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RECEIVER OPERATING CHARACTERISTIC CURVE ANALYSIS OF BMI AND PERCENTAGE BODY FAT IN TYPE 2 DIABETICS OF PUNJAB

K. D. SINGH, J. K. DHILLON, ANUPREET ARORA* AND B. S. GILL**

*Departments of *Physiology and **Medicine,*
Govt. Medical College,
Patiala – 147 001

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Abstract : The present study attempted to establish appropriate cut off levels of Body Mass Index (BMI) for defining overweight as a risk for the development of type 2 diabetes considering percentage body fat (BF) as standard. A total of 300 patients of known type 2 diabetes participated in the study (150 males and 150 females, all ≥ 40 years of age). Clinical examination was done. Anthropometric measurements as BMI, Waist Circumference (WC) and Waist-hip ratio (WHR) were calculated. Percentage BF was calculated using skinfold thickness method from the equation of Durnin and Womersley. Mean BMI for males was 24.97 (SD 4.3) kg/m^2 and for females was 27.56 (SD 5.14) kg/m^2. Mean percentage BF for males was 28.19 (SD 0.74) and for females was 38.22 (SD 5.29). A comparison of BF and BMI data with various ethnic groups revealed conspicuous differences. Receiver operating characteristic (ROC) curve analysis showed a low sensitivity of conventional cut off value of BMI ($25kg/m^2$) in identifying subjects with overweight as compared to the cut off values based on percentage BF (males >25, females >30). This results in substantial misclassification. Based on the ROC curve, a lower cut off value of BMI $22.3kg/m^2$, displayed the optimal sensitivity and specificity, and less misclassification in identification of type 2 diabetics with high percentage BF. BF: BMI was calculated and was found to be higher in females.

Key words : type 2 diabetes waist-hip ratio waist circumference body mass index percentage body fat skinfold ROC curve

INTRODUCTION

Epidemiological studies of type 2 diabetes mellitus evidence that overeating especially when combined with obesity and underactivity is associated with development of diabetes type 2. Obesity is a harbinger to a lot many disorders, for instance coronary artery disease, stroke and the increased risk of developing type 2 diabetes not withstanding. In fact, the syntropy of obesity and type 2 diabetes is so obvious that a term 'diabesity' has been coined that suggests a striking

*Corresponding Author

interrelationship between the two diseases (1). Diabesity means 'obesity' dependent diabetes mellitus'. Hypertension, hyperlipidaemia and central or abdominal obesity are commonly associated with NIDDM and this cluster of medical conditions is known as the metabolic syndrome 'X' (2).

Obesity is usually defined based on BMI. It is calculated as body weight (kgs) over height (m^2) and is an easy procedure for clinical purposes but it gives no idea about the type of obesity whether android/central/ upper abdominal (apple shaped) or gynoid/ lower abdominal (pear shaped). Waist-hip ratio gives a better viewpoint about the type of obesity but still leaves us in darkness about the total body fat. Various studies have been done to devise various methods to determine %BF, for instance, by hyprodensitometry and bioelectric impedance, skinfold thickness, to conclude that skinfold method can be used as an accurate and expedient method to determine body fat composition in the Indian population (3). The skinfold thickness is measured in the body at four different sites which are biceps, triceps, subscapular and suprailiac fat pads. Sum of the thickness of all the four skinfolds if estimated and tallied with the standard charts helps us to come closer to finding out the percentage body fat (4).

WHO has projected that the global prevalence of type 2 diabetes will more than double from 135 million in 1995 to 300 million by 2025. Many studies conclude that a high waist circumference is the best overall predictor of abdominal visceral obesity and in women WHR is a poor indicator of abdominal visceral fat and its use as a surrogate measure of visceral fat should be avoided (5). Another study also drew a conclusion that waist circumference alone or with hip circumference) is a simple and independent tool for assessing the risk of NIDDM (6). ROC curves were employed to examine the relative accuracies of BMI, WHR and subscapular skinfold thickness to assess obesity. The results suggested that certain measures of adiposity distribution are more accurate than measures of overall adiposity extent for screening NIDDM (7).

