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BMI Cutoffs for Obesity Based on Body Fat Percentage in the Tribal People of Purulia, West Bengal

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Abstract

Background: Generally, Body Mass Index (BMI) used to classify nutritional status; it also predicts obesity, but it does not directly reflect body fat. As tribal peoples have different types of body composition, the standard BMI cutoff may be less effective. This study aims to predict the BMI cutoff for obesity based on body fat percentage (%BF) among adult tribal groups of Purulia, West Bengal.

Methods: A cross-sectional study was conducted among adult males and females from tribal communities in Purulia. Anthropometric measurements (height, weight, biceps, triceps, subscapular, & suprailiac) were taken. Body fat percentage was estimated using skinfold thickness and used to classify obesity (≥25% for males and ≥30% for females). Statistical analyses, including correlation matrix, Bland altman method comparison, were performed using MedCalc to evaluate the association between BMI and %BF and to determine optimal BMI cut-off points for obesity.

Results: A strong positive correlation was observed between BMI and %BF ($p < 0.01$). ANOVA revealed significant differences in BMI across %BF-defined groups. BMI & other variables were found to be significant changes in respect of age for males, but no age-wise changes have been shown in females. ROC analysis yielded optimal BMI cut-offs of 22.82 kg/m² for males and 21.39 kg/m² for females, which were lower than WHO-recommended standards. It represents that a BMI > 22.82 kg/m² for males and > 21.39 kg/m² for females indicates obesity for adult tribal groups of Purulia. These new cutoffs demonstrated high sensitivity and specificity for predicting obesity.

Conclusion: Standard BMI cutoffs may underestimate obesity prevalence among tribal populations. The revised BMI threshold, based on body fat percentage, offers a more accurate assessment of obesity in this context. These findings support the need for population- and sex-specific criteria in public health assessments and interventions.

Keywords:

Percent body fat (%BF), Adult, Tribal Groups, Body Mass Index (BMI), Obesity, tribal population Purulia, ROC Curve, Cut-Off Value.

Abbreviation

"%BF/PBF" = Percent Body Fat

"FM (kg)" = Fat Mass

"FFM (kg)" = Fat Free Mass

"FMI (kg/m^2)" = Fat Mass Index

"FFMI (kg/m^2)" =Fat Free Mass Index

"BMI (kg/m^2)" = Body Mass Index

"WHR" = Waist Hip Ratio

"ROC" = Receiver Operating Curve

INTRODUCTION

Assessing nutritional status accurately is essential for identifying individuals at risk of obesity-related disorders. Obesity continues to be a significant public health problem worldwide [1] [2]contributing to numerous chronic conditions like cardiovascular disease, type 2 diabetes mellitus, and metabolic syndrome. Traditionally BMI is a simple and non-invasive tool commonly used to estimate nutritional status, it is increasingly criticized for its inability to directly assess body fat and fat distribution [3]. Hence, it's potentially leading to misclassification of individuals' health status.

The calculation of BMI is based on height and weight [4], [5], is widely used as a proxy for assessing overweight and obesity. While BMI is convenient and widely adopted, it has significant limitations—primarily, its inability to distinguish between fat mass and lean mass. [6] But it's also possible that higher BMI doesn't always show real health risks—because BMI can't tell the difference between fat and muscle, especially in the middle ranges[7]. While BMI is often recommended as a practical screening measure for overweight and obesity in large populations, some researchers caution against relying on it to estimate body fat and have questioned its accuracy[8]; [9]; [10].

BMI may misclassify individuals, particularly in populations with varying muscle mass and fat distribution. [11] Individuals with a normal BMI can sometimes have elevated body fat levels, whereas those with a high BMI might possess a leaner, more muscular physique [12]. To overcome these limitations, body fat percentage (PBF) is increasingly used as a more precise indicator of adiposity.

For the same BMI value, people of the same sex can have different body fat percentages depending on their race or ethnic group [13]. South Asian populations, including Indians, have been shown to have higher body fat levels at lower BMI values compared to Western populations[14]. Different ethnic groups, as well as males and females, should have different BMI cutoffs. Therefore, developing population-specific BMI cutoffs using PBF is essential to improve obesity screening and risk prediction.

