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ORIGINAL ARTICLE

Estimation of body fat mass percentage as measure of obesity among undergraduate medical students and its correlation with clinical markers of obesity

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A B S T R A C T

Introduction: This study was conducted to assess the burden of overweight and obesity among UG medical students by measurement of body fat mass percentage (BF%) and to evaluate the validity of BF% as a clinical marker of obesity by its correlation with BMI.

Methodology: The research was conducted as a cross-sectional, observational study using the principle of Bioelectric Impedance Analysis for the measurement of body fat.

Results: There are a total of 420 students among them, there were 233 males (55.4%) and 187 females (44.5 %) among the study participants. The burden of overweight and obesity among the students was found to be 26% and 9.8 % respectively according to WHO global BMI criteria whereas it was 18.8 % and 35.7 % respectively, if the Asian criterion was used. This abnormality was pervasive across all four years of UG MBBS students. The startling finding is that students who were labeled as 'Normal' using the BMI criterion were found to be obese by BF% assessment (43%) and even 'Underweight' students were found to have more than normal levels of BF% (15.2%). Measurement of waist circumference (WC) showed that 146 (34.8%) of the students had WC higher than normal. Likewise, 145 (34.5%) of the students had Waist-Hip Ratio higher than normal. Abnormalities of all the above parameters put the students at risk of NCDs(Non-Communicable diseases).

Conclusion: The study shows a high burden of overweight and obesity in medical students. Using body fat percentage as a clinical marker of adiposity is more desirable than using BMI only to screen for clinical obesity

Keywords: *BMI, Body fat mass, Epidemiological Investigations, Hip circumference, Obesity, Overweight, Waist circumference, Waist hip ratio.*

Introduction

Being overweight and obese leads to serious health consequences and increases the risk of morbidities and mortalities due to NCD (Non-communicable diseases). An increase in body fat alters the body's response to insulin, potentially leading to insulin resistance, and also creates a pro-inflammatory state, leading to the risk of thrombosis.[1, 2] India is currently experiencing an epidemic of Type 2 Diabetes Mellitus and related disorders.[3, 4] Obesity also increases the risk for coronary artery disease, hypertension, stroke, etc. The measurement of obesity (prevalence) in populations has thus become an important index of risk assessment of predisposition to NCDs. It has thus become very important to screen all adults and adolescents for obesity to ensure positive health. Body Mass Index (BMI) is the most commonly used measure of obesity.[5] It is commonly used as an important clinical marker of adiposity even though it is a surrogate measure of body fat since the index directly does not measure body

fat. Young people who have great muscular mass and hence more weight for a given height may have a higher BMI even though there is no extra adiposity. In such cases, assessment of BMI to screen overweight or obesity may have its drawbacks.[5]

Moreover, the relationship between body fat and BMI differs in different populations.[6] It has been demonstrated that Indians have different body fat and BMI relationships compared to Caucasians and African Americans and Indians tend to have more adipose tissue for a given BMI.[7, 8] This even prompted WHO to revise the BMI cut-off for Asians to define overweight and obesity.[9-, 10] Thus the use of BMI in a person is limited by its inability to discriminate between fat and lean body mass i.e. fat-free mass (FFM).

Therefore, the estimation of body fat mass as a percentage of the total body weight is an alternative and direct measure of abnormal body adiposity. Various tools are available for the assessment of body fat mass like hydrostatic weighing, air displacement plethysmography, dual-energy x-ray absorptiometry [DEXA], Computerised Axial tomography [CAT] scan, Magnetic Resonance imaging [MRI], and bio-electric impedance analysis [BIA] and measurement of skin fat by calipers. Among these BIA is the least invasive and perhaps the most convenient to use tool for body fat percentage assessment. The objectives of the current study are the following:

1. Burden of overweight and obesity among the UG medical students by using body fat mass and its correlation with BMI.

2. To assess the burden of overweight and obesity among UG medical students of PRMMCH(Pandit Raghunath Murmu Medical College and Hospital, Baripada, India) by measurement of body fat mass percentage.