A recent study suggests that the conventional cut off of BMI 25kg/m^2 may be true for some population groups but is not suited for the South Asians. So that cut off value of BMI above which the hazard for developing type 2 diabetes increases needs to be lowered or redefined (8).

In the present study, using the receiver operating characteristic (ROC) curves we have attempted to establish the appropriate cut off point of BMI (considering percentage BF as standard) for defining obesity/over weight in type 2 diabetics in Punjab.

METHODS

The present study was conducted on known type 2 diabetics coming to the medical and endocrinology OPD of Rajindra Hospital, Patiala (Punjab) from June 2001 to June 2002. Data was collected from 300 such patients out of which 150 were male and 150 were female. The inclusion criterion for the study were, age ≥40 years, FBS >126mg%, RBS>200gm%. The patients

attending the hospital were interviewed and examined for a complete clinical review including a detailed history, general physical examination, laboratory investigations and a detailed anthropometric analysis. The data collected were recorded on predesigned proformas.

Anthropometric analysis

Body weight was observed to the nearest of 0.1 kg. Height was measured to the nearest of 0.1 cm without shoes. Body mass index or BMI was calculated by the formula: body weight in kgs by height in metre squares. Waist circumference was measured in cms midway between the uppermost point on the iliac crest and the lowermost margin of the ribs with the measuring tape parallel to the ground and patient in inspiration (9). Hip circumference was measured in cms at the maximum circumference of the buttocks at the level of the greater trochanter (9). Waist hip ratio was calculated to be waist circumference in cms divided by hip circumference in cms. Mean of three readings of each measurement was taken for the calculation of WHR. Biceps (B), triceps (TR), subscapular (SS) and suprailiac (SI) skinfolds were measured very carefully using skinfold measuring calipers. Biceps fat pad was measured at the level of the nipple line; triceps skinfold fat pad was measured midway between acromion process of scapula and olecranon process. Fat pads at the inferior angle of scapula and superiorly on iliac crest directly in the mid axillary line were measured for subscapular and suprailiac skinfolds respectively (10). All skinfolds were measured to the nearest 1 mm. Mean of 3 readings was recorded at each site.

Calculation of percentage body fat

Sigma 4SF i.e. biceps + triceps + subscapular + suprailiac in mm was calculated and then using the equation of Durnin and Womersley (4), %BF was calculated. From this equation, a table is derived from where percentage body fat can be read off corresponding to differing values for the total of the 4 standard skinfolds (sigma 4SF). This table is subdivided for sex and for age (4).

For the calculation of body fat, this equation has been validated in Asian Indians (3). Another variable BF: BMI was calculated as the ratio of BF to BMI.

Statistical analysis

The data were collected on predesigned proformas and managed in a Microsoft Excel spreadsheet. All the entries were checked for any possible keyboard errors. Descriptive statistics for anthropometric variables was computed by arithmetic mean and standard deviation. t-test was applied to determine the level of statistical significance of mean difference amongst male and female subjects for various anthropometric parameters. Chi-square test was used for the qualitative data. Percentage body fat was considered as the standard for drawing the receiver operating characteristic curve of BMI for the 300 type 2 diabetics examined. ROC curve is used to measure the accuracy of the test being conducted. It is a plot of true positive fraction (sensitivity) against the false positive fraction (1–specificity) for increasingly stringent positivity criterion (11). In this study $P<0.05$ was considered

as statistically significant. New cut off value was calculated for BMI from the ROC curve. This value reduced the overall misclassification and indicated higher sensitivity and lower specificity.

TABLE I: Cut off values of various anthropometric parameters above which the risk for type-2 diabetes increases.