The present study aims to derive BMI cutoff points based on body fat percentage among the six major tribal groups (Bediya, Mahali, Munda, Kora Mudi, Oraon & Sabar) of Purulia district. These tribal groups are less exposed as well most of the participant are living far away from the local town. The objective of enhancing the reliability of nutritional status classification and guiding targeted public health strategies. According to Durenberg et al.,1991 [15], optimal Body fat percentage cutoffs for obesity for the men and women were around 25% and 30%, respectively were taken as reference.

METHODOLOGY

The study was cross-sectional-based using stratified random sampling. It was conducted in Purulia, which is a tribal-concentrated district of West Bengal. Six major tribal groups (Bediya, Munda, Kora Mudi, Mahali, Oraon & Sabar), those who are living in the rural areas, have been selected for this study. A total of 1344, among them 696 were female and 648 were male, belonging to the adult (18+) age group.

All anthropometric assessments adhered to the standardized guidelines established by Norton (2018)[16]. Measurements included standing height, body weight, and skinfold thickness at four anatomical sites: biceps, triceps, subscapular, and suprailiac. Body density was estimated using the Durnin and Womersley (1974) regression equation[17]. Subsequently, body fat percentage was derived using Siri's equation. Fat mass and fat-free mass was then computed based on the estimated percentage of body fat.

(Durnin & Womersley 1974)[17] Body Density (g/cm³)

- For males: Body Density = 1.1765 − 0.0744 × log(sum of four skinfolds)
- For females: Body Density = 1.1567 − 0.0717 × log(sum of four skinfolds)

(sari's equation)

- % body fat = ((4.95/body density) - 4.50) * 100)

Fat mass was calculated by multiplying the percentage of body fat by the individual's body weight. Fat-free mass was then determined by subtracting fat mass from total body weight. To obtain the fat mass index (FMI) and fat-free mass index (FFMI), fat mass and fat-free mass was each divided by the square of the individual's height (kg/m^2).

FMI = Fat mass (kg)/Height $(cm)^2$

FFMI = Fat Free Mass (kg)/Height $(cm)^2$

Participants were selected proportionally based on the representation of tribal populations within the total population of Purulia district. Individuals from six distinct tribal groups were recruited in accordance with predefined inclusion and exclusion criteria, and only those who provided informed consent were included in the study.

Statistical analysis

Statistical analyses, both descriptive and inferential, were conducted using SPSS 27 and MedCalc software. Summary statistics were computed for various anthropometric measures including height (cm), weight (kg), mid-upper arm circumference (MUAC) (cm), as well as skinfold thicknesses at the biceps, triceps, subscapular, and suprailiac sites (mm), along with Body Mass Index (BMI) in kg/m² and body fat percentage (%BF). Essential fat percentage cutoff and over body fat cutoff were taken as a standard ≥25% for males and ≥30% [15] .Receiver operating curve (ROC) was used to predict BMI cutoff value for obesity. While - For males, those with >25% body fat is coded as 1, otherwise 0. For females, those with >30% body fat is 1, otherwise 0. This now represents your target condition. BMI was taken as a independent variable. t-test & Bland Altman has been used to know the mean differences of body fat percentage using (BIA) MEDITIVE and Skin Fold.

RESULTS

Table:1. Independent-samples t-tests were performed to examine differences in anthropometric and body composition variables between male participants (n = 648) and female participants (n = 696). Males were, on average, significantly taller (*Mean* = 160.33 cm, SD = 6.83) than females (*Mean* = 149.57 cm, SD = 6.15), $t = 30.42, p < 0.001$. Similarly, males had significantly higher mean weight (52.17 ± 8.99 kg) compared to females (43.78 ± 7.34 kg), $t = 18.78, p < 0.001$, as well as higher mid-upper arm circumference (MUAC) and Body Mass Index (BMI) found in Male (24.17 ± 2.65) compare to female (23.36 ± 2.68 cm), $t = 5.57, p < 0.001$) and BMI (20.25 ± 2.99 vs. 19.57 ± 3.14 kg/m²; $t = 4.02, p < 0.001$). In contrast, females exhibited significantly greater mean biceps skinfold thickness (5.41 ± 2.71 mm) than males (4.09 ± 2.05 mm), $t = -10.02, p < 0.001$, and triceps thickness (10.67 ± 4.44mm & 7.96 ± 3.56 mm; $t = -12.30, p < 0.001$).

