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The normal range of body mass index with high body fat percentage among male residents of Lucknow city in north India

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***Background & objectives*: Several studies have raised the suspicion that the body mass index (BMI) cut-off for overweight as defined by the WHO may not adequately reflect the actual overweight status. The present study looked at the relationship between BMI and body fat per cent (BF %) / health risks (hypertension and type 2 diabetes) in male residents of Lucknow city, north India to evaluate the validity of BMI cut-off points for overweight.**

***Methods*: One thousand one hundred and eleven male volunteer subjects (18-69 yr) who participated in different programmes organized by the Institute during 2005 to 2008 were included in the study. BF% was measured using commercially available digital weight scale incorporating bioelectrical impedance (BI) analyzer. The proposed cut-off for BMI based on BF % was calculated using receiver operating characteristics (ROC) curve analysis.**

***Results*: Forty four per cent subjects showed higher BF % (>25%) with BMI range (24-24.99 kg/m^2). Sensitivity and specificity at BMI cut-off at 24.5 kg/m^3 were 83.2 and 77.5, respectively. Sensitivity at BMI cut-off >25 kg/m^2 was reduced by 5 per cent and specificity increased by 4.6 per cent when compared to 24.5 cut-off.**

***Interpretation & conclusions*: The study subjects showed higher body fat percentage and risk factors like hypertension and type 2 diabetes at normal BMI range proposed by the WHO. The cut-off for BMI was proposed to be 24.5 kg/m^2 for our study population. If overweight is regarded as an excess of body fat and not as an excess of weight (increased BMI), the cut-off points for overweight based on BMI would need to be lowered. However, the confidence of estimate of the BMI cut-off in the present study may be considered with the limitations of BI analysis studies.**

Key words BMI - body fat % - new cut-off - overweight

The disease risk stratification was commonly analyzed based on Quetelets Index (body mass index-BMI), a surrogate measure of fatness[1]. World Health Organization (WHO) expert committee[2] recommended BMI cut-off points for determining overweight and obesity in Asian populations. Several reports from Asian populations[3-6] suggested the need for population-specific cut-off points for BMI. Polynesians have a lower percentage of body fat than do white people, for the same age, sex and BMI[7]. No difference was observed in BMI and body fat % between white people in the Netherlands and Chinese people in Beijing[8]. White people in the USA generally have a lower percentage of body fat for the same BMI than do those in Europe[9].

Studies in Hong Kong and Singapore[10,11] showed that risk for cardiovascular disease or diabetes is high at lower BMIs. Data from China indicate that the prevalence of hypertension, diabetes, dyslipidaemia and clustering of risk factors with higher BMI even at indices at 22 kg/m^2 was below the current cut-off point for overweight (25 kg/m^3) [12]. Asian Indians have a high BMI and abdominal obesity and excess fat[13,14].

These studies raised the suspicion that the BMI cut-off for overweight as defined by WHO may not adequately reflect the actual overweight status of all populations. The present study was undertaken to establish the association of BMI with body fat percentage (BF%) and health risk outcomes (specifically type 2 diabetes and hypertension) among a large number of male residents of Lucknow city, north India, using receiver operating characteristic (ROC) curve analysis. Earlier studies[1,14] to determine the BMI 'cut-off' were conducted on small samples without analyzing the health risk outcomes for BMI classification. Hence ROC curve analysis was used in the present study to propose a new cut-off limit for BMI for overweight in north Indian males.

Material & Methods

The visitors were informed that the data will be used for research purpose and verbal consent was obtained. This study was done on 1111 male (18-69 yr) volunteers during 2005-2008. These volunteers were visitors to various awareness programmes organized by the Indian Institute of Toxicology Research, Lucknow, during this period. Children below 18 yr, people with fever, body builders/highly trained athletes, patients undergoing dialysis, patients with osteoporosis, people having weight loss problems, weight loss associated with cancer, subjects with hepatitis B or C infection, tuberculosis, haemophilia and other severe coagulation disorders and subjects using drugs (like diuretics) were excluded. Of the 2000 male individuals originally selected 1111 fulfilling the inclusion criteria were included. Clinical examination included general and physical examination of volunteers and details of clinical examination including self reported cases of type 2 diabetes and hypertension were recorded in a questionnaire. Systolic and diastolic blood pressure was recorded for all volunteers. All the type 2 diabetes cases were self reported by the subjects.

Body weight was measured to the nearest 0.1 kg in light indoor clothing without shoes, using a digital scale. Height was measured using same portable stadiometer. A correction of 0.5 kg was made for the weight of the cloths.