S.No.	Parameter	Cut off value	
		Males	Females
1.	Body mass index (BMI) in Kg/m^2	25	25
2.	Percentage body fat	25	30
3.	Waist circumference (in cm)	102	88
4.	Waist-hip ratio	0.95	0.80
5.	Sigma 4SF (mm)	50	50

Based on WHO criteria (12)

RESULTS

The present study included 300 patients of known non-insulin dependent diabetes mellitus. Out of these 150 were males and 150 were females. All were above 40 years of age. The mean age for males was 55.95 years (SD 10.6) and the mean age for females was 54.75 (SD 10.66) years.

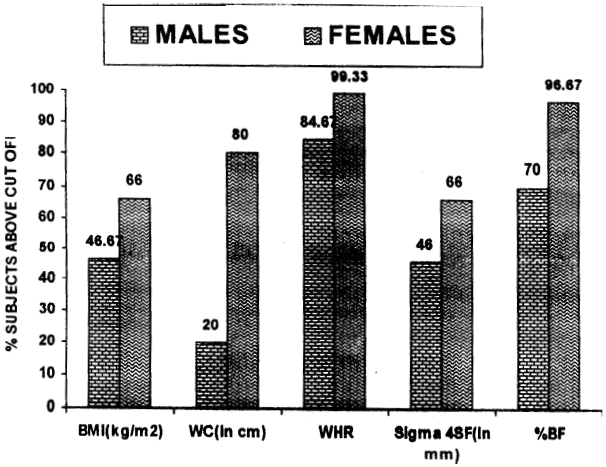

Fig. 1: Bars showing measures of obesity (in percentage) in Punjabi type 2 diabetics. The figure is based on the cut off values in Table I.

Anthropometry and body fat analysis

Fig. 2: A ROC curve was drawn to determine the appropriate cut off value of

TABLE II: Anthropometric profile and % BF of Punjabi type 2 diabetics (mean values & SD adjusted for age).

S.No.	Anthropometric measurements	Males (n=150)		Females (n=150)		Statistical sig. of diff. (p)
		Mean	SD	Mean	SD	
1.	Height (m)	1.675	0.855	1.556	0.062	0.0000
2.	Weight (kg)	70.38	14.461	66.827	13.225	0.0271
3.	BMI (kg/m^2)	24.966	4.249	27.56	5.142	0.0000
4.	Waist circumference (cm)	93.12	12.218	97.9	11.516	0.0006
5.	Waist hip ratio	1.006	0.071	1.005	0.070	0.9013
6.	Biceps skinfold thickness (mm)	7.193	3.550	10.82	4.255	0.0000
7.	Triceps (TR) skinfold thickness (mm)	11.66	5.253	19.293	7.759	0.0000
8.	Subscapular (S) SFT (mm)	18.867	8.126	24.66	8.426	0.0000
9.	Suprailiac SFT (mm)	26.147	10.679	30.627	9.748	0.0002
10.	S:TR	1.688	0.542	1.335	0.350	0.0000
11.	ε4SF (mm)	63.86	25.750	85.067	27.712	0.0000
12.	Peripheral (P) skinfold thickness (mm)	18.787	8.316	29.913	11.411	0.0000
13.	Central (C) skinfold thickness (mm)	45.02	18.360	55.1	17.683	0.0000
14.	C:P	2.4814	0.740	1.889	0.527	0.0000
15.	Percentage BF	28.185	5.977	38.219	5.285	0.0000
16.	%BF : BMI	1.132	0.18	1.412	0.22	0.0000

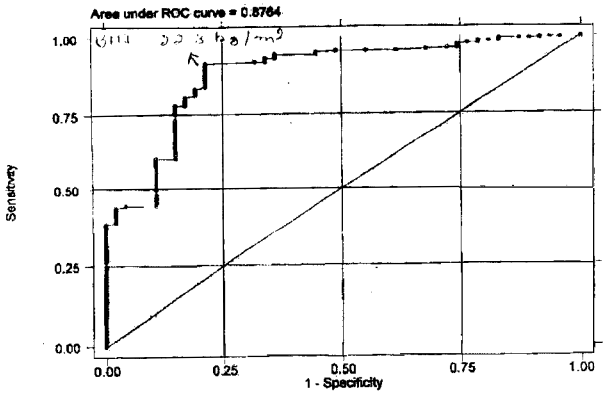

Fig. 2 : Receiver operating characteristic curve to determine the appropriate cut off value of the BMI (kg/m^2), while taking percentage body fat as standard. Subjects were known type 2 diabetics of Punjab.

the BMI while taking %BF as the standard. Only 5 out of 150 females were non obese as per %BF. Hence no separate ROC curve could be plotted for them. So a combined ROC curve was made for both the sexes for the 300 type 2 diabetics examined.

