Cutoff Values for Normal Anthropometric Variables in Asian Indian Adults

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OBJECTIVE — Asian Indians have a high risk of developing glucose intolerance with small increments in their BMI. They generally have high upper-body adiposity, despite having a lean BMI. Therefore, this analysis was performed to find out the normal cutoff values for BMI and upper-body adiposity (waist circumference [WC] or waist-to-hip ratio [WHR]) by computing their risk associations with diabetes.

RESEARCH DESIGN AND METHODS — The risk of diabetes with stratified BMI, WC, or WHR was computed in 10,025 adults aged ≥20 years without a history of diabetes, and they were tested by oral glucose tolerance tests, using World Health Organization criteria. The calculations were performed separately in men and women using diabetes as the dependent variable versus normoglycemia (normal glucose tolerance) in multiple logistic regression analyses. Age-adjusted and stratified BMI, WC, or WHR were used as the independent variables, using the first stratum as the reference category. The upper limit of the stratum above which the risk association became statistically significant ($P < 0.05$) was considered to be the cutoff for normal values.

RESULTS — Normal cutoff values for BMI was 23 kg/m^2 for both sexes. Cutoff values for WC were 85 and 80 cm for men and women, respectively; the corresponding WHRs were 0.88 and 0.81, respectively. Optimum sensitivity and specificity obtained from the receiver operator characteristic curve corresponded to these cutoff values.

CONCLUSIONS — The cutoff value for normal BMI for men and women was 23 kg/m^2. The cutoff values for WC and WHR were lower in women than in men. The values were significantly lower compared with the corresponding values in white populations.

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Obesity has emerged as a major disorder associated with many metabolic diseases in both developed and developing countries. Although obesity has a genetic etiology, the major precipitating factor is environmental, mostly related to sedentary lifestyle and causing conservation of energy as body fat (1).

Although BMI is the most frequently used index, it does not reflect fatness uniformly in all populations, and interethnic extrapolations are not justified (2). For a given age, sex, and body fat level, Caucasians have higher BMI than the Chinese, Ethiopians, and Polynesians. It is generally recommended to consider Asians as obese if their BMI is ≥25 kg/m^2, but Pacific Islanders as obese if their BMI is only >32 kg/m^2 (1).

The World Health Organization (WHO) had shown a simplistic relationship between BMI and the risk of comorbidity, in which a normal range was considered between 18.5 and 24.9 kg/m^2. Because of variations in body proportions, BMI may not correspond to the same body fat in different populations (3). Epidemiological studies have shown that the ideal BMI may differ for different populations. A positive association between obesity and the risk of developing type 2 diabetes has been consistently observed in many populations (3–5).

In Asian subjects, the risk association with diabetes and cardiovascular diseases occurs at lower levels of BMI when compared with the white population (6–8). This is attributed to body fat distribution; Asian Indians tend to have more visceral adipose tissue, causing higher insulin resistance, despite having lean BMI (7,9). A similar picture is also seen in Australian aboriginals, who have an epidemic proportion of glucose intolerance and have BMI values much lower than the obesity limits suggested by Western standards (10).

It has been consistently observed that in urban Asian Indian subjects, even minor changes in BMI could tilt the metabolic balance toward hyperglycemia (5,11,12). The mean BMI of the healthy Asian Indian adult population is much lower than 25 kg/m^2. We have attempted to determine the cutoff for normal BMI by calculating the odds ratio for the risk of diabetes in stratified ranges of BMI. It is also observed that Indians have higher upper-body adiposity, measured as the waist-to-hip ratio (WHR) or waist circumference (WC), although they have lean body mass (6,7,13,14). Therefore, in this analysis cutoff values for normal WC and WHR have also been calculated in the same study group. Because the reproducibility of impaired glucose tolerance (IGT) is relatively poor, we have calculated the risk associations for diabetes only.

RESEARCH DESIGN AND METHODS

— Diabetes survey data collected in an urban adult population aged ≥20 years from six cities in India was used (5). A multiple stratified sampling procedure was used for sample selection. The sample population was

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Abbreviations: 2hBG, 2-h blood glucose; IGT, impaired glucose tolerance; ROC, receiver operator characteristic; WC, waist circumference; WHO, World Health Organization; WHR, waist-to-hip ratio.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