BF % was measured using a commercially available digital weight scale incorporating a bioelectric impedance analyzer (HBF-352, Omron Health care Co., Kyoto, Japan). The instrument is portable and easy to use in epidemiological field surveys. BF % was measured to the nearest 0.1 per cent. The digital weight scale includes a hand grip and foot plate, each of which is equipped with two electrodes. The two electrodes between the left and right grip were short-circuited, along with those for the left and right feet. Upon measurement, the study subject stood on the foot plate and gently grasped the two handgrips with arms held straight forward. During the measurement, the instrument records impedance from the hands to the feet, which corresponds to the whole body impedance, by applying an electric alternating current flux of 500 μA at an operating frequency of 50 kHz. Consequently, BF % was calculated from the impedance value and the pre entered personal data. Total body water was predicted from the impedance index (height^2/impedance)[15-17]. From the total body water, the BF % was calculated as 100 x [weight-(total body water)]/weight[17]. The calculation is done by software program based on algorithm developed and patented by Omron Health Care Co., Kyoto, Japan. Impedance measured and predicted total body water, which is not displayed to user, is automatically fed to algorithm along with pre entered data and the software calculates the body fat%.

The reproducibility of the body fat measurement was assessed by repeating the measurements twice on 100 subjects on the same day. The reproducibility was satisfactory with 3.5 per cent standard error of estimate (SEE). Body fat per cent normal ranges were taken from earlier report[18]. Subjects were refrained from food and drink for at least 6 h and voided urine prior to the measurement session[19,20]. Prior information about the protocol for the body fat % test like refrained from food and drink for at least 6 h and voided urine before measurement was given to subjects 2-3 days by our volunteers before the programme. Subjects were requested to moisten the soles of the feet with a wet towel before taking a measurement. Ten minutes were given for the electrode to warm up. Validation of predicted body fat % from body mass index and from impedance in samples of five European populations showed that prediction formulae gave generally good estimates of BF % on a group level in the five population samples[21] and in Indians[22].

Table I. Physical characteristics, BMI and body fat % among study subjects

Parameter	Male (1111) (Mean ± SD)	Range	Median	25th percentile	75th percentile
Age (yr)	38.2 ± 10.28	18-69	37	30.0	46.0
Height (cm)	170.8 ± 4.9	145-190	171.0	169.0	174.0
Weight (kg)	72.2 ± 11.3	33.6-81.00	72	64.4	79.2
BMI (kg/m^2)	24.7 ± 3.6	11.3-43.6	24.7	22.0	26.9
Body fat (%)	23.8± 5.7	1.5-44.7	24.6	20.9	27.6

Data recorded on a predesigned proforma were entered in a Microsoft Excel spreadsheet. All the entries were double-checked for any possible keyboard error. Descriptive statistics (mean, standard deviation, median, 25th and 75th percentile) for all the anthropometric parameters were computed. Pearson's correlation coefficients were calculated for BMI with age, height, weight and body fat per cent and their significance for linearity was tested using F-test. Multiple linear regression analysis was used to investigate the possible influence of age, ethnic relationship between body fat % and BMI using SYSTAT 9.0 package (Systat 12, Systat Software, Inc., Chicago IL). Statistical significance for prevalence of cardiovascular disease risk (hypertension) and type 2 diabetes related to different BMI categories was ascertained by Chi square test for trend in proportions using EPI INFO 5.0 software (Epi Info Version 3.5.1, Centre for Disease Control and Prevention, Georgia). ROC curves were drawn to determine an appropriate cut-off of the BMI, considering body fat per cent as standard.

Results

The age of subjects ranged between 18 - 69 yr with a mean of 38.2 yr. All the variables studied follow normal distribution (Table I). BMI increased significantly (r=0.24, P<0.001) with age. BMI was found to be highly correlated with body fat percentage (r=0.73, P<0.001) indicating statistical linear relationship between body fat percentage and BMI (Fig. 1). Forty four per cent subjects showed higher body fat % (> 25%) with BMI range between 24 - 24.9 kg/m^2. Even at lower BMI (<20), the high body fat per cent was found to be 4.7 per cent subjects (Table II). High body fat per cent in the BMI range of 20 to 21.9 and 22 - 23.9 kg/m^2 was found to be 9.5 and 18.4 per cent, respectively showing large number of subjects having body fat more than 25 per cent in lower BMI range.

Presence of at least one risk factor of having type 2 diabetes or hypertension in different BMI categories are shown in Table III .