Fig. 3 : Shows that while the specificity

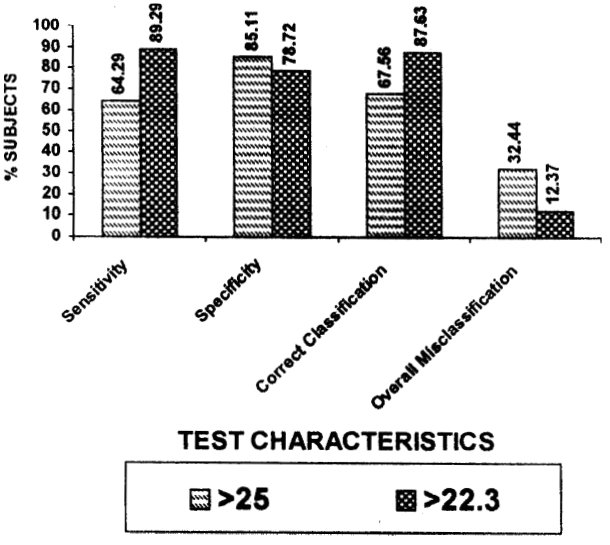

Fig. 3 : Bars showing test characteristics of using BMI (kg/m^2) as a measure of obesity in type 2 diabetes mellitus (Punjabis).

of a BMI of 25 kg/m^2 in defining overweight was high, the sensitivity was low (85.11% and 64.29% respectively). When a BMI of 22.3 kg/m^2 was used as the cut off point for overweight, the specificity decreased marginally by (6.39%), however the sensitivity increased substantially by almost 25% i.e. from 64.29% to 89.29%.

Thus, derived lower BMI cut off values decreased overall misclassification from 32.44% to 12.37% and increased the correct classification from 67.56% to 87.63%. Area under the ROC curve was 0.8764.

We analysed another variable i.e. BF : BMI. From the observations on Asian Indians, there is a suggestion that females have a higher BF per unit BMI (8). This finding coincides with our study. In our study on Punjabi diabetics this value was also lower in males 1.132 (SD 0.18) and much higher in females 1.41 (SD 0.22).

DISCUSSION

In the present study, the mean BMI for diabetic males was 24.97 and in diabetic females was 27.56 which is almost similar to migrant Indians i.e. 25.7 and 27 ($P<0.001$). Mean BMI of diabetic males in current study (24.97) is lower than that of Europeans (26.9) and Americans (25.1) while BMI of female diabetics (27.56) is high as compared to Europeans (26.2). WHR was found to be highest in our study group of Punjabi diabetics both for males (1.006) and females (1.005) as compared to European and migrant Asians. In the present study group, the values of various skinfold thickness were more as compared to Europeans and South Asians in men but in

females the values were higher in migrant Indians. Generally all skinfolds were higher in females and hence %BF (13).

