies by Gu et al. (42) and Zhou (43), the differences in death rates or risk ratios between different BMI levels were negligible (most of them had an overlapping 95% CI or a \(P\)-value > 0.05).

Even though the use of longitudinal data was a strength of our study, participant selection for this analysis sample may reduce the generalizability of the findings. This sample included only participants of both surveys (2000 and 2004), who tended to be older, and normotensive participants in 2000, who tended to have a lower risk of hypertension (and associated risk factors, e.g. being younger or female, having a lower BMI or smaller waist circumference, or less likely to smoke or drink alcohol). The inclusion of older participants who had additional risk factors other than increased BMI would bias the estimate for the association between BMI and hypertension toward the null and decrease the AUC values. In contrast, the inclusion of persons with a lower risk of hypertension in the longitudinal sample would bias the estimate away from the null and increase the AUC values.

Because a sensitivity analysis showed that optimal BMI cutoffs by level of risk factors such as age, smoking, or drinking status were similar to the overall sex-specific BMI cutoffs, selection bias was not likely to be a notable problem in this sample. Even though this participant selection did not affect our overall results, it would be better to have an open cohort to measure an incidence density, based on the number of new cases and total person-time at risk. However, we were not able to estimate the incidence density of hypertension in the CHNS samples, because the exact time when the hypertension outcome occurred was unknown.

Similar to other cardiovascular risk factors, blood pressure might vary over time (18) and, thus, a hypertensive patient in one survey could become normotensive in the next survey. In our study, the exclusion of hypertensive patients in 2000 led to a decrease in the mean blood pressures in 2000 and, thus, an increased hypertension incidence. The findings need verifications from further studies that use other outcomes such as incidence of diabetes mellitus, dyslipidemia, cardiovascular disease events, or mortality. Although BMI is positively associated with increased risk of cardiovascular risk, its predictions for those outcomes are moderate (AUC of 0.6–0.8) in Asian populations (11,12,14,21). The moderate levels of AUC indicate that other factors also contribute to the prediction of cardiovascular risk. Thus, the BMI cutoff based on the sensitivity-specificity approach is considered as a useful threshold to define overweight for public health and clinical recommendations and actions but is not considered as the screening level for cardiovascular disease risk.
It is uncertain if the optimal BMI cutoffs, based on the longitudinal sample of Chinese adults, could be extrapolated to other Asian countries, because Asians differ from each other in the association between BMI and noncommunicable diseases. As noted earlier, Asian subpopulations may have different combinations of genes associated with hypertension and different gene-environment interactions that lead to variation in blood pressure (28, 32–35, 44). There is a tendency of genotype clustering among residents in South Asia and some of Southeast Asia (e.g., Thailand, Malaysia, and apart of Indonesia) and residents in East Asia (e.g., China, Japan, and Korea) and some of Southeast Asia (Vietnam, the Philippines, and apart of Indonesia) (34, 44). In combination with differences in environment, we might expect different associations between BMI and health risks in those countries.

In conclusion, this study suggests BMI values of 23.5 kg/m^2 in women and 22.5 kg/m^2 in men may be more appropriate for defining overweight in Chinese adults. Consistent with other cross-sectional studies, this study suggests that earlier prevention of excessive weight gain is needed to reduce hypertension in this population. Early prevention and control of hypertension and overweight are considered a cost-effective approach to decrease economic and health burdens of noncommunicable diseases worldwide (2).

Acknowledgments

We thank Dr. Chirayath Suchindran for critically reading the article, Bill Shapbell for editing, and Frances Dancy for administrative assistance.

Literature Cited