No statistically significant sex difference was observed for subscapular skinfold thickness ($p = 0.142$). However, males had significantly greater suprailiac (11.42 ± 6.33 & 9.94 ± 5.06 mm; $t = 4.76, p < 0.001$) and abdominal skinfold thickness (16.95 ± 8.70 & 13.14 ± 6.16 mm; $t = 9.32, p < 0.001$) compared to females. These findings indicate a clear trend: males have larger overall body size and greater trunk fat accumulation, whereas females tend to carry more peripheral subcutaneous fat, especially at the arm sites.

Table 2 displays the Pearson correlation coefficients among key anthropometric and body composition variables for males and females.

In both sexes, BMI showed strong positive correlations with weight, MUAC, percent body fat (%BF), fat mass index (FM), and fat-free mass index (FFMI) (all p<0.01). For males, the highest correlations were observed between BMI and FFMI_SF (r=0.882) and between PBF

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and FMI (r=0.963). Similarly, in females, BMI was highly correlated with FFMI (r=0.899) and FMI (r=0.886), while PBF and FMI also showed a strong correlation (r=0.929).

Weight was strongly correlated with MUAC, FMI, and FFMI in both sexes. MUAC was moderately to strongly correlated with PBF and FMI.

Table 1 Independent-samples t-tests were performed to examine differences in anthropometric measurements and body composition between groups.

Measure Variables	SEX				t-value
	Male (N = 648)		Female (N =696)		
	Mean	SD	Mean	SD	
Heigh(cm)	160.33	6.83	149.57	6.15	30.416***
Weight (kg)	52.17	8.99	43.78	7.34	18.782***
MUAC (cm)	24.17	2.65	23.36	2.68	5.571***
BMI (Kg/m2)	20.25	2.99	19.57	3.14	4.019***
Biceps (mm)	4.09	2.05	5.41	2.71	10.022***
Triceps (mm)	7.96	3.56	10.67	4.44	12.299***
Subscapular (mm)	12.17	5.40	12.61	5.48	1.47
Suprailliac (mm)	11.42	6.33	9.94	5.06	4.76***
Abdomen (mm)	16.95	8.70	13.14	6.16	9.321***

Fig:1. Showing Bland altman Method Comparison of Percent body fat (BF%) measure by skinfold & MEDITIVE (BIA).

To validate the accuracy of skinfold-based body fat estimation, measurements were also taken using a digital bioelectrical impedance analysis (BIA) device (MEDITIVE) on a sample of 133 individuals. The mean body fat percentage obtained through the skinfold method was 19.16%, while the BIA method produced a nearly identical mean of 19.14%, with both methods showing similar variability. A paired sample *t*-test was conducted to compare the two approaches, yielding a *t*-value of 0.02. The result indicates no statistically significant difference between the two methods. This finding suggests that the skinfold method provides comparable estimates of body fat to the MEDITIVE BIA device, supporting its reliability for body composition assessment in this population.

The Bland-Altman plot confirms that there is no systematic difference between skinfold and BIA methods of estimating body fat, supporting the use of either method for body composition assessment in this sample.

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Table 2 displays the Pearson correlation coefficients among key anthropometric and body composition variables.