In our study we have calculated %body fat from skinfold thickness method, sigma 4SF and finding the value from the tables given by Durnin and Womersley (4) with specific correction to age and sex (4). Skinfold method can be used as an accurate and expedient method to determine body fat composition in the Indian population (3). Studies conducted in Harvard Medical School Boston also indicate that measurement of skinfold thickness can provide a reasonable assessment of body fat taken at multiple sites and they provide additional information on the location of the fat (10). Percentage body fat was the most important parameter studied in our study and that too in comparison with BMI. According to our observations only 46. 67% males and 66% females were obese considering BMI, on the other hand, 70% of males and 96.67% females were overweight or obese keeping %BF in mind. Other workers have also observed a higher percentage body fat in Asian Indians at a comparatively low BMI. This puts us in doubt regarding the accuracy of BMI in predicting the risk for NIDDM. Similarly high percentage of BF was also observed in other Asian ethnic groups. Wang et al. (14) studied a Chinese population residing in New York City and observed that both males and females of Asian origin had lower BMI values than Whites, but had a higher %BF. However, although the %BF in males was similar, it was comparatively higher in females. These comparative observations are of considerable interest, denoting that all Asians may not be similar in body composition and that Asian Indians may have a higher %BF per unit BMI than other Asian ethnic groups. From this study another important conclusion was that Asians had more body fat and significantly thicker biceps, subscapular and suprailiac skinfolds than Whites in both sexes.

The BF: BMI, a novel ratio for assessing obesity was introduced for the first time by Dudeja et al. (8). Derivation of this ratio is based on the observation that different ethnic groups have widely different BF for a similar level of BMI. The BF:BMI would thus theoretically be a better variable for comparisons between different races if data for both BMI and BF were available. Moreover, a higher %BF per unit BMI, giving a higher BF:BMI would be metabolically detrimental. Apart from this, Dudeja et al., (8) in a study conducted in AIIMS, New Delhi, one of the largest tertiary referral hospitals in North India, attempted to establish appropriate cut off levels of the BMI for defining overweight, considering %BF in healthy Asian Indians as the standard. ROC analysis of the data from their study showed that the sensitivity of BMI at the current cut off level of overweight is rather low. However, if the cut off level of BMI in males was proposed as 21.5 kg/m^2 and in females as 19.0 kg/m^2, the sensitivity and the negative predictive value improved considerably and misclassification was reduced. In a study in Dayton, Ohio, USA, the BMI (28 kg/m^2 for males and 26 kg/m^2 for females) correctly identified 44% of the obese men and 52% of obese women when obesity was determined by percentage BF (25 for males and 33 for females). ROC curve analysis by the authors

showed that a BMI of 25 kg/m^2 for males and 23 kg/m^2 for females should be used as a diagnostic criterion for obesity (15). Whereas ROC curve data of the current study is of considerable interest, there is a paucity of comparative study on Asian Indians.

Our present study has been conducted on similar grounds substituting healthy individuals with known type 2 diabetics. ROC curve analysis of the data from the current study showed that the sensitivity and specificity of BMI at the current cut off level of overweight is rather low. It was found that at the conventional cut off value of 25 kg/m^2, overall misclassification was quite high as compared to a cut off value of 22.3 kg/m^2 where the sensitivity improved considerably and the overall misclassification decreased. So a new cut off value of 22.3 kg/m^2 for BMI was proposed for Punjabi type 2 diabetic males as well as females. When a ROC curve was plotted only for males, the cut off remained the same. The reason being that 145 out of 150 female diabetics examined were obese as per %BF criterion. So no ROC could be drawn and no new cut off could be calculated from female diabetics in the current study. The recent WHO (12) monograph on obesity in South Asians supports these observations. The working group has redefined the criteria of obesity in an Asian population acknowledging the need for different standards that are culturally specific and taking cognizance of the fact that co-morbidities like NIDDM, CAD, occur at a lower BMI in Asian Indians. The proposed reclassification of overweight for adult Asian >23 kg/m^2 and for obesity is >25 kg/m^2. Similarly the cut off level has been lowered in the proposed criteria (12).

Conclusion

We propose that BMI not 25 kg/m^2 but 22.3 kg/m^2 should be applied as a cut off for defining obesity as a risk for developing NIDDM in Punjabis. The percentage of individuals above BMI 22.3 kg/m^2 in the present study is 76%, thus indicating that majority of the Punjabi patients having NIDDM are obese. Another interesting finding of the study is that Punjabi female diabetics are highly obese with a higher waist circumference indicating high levels of visceral obesity and the cause whether is genetic, environmental or habitual is yet to be discovered.

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