3. To evaluate the validity of body fat mass percentage as a clinical marker of obesity by its correlation with BMI.

Methodology

Study Population The study which was designed as a cross-sectional, descriptive study was completed within two months after obtaining due ethical clearance at PRMMCH (Pandit Raghunath Murmu Medical College and Hospital; ICMR STS Id no; 2022-02901), Baripada, India. Assuming a prevalence of 50 % obesity among the UG MBBS students a minimum of 384 MBBS students was calculated as the minimum desired sample size. The study was conducted in the clinical anthropometry lab of the Department of Community Medicine of PRMMCH (Pandit Raghunath Murmu Medical College and Hospital) using a Bioelectric Impedance Analysis (BIA) machine for measurement of body fat % and weight, measurement tape for waist and hip circumference and stadiometer for assessing the standing height of the study subjects. All healthy students who consented to participate in the study were included in the study provided they were not disqualified by any of the exclusion criteria.

The criteria for categorizing BMI are based on two widely accepted standards. The first one is the WHO global standards which classify BMI as Underweight (< 18.5), Normal (18.5 –24.9), Overweight (25.0 –29.9), and Obese (>=30). While there are no universally acceptable norms for body fat percentage like BMI, one set of criteria recommended by the ACSM (American College of Sports Medicine) in its ACSM Health Related Physical Fitness Assessment Manual 2008 is widely used and referred to.

Exclusion criteria:

1. All students who were suffering from any illness (acute or chronic) which does not permit anthropometric evaluation

2. All students with any locomotor disability that prevented accurate estimation of standing height measurement by stadiometer

3. All students who had implants or prosthetics (either electrical or non-electrical) on their person.

The assessment of the students was done in batches of 10 to 20 students each. After recording the socio-demographic details, the anthropometric measurements were recorded using the equipment listed above. For body fat percentage measurement by bioelectric impedance analysis (BIA) machine, the students were advised to come on empty stomachs (8-12 hours overnight fasting) with minimal clothing and remove all metallic objects from their person like coins, mobiles, hair clips, etc, which is known to interfere with the measurements. For the BIA

measurements (i,e body fat %), the OMRON Karada body composition monitor HBF-375 was used.

The BIA machine also gave the reading of body weight in kilograms. The anthropometric measurements of waist and hip circumference (in centimeters) were assessed using SECA 201 measuring tape. Height in centimeters was measured using a commercially available stadiometer (Prestige). The collected data was tabulated and analyzed as per the standards for BMI recommended by the World Health Organization (WHO) and their modified version recommended for Asians, particularly Indians. The statistical significance of the results was evaluated by appropriate comparisons and statistical tests (Chi-square).

Results

The medical college has an intake capacity of 100 students per year with an additional capacity for 25 students in the EWS (Economically Weaker Sections) category from 2019 onwards.

The college therefore has an enrollment capacity of 100 students in 4th year MBBS and 125 students each in the first, second, and third year respectively adding to 475 students in total. From the first year MBBS 108 students, 119 students from 2nd year MBBS, 116 students from 3rd year MBBS, and 77 students from the final year MBBS, adding up to a total of 420 students from all four years consented to participate in the study. Thus the research had the participation of 88.4% of the enrolled students.

There were 237 males (55.5%) and 187 females (44.5 %) among the study participants. From among them, 169 students (40.2%) were from a rural background and the rest 251 students (58.2%) were from an urban background. Analysis of the religious faith of the students revealed that 408 were Hindus (97.1%), 7 were Muslims (1.7%) and the remaining 5 study participants (1.2%) were Christians. The mean age of the students was 20.72±1.69, 21.26±1.20, 22.32±1.2 and 23.34±1.4 for the first-year, second-year, third year and final-year students respectively. The overall mean age of the students was 21.8 years across all four years of the students (21.8±1.6) with a minimum age of 18