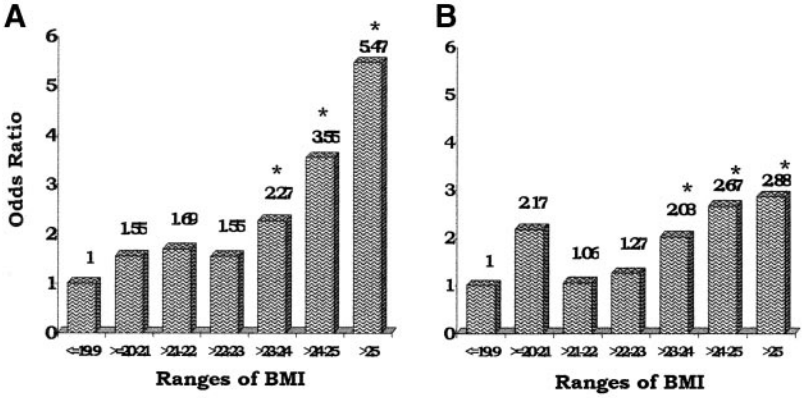

Figure 1—*Risk for diabetes associated with increasing BMI. Odds ratios for diabetes in relation to BMI categories are shown.* A: *Values for men.* *P < 0.005. B: *Values for women.* *P < 0.009. *Significant associations are seen at BMI >23 kg/m^2.*

drawn to get a fair representation from all of the socioeconomic strata. Age, height, and weight were recorded. BMI (kg/m^2) was calculated. WC was measured in centimeters, and WHR was calculated using standard procedures. BMI and waist measurements were adjusted for age using linear regression equations. For the analysis, known diabetic subjects were excluded. Demographic and anthropometric data and details of glycemic responses were used for the analysis. All study subjects had measurements of fasting blood glucose and 2-h blood glucose (2hBG; values taken 2 h after a 75-g glucose load) by capillary blood glucose measurements using a glucometer (5). Diabetes was diagnosed if the fasting blood glucose was ≥126 mg/dl and/or the 2hBG was ≥200 mg/dl (15).

Statistical procedure

The data analysis was performed in men and women separately. BMI was stratified in units of 2 for both sexes. A BMI of ≤19.9 kg/m^2 was taken as the reference. Waist categories (units of 5 cm) were also similar for both sexes, starting with a value of <60 as the reference. For WHR, the stratification was in units of 0.03, starting with ≤0.79 for men, and for women the reference unit was ≤0.74.

The associations of the stratified anthropometric variables with diabetes were computed using multiple logistic regression analyses. Age-adjusted anthropometric values were used. The upper limit of the stratum, above which a significant association with diabetes occurred ($P < 0.05$), was considered to be the cutoff value for normal. The 95% CIs of odds ratios were calculated. Sensitivity and specificity for diagnosing diabetes were calculated by using the receiver operator characteristic (ROC) curve for strata of the anthropometric variables in men and women separately. The optimal values were extrapolated from the curves. Tertiles of BMI, WC, and WHR were calculated. Prevalence of diabetes in crossed tertiles of BMI and WC and in crossed tertiles of BMI and WHR were calculated for men and women separately in order to look for interactions. A trend χ^2 test was used to assess the interactions. Statistical calculations were performed using the SPSS 4.0.1 package.

RESULTS

— The data were analyzed in 10,025 subjects (4,711 men and 5,314 women). The age (mean ± SD) of the study subjects was 40.4 ± 14.2. The mean BMI, WC, and WHR for men were 22.4 ± 4.2 kg/m^2, 80.7 ± 12.2 cm, and 0.89 ± 0.07, respectively, and for women the respective values were 23.6 ± 4.9 kg/m^2, 79 ± 13 cm, and 0.84 ± 0.07.

Figure 1 shows the odds ratios for the association between diabetes and categories of BMI in men and women. For men and women, the association was significant in the categories of >23–24 kg/m^2 ($P = 0.0045$, OR 2.27, 95% CI 1.29–3.99 for men; $P = 0.009$, 2.03, 1.19–3.46 for women). Therefore, the cutoff value for normal BMI was considered to be 23 kg/m^2. The sensitivity for detecting diabetes in men and women was 67.1 and 66.8%, respectively, and the corresponding specificity was 62.7 and 52.9%. A WC of 85 cm in men had 63.7% sensitivity and 67.1% specificity, and a WC of 80 cm in women had 69.7% sensitivity and 56.4% specificity. These values corresponded to the optimum obtained from the ROC. The cutoff value for WC was 85 cm for men, the significant association being seen in the category of >85–90 cm ($P = 0.003$, 1.98, 1.27–3.1). The corresponding cutoff value in women was 80 cm, with a significant association in the category of >80–85 cm ($P = 0.014$, 1.8, 1.12–2.83) (Fig. 2). Figure 3 shows the results of the analysis with WHR. The cutoff value for WHR for men was 0.89, with a significant association with diabetes in the category of >0.89 ($P = 0.005$, 2.87, 1.38–5.98). The sensitivity and specificity for diabetes were 78.2 and 49.1%, respectively. For women, the cutoff value was 0.81, the significant association being observed in the category of >0.81 ($P = 0.001$, 3.42, 1.66–7.07), with a sensitivity of 85.4% and a specificity of 34.9%. The optimum sensitivity and specificity obtained from the ROC curve were 0.92 in men (61.3 and 66.3%, respectively) and at 0.85 in women (65.5 and 54%, respectively). Figure 4 shows the interaction of BMI and WC (*A*) and BMI and WHR (*B*). Significant interactions were observed across all of the tertiles of BMI and WC in both sexes. Significant interactions were seen only in the first and second tertiles of BMI with tertiles of WHR.