SEX		BMI (kg/m²)	Weight (Kg)	MUAC (cm)	%BF	FMI (kg/m²)	FFMI (kg/m²)
MALE	BMI (kg/m²)	1	.871**	.707**	.699**	.843**	.882**
	Weight (Kg)	.871**	1	.738**	.619**	.746**	.759**
	MUAC (cm)	.707**	.738**	1	.660**	.721**	.513**
	%BF	.699**	.619**	.660**	1	.963**	.290**
	FMI (kg/m²)	.843**	.746**	.721**	.963**	1	.490**
	FFMI (kg/m²)	.882**	.759**	.513**	.290**	.490**	1
FEMALE	BMI (kg/m²)	1	.859**	.672**	.673**	.886**	.899**
	Weight (Kg)	.859**	1	.707**	.662**	.812**	.725**
	MUAC (cm)	.672**	.707**	1	.657**	.728**	.480**
	%BF	.673**	.662**	.657**	1	.929**	.291**
	FMI (kg/m²)	.886**	.812**	.728**	.929**	1	.595**
	FFMI (kg/m²)	.899**	.725**	.480**	.291**	.595**	1

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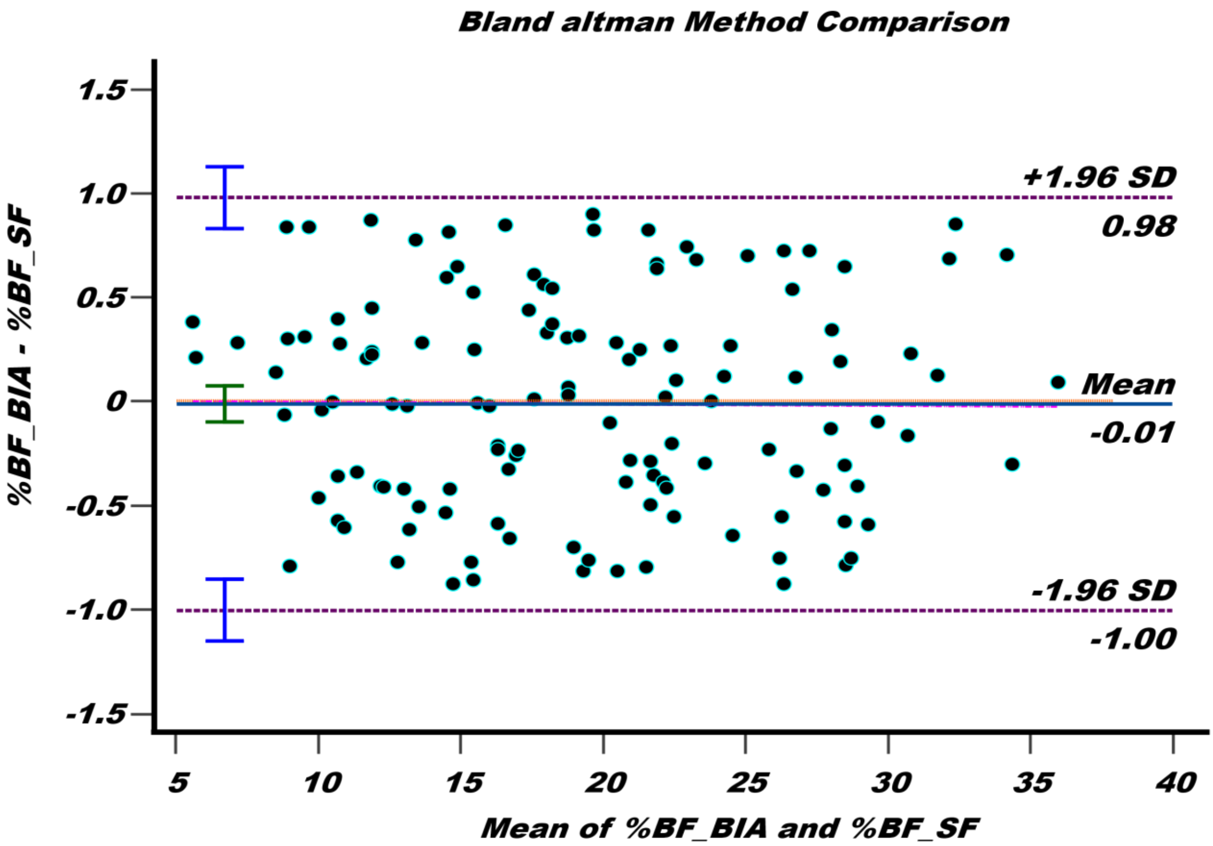

Figure 1 . Showing Bland Altman Method Comparison of Percent body fat (BF%) measure by skinfold & MEDITIVE (BIA).