Table 1: Anthropometric Measurements of the Study Subjects

Parameter	Height (cms)	Weight (kgs)	BMI (Kg/ m²)	Body fat (%)	Waist Circum. (cms)	Hip Circum. (cms)	W/H ratio
Overall (n=420)	163.8 ± 9.51	64.2 ± 13.25	23.9 ± 4.25	26.5 ± 7.36	82.4 ± 10.22	95.7 ± 8.88	0.86 ± 0.05
Year Wise							
1st-year MBBS	164.6 ± 10.0	65.0 ± 13.68	23.9 ± 4.34	26.5 ± 6.90	82.3 ± 10.8	96.7 ± 9.26	0.85 ± 0.06
2nd-year MBBS	163.7 ± 8.6	65.0 ± 13.93	24.1 ± 4.27	26.2 ± 7.43	82.2 ± 10.1	95.1 ± 9.01	0.86 ± 0.05
3rd-year MBBS	163.8 ± 9.4	63.3 ± 13.54	23.7 ± 4.66	26.0 ± 7.79	82.6 ± 10.76	95.03 ± 9.39	0.86 ± 0.05
4th-year MBBS	162.9 ± 10.2	63.1 ± 11.01	23.7 ± 3.45	27.6 ± 7.25	82.5 ± 8.7	96.1 ± 7.17	0.85 ± 0.05
Gender Wise							
Female	153.6 ± 6.19	58.3 ± 11.7	23.9 ± 4.52	32.1 ± 4.73	80.8 ± 10.44	97.1 ± 9.06	0.83 ± 0.05
Male	169.9 ± 7.03	68.9 ± 12.4	23.9 ± 4.04	22.0 ± 5.84	83.7 ± 9.87	94.6 ± 8.58	0.88 ± 0.04
Residence							
Rural	164.5 ± 9.31	64.8 ± 13.5	23.8 ± 4.12	25.6 ± 7.20	82.7 ± 10.30	95.3 ± 8.67	0.86 ± 0.05
Urban	163.4 ± 9.6	63.8 ± 13.07	23.9 ± 4.35	27.1 ± 7.42	82.2 ± 10.18	95.9 ± 9.02	0.85 ± 0.05

years and a maximum age of 27 years. The anthropometric measurement of the study subjects (Table 1).

Table 2: Distribution of overweight and obesity among the various subgroups

BMI Category	Underweight	Normal	Overweight	Obese
Range	< 18.5	18.5—22.9	23—24.9	>=25
Overall (n=420)	33 (7.9%)	158 (37.6%)	79 (18.8 %)	150 (35.7%)
Year Wise				
1st-year MBBS	27 (6.5%)	43 (39.8%)	19 (17.6%)	39 (36.1%)
2nd-year MBBS	10 (8.4%)	40 (33.6%)	23 (19.3%)	46 (38.7%)
3rd-year MBBS	14 (12.1%)	43 (37.1%)	17 (14.7%)	42 (36.2%)
4th-year MBBS	2 (2.6%)	32 (41.6%)	20 (26.0%)	23 (29.9%)
Gender Wise				
Female	19 (10.2%)	67 (35.8%)	32 (17.1%)	69 (36.9%)
Male	14 (6.0%)	91 (39.1%)	47 (20.2%)	81 (34.8%)
Residence				
Rural	13 (7.7%)	61 (36.1%)	37 (21.9%)	58 (34.3%)
Urban	20 (8.0%)	97 (38.6%)	42 (16.7%)	92 (36.7%)

The breakup of the data on BMI computed from the anthropometric measurements on the study subjects reveals that 33 (7.9%) students were underweight, 109 (26%)students were overweight, and 41 (9.8%) students were obese while the remaining 237 (56.4%) students had normal BMI. So, one of the questions about the burden of overweight and obesity among the UG medical students was found to be 26% and 9.8 % respectively according to WHO global criteria of assessing obesity by using BMI.

Table 3: Distribution of body fat percentage (BF%) of BMI and their co-relation

BMI Category	Underweight	Normal	Overweight	Obese	Overall
Range	< 18.5	18.5—22.9	23—24.9	>=25	(n=420)
Body Fat Percent (BF%)					
Normal	28 (84.8%)	90 (57.0%)	26 (32.9%)	10 (6.7%)	154 (36.7%)
Obese (At risk)	5 (15.2%)	68 (43.0%)	53 (67.1%)	140 (93.3%)	266 (63.3%)
r^2	-0.24	0.24	0.14	0.42	0.57
P value	0.16	0.00	0.20	0.00	0.00