Table II. Body fat per cent in different categories of BMI in study subjects

BMI category (kg/m^2)	Body fat %			
	Actual		Cumulative	
	Total	> 25	Total	> 25
< 20	107	5 (4.7)	107	5 (4.7)
20-21.99	147	14 (9.5)	254	19 (7.5)
22-23.99	207	38 (18.4)	461	57 (12.4)
24-24.99	125	55 (44.0)	586	112 (19.1)
25-25.99	126	80 (63.5)	712	192 (27.0)
26-27.99	212	157 (74.0)	924	349 (37.8)
28-29.99	109	103 (94.5)	1033	452 (43.7)
≥30	78	78 (100.0)	1111	530 (47.7)

Values in parentheses are percentages

Table III. Prevalence of risk factors of hypertension or type 2 diabetes among study subjects in different BMI categories

BMI categories (kg/m^2)	Total no.	Subjects with risk factors n (%)
< 20	107	23 (21.5)
20-21.99	147	41 (27.9)
22-23.99	207	75 (36.2)
24-24.99	125	43 (34.4)
24-25.99	126	34 (27.0)
26-27.99	212	75 (35.3)
28-29.99	109	42 (38.5)
> 30	78	28 (35.9)

Curve was plotted based on ROC analysis at different cut-off values of BMI while taking percentage of body fat as standard (Table IV, Fig. 2). Area under the curve was between 85 to 88 per cent which is considered good fit in discriminating the population with body fat below and above 25 per cent. Sensitivity and specificity at cut-off level of BMI at 24.5 was 83.2 and 77.5, respectively. Sensitivity at BMI cut-off > 25 kg/m^2 was reduced by 5 per cent and specificity increased by 4.6 per cent compared to 24.5 kg/m^2. There was a minimum misclassification rate of 19.8 per cent at BMI cut-off 24.5 kg/m^2 compared to 21.3 per cent at >25 kg/m^2.

Table IV. Test characteristics (%) of BMI as a measure of overweight in study subjects considering body fat percentage as standard (BFAT % >25)

BMI Cut-off kg/m^2	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Misclasification rate
>20	99.0	18.4	51.5	95.6	43.9
>21	98.4	28.4	54.6	95.4	38.9
>22	95.9	43.4	59.8	92.4	38.9
>23	93.3	57.7	65.9	90.7	25.6
>24	88.1	71.8	73.2	87.3	20.6
>24.5	83.2	77.5	76.4	84	19.8
>25	78.2	79.2	76.6	80.5	21.3
>26	62.2	90.8	85.7	73.2	22.5
>27	46.4	96.1	91.3	67.2	27.1
>28	33.3	99.1	97.2	62.9	31.6
>29	21.6	99.8	99.1	59.2	36.7

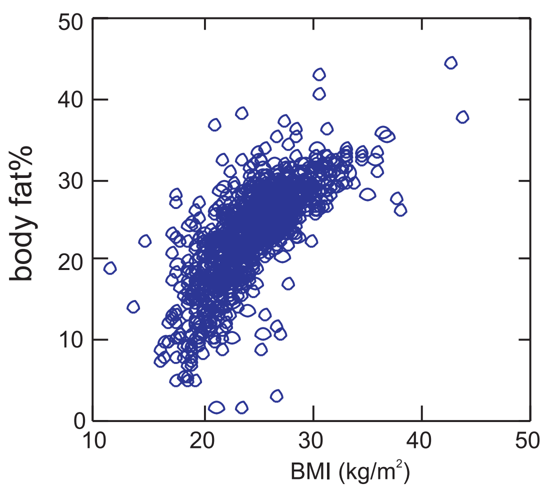

Fig. 1. Scatter plot between BMI and body fat per cent.

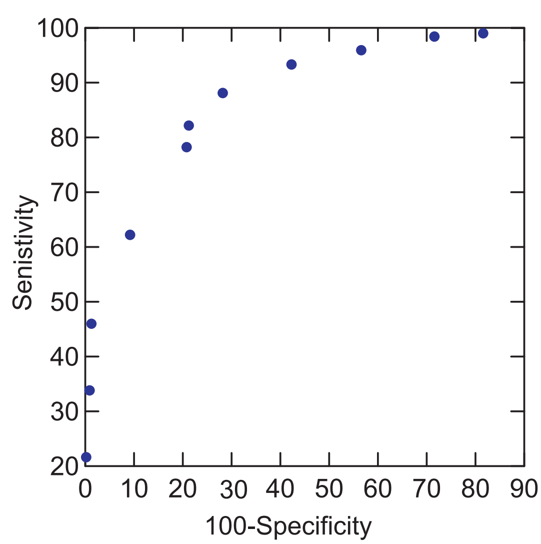

Fig. 2. Receiver operating characteristic curve (ROC) at different BMI cut-off points using body fat as standard.

There were 23 cases with BMI < 18 kg/m^2 even though they were healthy as per our inclusion / exclusion criteria. There was one individual with 1.5 per cent body fat, two cases with body fat % between 4-5 per cent and seven between 5-7 per cent.