Table 4. Evaluation of BMI Accuracy for Obesity Classification Using Sex-Specific Body Fat Percentage Standards.

Receiver Operating Characteristic (ROC) analysis was utilized to evaluate how accurately Body Mass Index (BMI) predicts diagnostic outcomes for obesity, using sex-specific percent body fat (%BF) cutoffs (≥25% for males; ≥30% for females). For males, the ROC analysis yielded an AUC of 0.872 ($p < 0.0001$), indicating excellent diagnostic accuracy. The optimal BMI cutoff for identifying obesity in males was determined to be >22.82 kg/m², which provided a sensitivity of 85.37% and specificity of 86.33%. The corresponding Youden Index was 0.7169, indicating a strong balance between sensitivity and specificity.

Among females, the AUC was 0.893 ($p < 0.0001$), also reflecting excellent accuracy. The optimal BMI cutoff for females was established at >21.39 kg/m², yielding a sensitivity of 81.11% and specificity of 85.31%. The Youden Index in this group was 0.6642.

These results demonstrate that BMI is a highly accurate indicator of obesity, as defined by %BF, in both males and females. The optimal BMI thresholds observed in this population were lower than the traditionally utilized definitions, underscoring the importance of population- and sex-specific assessment tools for obesity classification.

Table: 4. Diagnostic performance of BMI for the classification of obesity by sex-specific body fat percentage criteria.

Sex	Obesity Definition	AUC	BMI Cutoff (kg/m²)	Sensitivity (%)	Specificity (%)	Youden Index	p-value	Interpretation
Male	%BF ≥ 25	0.872	>22.82	85.37	86.33	0.7169	<0.0001	Excellent accuracy
Female	%BF ≥ 30	0.893	>21.39	81.11	85.31	0.6642	<0.0001	Excellent accuracy