CONCLUSIONS

— The definition of the cutoff value for "normal" BMI in a population would depend on identifying the risk association with a disorder strongly associated with BMI. In view of the high prevalence of diabetes and also its strong independent association with BMI in Asian Indians, it may be appropriate to use this association to derive the normal cutoff value for BMI.

Diabetes is becoming an epidemic disease in Asian countries like India (4,5). There is an urgent need to evolve methods of primary prevention in these popula-

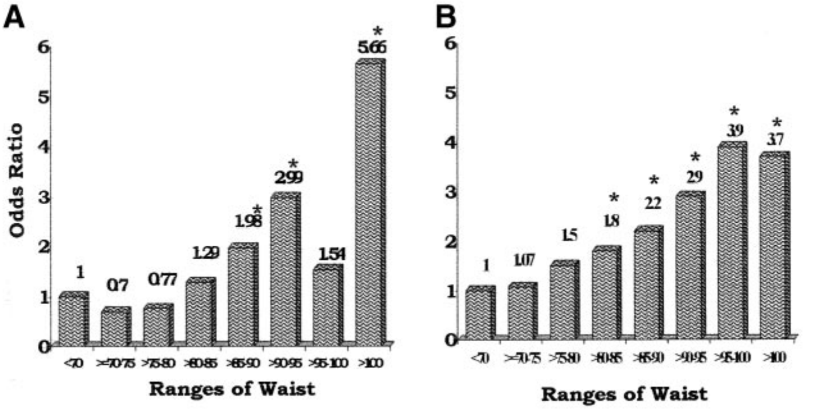

Figure 2—*Risk for diabetes associated with increasing WC. Odds ratios for diabetes in relation to WC categories are shown.* A*: Values for men.* *P *< 0.003.* B*: Values for women.* *P *< 0.01.*

tions to save the community from the burden of diabetes and its sequelae. There is compelling evidence that indicates that maintenance of ideal BMI by lifestyle modifications helps to delay or postpone the onset of diabetes (16–18). Therefore, identification of the normal cutoff values for each population is the primary step, since universal criteria do not hold good for all races (1). Because upper body adiposity is also an important risk indicator for insulin resistance, the cutoff values for WC and WHR have also been determined.

The risk of diabetes was significant at BMI >23 kg/m^2 for urban Indians of both sexes. Although an increasing trend with BMI >22 kg/m^2 had been indicated in our previous studies in urban southern Indians, the cutoff values had not been derived with age-adjusted BMI using appropriate statistical procedures (11,12). The cutoff values obtained by the multiple logistic regression procedure showed good sensitivity and specificity for detecting diabetes as calculated by the ROC curve. The optimal values for both corresponded to the derived cutoff values for BMI and WC in both sexes. Studies from northern parts of India (19,20) had also shown that the normal BMI for an Indian was <22 kg/m^2. Dudeja et al. (20) had derived the cutoff value of the BMI based on the ROC curve and has shown that a BMI of 21.5 kg/m^2 for male subjects 19.0 kg/m^2 for female subjects displayed optimal sensitivity and specificity in identifying subjects with a high percentage of body fat. The methodology used by the authors differed from the one used in our study. However, it supports the view that a BMI of <23.0 kg/m^2 might be ideal for the Asian Indian population. One of the limitations of the above study was that it was preliminary data on a small number of subjects. Several studies in migrant Indians from the U.K. and the U.S. (7,9,13,16) had also shown that the cutoff levels were lower for Asian Indians, and the values were >22.0 kg/m^2. The WHO also advocated a lower limit of normal BMI in Asian Indians (3). The proposed classification for adult BMI was 23 kg/m^2, and for obesity it was >25 kg/m^2. The cutoff levels for WC have also been lower for the proposed criteria. In the diabetes prevention program in the U.S., the cutoff value of >22 kg/m^2 has been used to indicate overweight in Asian Americans (16).

High risks for IGT and diabetes for BMI of >22 kg/m^2 had been noted in studies in Japan (21,22), China (23), and northern Europe (24). Daniel et al. (10) had shown that Australian aboriginals who have a high risk of diabetes also had a healthy range of BMI between 17 and 22 kg/m^2. The aboriginal women had BMI ~2 units lower than the age-matched Australian women of European origin.