Discussion

In the present study, higher body fat % was observed within WHO proposed normal limits of BMI. Hence a proposal to lower the WHO normal BMI standard from 24.9 to 24.5 kg/m^2 was suggested for the male residents of the study location. Earlier study also showed that the diagnosis of obesity (using reference of BMI of 30 kg/m^2) need to be lowered to 27 kg/m^2 for Malys, Chinese and 26 kg/m^2 for Asian Indians[23]. World Health Organisation and International Obesity Task Force have also suggested lowering the limits of BMI for the diagnosis of overweight and obesity to 23 and 25 kg/m^2, respectively[11,23]. Another study[24] undertaken to know the relationship between BMI and BF % among Japanese and Australian Caucasian living in Australia showed that Japanese men had greater body fat deposition than Australian - Caucasians at the same BMI value. Japanese men may, therefore, require lower BMI cut-off points to identify obese individuals compared with Australian-Caucasian men.

ROC curve analysis[1] proposes BMI of 23.85 kg/m^2 as the cut-off for overweight with a sensitivity of 70.2 per cent (95% CI 56.6 - 81.6) and 87.5 per cent specificity (95% CI 76.8-94.4) and a BMI of 24.38 kg/m^2 with 90 per cent sensitivity (95% CI; 68.3-98.5) and 81.2 per cent specificity (95% CI; 72.2-88.3) for obesity. Earlier studies[23,25] have shown poor sensitivity and specificity of BMI for diagnosis of obesity in the Asian ethnic groups using ROC curve analysis.

In the present study, within normal limits of BMI, higher body fat % and presence of risk factor(s) (type 2 diabetes/hypertension) were observed. The 1993 WHO Expert Committee[26] reported that weight gain in adult life was associated with increased morbidity and mortality at higher BMI range. Therefore, BMI cut-off for overweight should be interpreted based on risk factors of morbidity and mortality. Type 2 diabetes mellitus, cardiovascular disease and increased mortality are the most important sequelae of obesity and abdominal fatness, but other associations like musculoskeletal disorders, limitations of respiratory function and reduced physical functioning and quality of life were also observed[27]. Three specific factors led WHO to convene another expert consultation on BMI classifications. First, there was increasing evidence of the emerging high prevalence of type 2 diabetes and increased cardiovascular risk factors in parts of Asia at BMI below the cut-off point of 25 kg/m^2 that defines overweight in the current WHO classification. Second, there was increasing evidence that the association between BMI, percentage of body fat, and body fat distribution differ across population. Third, there had been two previous attempts to interpret the WHO BMI cut-offs in Asian and Pacific population which contributed to the growing debate on whether there is a need for developing different BMI cut-off points for different ethnic groups[28]. The existing assumptions and definitions of cut-offs of each parameter are based on the data from Caucasian populations[26,29]. Asian Indians have a characteristic obesity phenotype, consisting of relatively lower BMI, excess body fat %, abdominal and truncal adiposity and less lean tissue[13,14].

WHO Expert Consultation proposed a new BMI cut-off of 23.0 kg/m^2 for public health action in Asia[23]. The use of this cut-off, however, was not directly supported by data on mortality[6,30], since deaths from any cause were lowest among men with BMI of 24.0 to 24.9 and women with a BMI of 25.0 to 26.9 kg/m^2 in a representative group of Chinese subjects[5,31].

Clinical use of bioelectrical impedance analysis (BIA) in subjects at extremes of BMI ranges or with abnormal hydration cannot be recommended for routine assessment of patients until further validation studies prove for BIA algorithms to be accurate in such conditions. Multi frequency and segmental BIA may have more advantage in these conditions[32] over single frequency BIA included in the present study. Since hydration studies were not undertaken in our subjects, we were not able to clinically prove whether our subjects possess abnormal hydration, even though we assured that no subject was taking diuretic drugs.

In our study we followed the earlier reports for cut-off points for BF% (25 %)[14]. In Asian Indians, abdominal fat increased with increasing age, while the percentage of BF showed little change. In the other ethnic groups, both abdominal and total BF increased with age[33]. Ethnic differences in fat distribution, muscularity, bone mass and leg length may contribute to ethnic-specific relationships between body fatness and BMI. Thus the use of universal BMI cut-off points may not be appropriate for the comparison of obesity prevalence between ethnic groups[34]. Since the body fat % cut-off is a debatable issue, further studies to validate the cut-off for Indian population are required. The relationship between waist circumference and body fat % was not considered in the study and it might be considered as a limitation of the study.

In BI studies[35], applied current flows throughout all conducting tissue within the body and does not uniquely reflect the properties of any single tissue, compartment, or region. Another drawback of BIA measurements is its statistical association linked with output variables such as body fat % without display of biophysical parameters. BIA values are affected by numerous variables including body position, hydration status, consumption of food and beverages, ambient air and skin temperature, recent physical activity, and conductance of the examining table. Reliable BIA requires standardization and control of these variables. Standard equations of body fat % from the BI method are based on population-specific equations and hence the standard errors of the estimate for the individual are not known[42]. Confidence of estimate of the BMI cut-off in the present study may be considered with the above limitations of BIA studies.

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