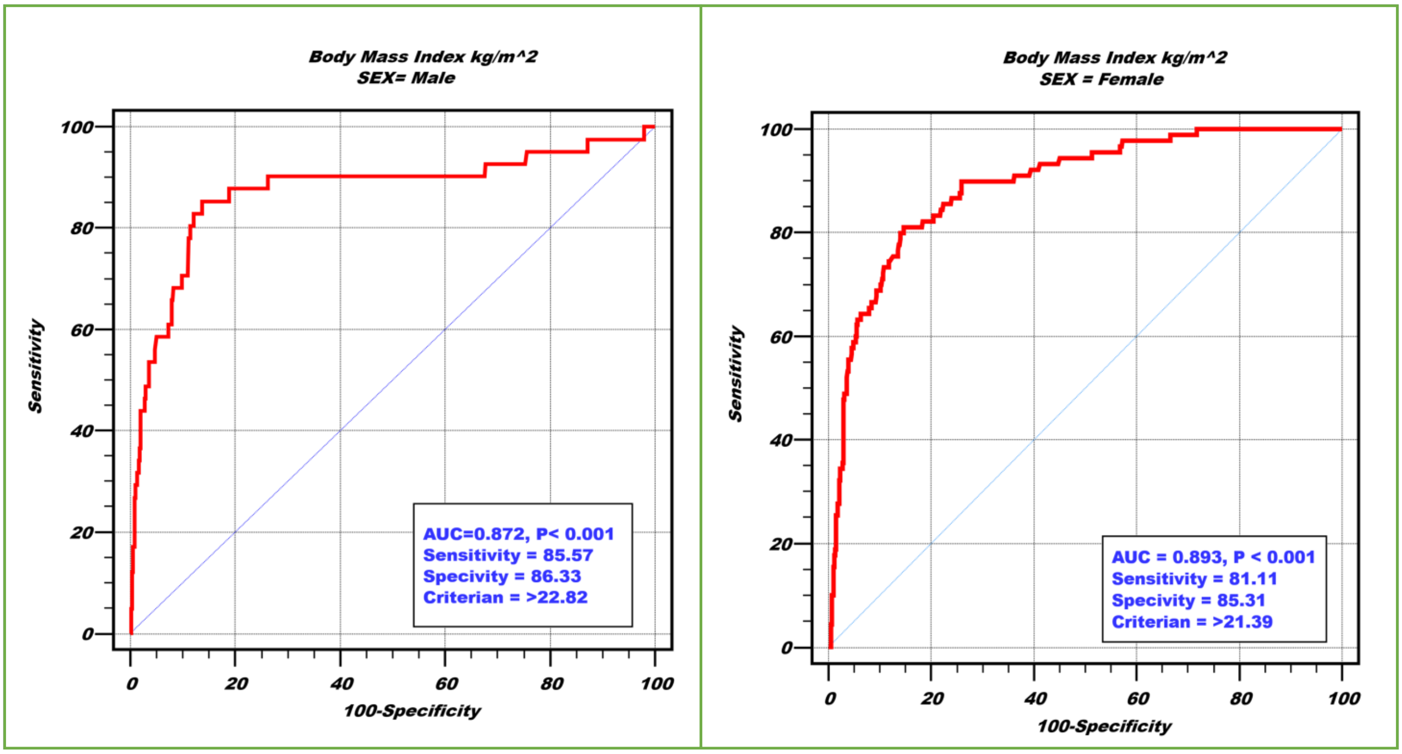

Figure 2. Showing the ROC graph male and female

DISCUSSION

This present study aimed to determine the BMI cutoff point for obesity based on percent body fat. The Correlation analysis revealed a strong positive relationship between BMI and %BF, indicating that as BMI increases, % body fat tends to increase as well. However, the strength of this relationship varied by sex, highlighting that BMI may not uniformly reflect adiposity across different population subgroups. These findings are consistent with earlier studies (e.g., Gallagher et al.,[18]; Deurenberg et al., 1998[19]), which emphasized sex- and ethnicity-specific differences in fat distribution and the need for revised cut-off values.

The optimal BMI cutoff value for obesity is 22.82 kg/m² for males and 21.39 kg/m² for females. This cutoff value is for predicting obesity of tribal people of Purulia. These findings are consistent with some earlier studies. Similar results have been suggested Pal et al., 2012[20], Among the Bangalee population, the BMI cutoff values established are 21.87 kg/m² for overweight and 24.33 kg/m² for obesity. Aizuddin et al., 2021 [21], found that the optimal cutoff value for classifying obesity based on body fat percentage in the Malaysian population is 24.8 kg/m². Which improves in detecting high adiposity. Moreover, Wang et al., 2022,[22] The study identified optimal BMI cutoff values for obesity screening as 23.53 kg/m² for males and 23.41 kg/m² for females, with both sexes showing comparable results when assessed using other related indices. Di Renzo et al., 2022 [23] the study identified a new BMI cut-off point of 27.27 kg/m² to predict obesity. This study found most appropriate BMI threshold corresponding to %BF-defined obesity, ROC curve analysis was employed. The area under the curve (AUC) values indicated good discriminative ability of BMI to classify obesity. The optimal cut-off point, determined using Youden's Index, differed from the conventional WHO standards.

These results have practical implications. Using fixed international BMI cutoffs may lead to underestimation or overestimation of obesity-related health risks in different demographic groups. The BMI cutoffs identified in this study, derived from actual %BF measurements, may serve as more accurate indicators for clinical and public health decision-making in the tribal groups.

CONCLUSION

This study found the BMI cutoff is lower than in other studies. That means tribal people may have high body fat in spite of their BMI. The WHO cutoff points for overweight and obesity may not be appropriate for tribal communities because these populations tend to have lower BMI values despite having higher body fat percentages. This study highlights the need to revisit BMI cutoffs for obesity classification and supports the incorporation of body fat percentage in defining adiposity. Our results suggest that BMI cutoffs aligned with %BF-defined obesity improve the accuracy of identifying individuals at metabolic risk, particularly in sex-specific and regional contexts.

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