Asian Indians have higher upper-body adiposity and higher visceral fat for a given BMI when compared with the Western population (7). In our population, an interaction between upper-body adiposity and general adiposity increased the risk at lower tertiles of BMI in both men and women. The cutoff values derived for WC and WHR were also lower than those suggested in earlier studies. Use of WC as an index of upper-body adiposity appeared to be more sensitive than WHR, as shown by the interactions between WC and BMI in either sex.

In summary, the healthy BMI for an urban Indian is <23 kg/m^2, and cutoff values for WC were 85 cm for men and 80

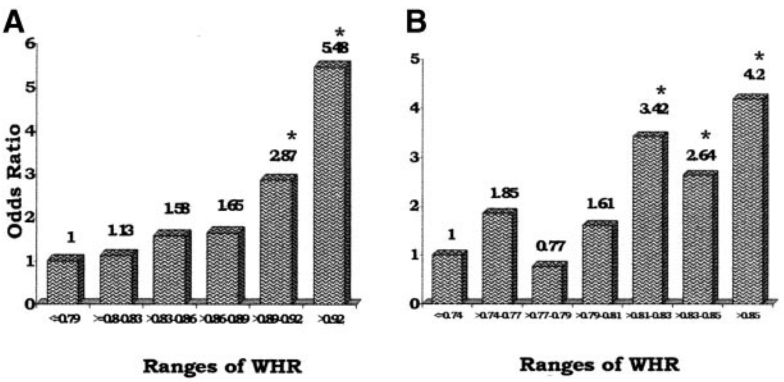

Figure 3—*Risk for diabetes associated with increasing WHR. Risk association for increasing WHR with diabetes is shown as odds ratios.* A*: Values for men.* *P *< 0.005.* B*: Values for women.* *P *< 0.01.*

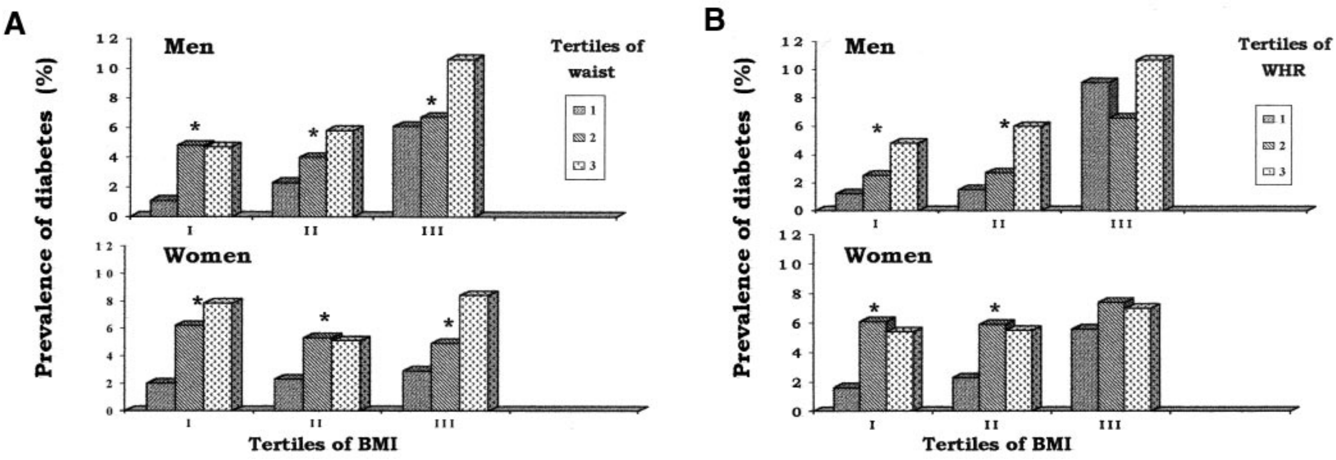

Figure 4—A*: Prevalence of diabetes in cross tertiles of BMI and WC. Men: tertile II trend* $\chi^2 = 6.1$, $P = 0.01$; *tertile III trend* $\chi^2 = 4.7$, $P = 0.029$. *Women: tertile I trend* $\chi^2 = 20.6$, $P < 0.0001$; *tertile II trend* $\chi^2 = 5.4$, $P = 0.02$; *tertile III trend* $\chi^2 = 13.5$, $P < 0.001$. $^*P < 0.03$ *by trend* χ^2 *test.* B*: Prevalence of diabetes in cross tertiles of BMI and WHR. Men: tertile I trend* $\chi^2 = 11.9$, $P = 0.0005$; *tertile II trend* $\chi^2 = 11.9$, $P = 0.0006$. *Women: tertile I trend* $\chi^2 = 16.6$, $P < 0.001$; *tertile II trend* $\chi^2 = 8.2$, $P = 0.004$. $^*P < 0.03$ *by trend* χ^2 *test.*

cm for women, and for WHR they were 0.89 for men and 0.81 for women. It may be appropriate to use WC as an index for upper-body adiposity.

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