The second set of standards is by the WHO for classifying BMI in Asians and Indians.[9, 10] This standard classifies BMI as Underweight (< 18.5), Normal (18.5 - 22.9), Overweight (23.0 - 24.9) and Obese (>=25). When the dataset was reanalyzed with the Asian standards the underweight group remained unchanged (7.9%) but there was a remarkable reduction in the normal fraction as well as the overweight fraction i.e. normal (56.4 % to 37.6%) and overweight (26 % to 18.8 %) as compared to the WHO global standards. The obese fraction rose sharply from 41 to 150 students i.e 9.8 % to 35.7 %. Thus the burden of overweight and obesity among UG MBBS students of our college was found to be 18.8 % and 35.7 % respectively, if the Asian criterion for BMI was used.

It is already a well-established fact that all the risk factors for non-communicable diseases (NCDs) operate on a continuum of risk concepts i.e. even within the so-called 'normal' range of BMI the persons on the higher side of the range are at higher risk of NCDs than those lower than them. Furthermore, it is also a well-accepted scientific fact that Asians are at a higher risk of NCDs compared to their Western counterparts even at lower levels of obesity, thus necessitating the separate criteria for Asian Indians with lower limits.

Thus in the present study using the Asian criteria was considered prudent as it helped in identifying the higher

burden of risk among the students. The sub-group analysis of the BMI data (Table 2) shows that the distribution of overweight and obesity among the students from rural backgrounds (21.9% and 34.3%) is comparable to those from urban backgrounds (16.7% and 36.7%), which dispels the myth that obesity is an urban problem as students from both backgrounds are at equal risk. The burden of overweight and obesity seen from the sex perspective also mirrors a similar picture with 17.1% and 36.9% of the females while 20.2% and 34.8% of the males being overweight and obese respectively. The male students as well as female students are at similar risk.

Table 4: Distribution of Waist Circumference (WC) and Waist/ Hip Ratio (WHR) to BMI

BMI Category	Underweight	Normal	Overweight	Obese	Overall
Range	< 18.5	18.5—22.9	23—24.9	>=25	(n=420)
Waist Circumference					
Normal (<=90 cm in males and <= 80 cm in females)	31 (93.9%)	152 (96.2%)	53 (67.1%)	38 (25.3%)	274(65.2%)
At risk (High)	2 (6.1%)	6 (3.8%)	26 (32.9%)	112 (74.7%)	146 (34.8%)
Chi square =184.23					p=0.00
Waist/ Hip ratio					
Normal (<=0.9 in males and <=0.85 in females)	31 (93.9%)	129 (81.6%)	51 (64.6%)	64 (42.7%)	275(65.5%)
At risk (High)	2 (6.1%)	29 (8.4%)	28 (35.4%)	86 (57.3%)	145 (34.5%)
Chi square =184.23					p=0.00

Table 5: Distribution of Waist Circumference (WC) and Waist/ Hip Ratio (WHR) to Gender

Waist Circumference (WC)			
Sex	**Female**	**Male**	**Total**
Normal	93 (49.7%)	181 (77.7%)	274 (65.2%)
At risk (High)	94 (50.3%)	52 (22.3%)	146 (34.8%)
Chi square=35.73			p=0.00
Waist/ Hip ratio			
Normal	120 (64.2%)	155 (66.5%)	275 (65.5%)
At risk (High)	67 (35.8%)	78 (33.5%)	145 (34.5%)
Chi square = 0.254			p=0.614

The year-wise distribution of the students shows that the pattern of the burden of overweight and obese is seen in all four years of students with minor differences in the absolute proportions, which reflects the pervasive nature of the malady across the entire student population. The research study also attempted to explore the utility of other clinical markers of obesity like body fat percentage (BF%) in assessing obesity compared to the often-used parameter of BMI. The students were assessed for body composition using a BIA (Bioelectric Impedance Analysis) machine which gave out a cluster of measurements related to body composition for each study subject. Since our objective was to study the relationship and utility of body fat percentage, only that parameter was recorded and the rest of the output was conveniently ignored for this study.

While there are no universally acceptable norms for body fat percentage like BMI, one set of criteria recommended by the ACSM (American College of Sports Medicine) in its ACSM Health Related Physical Fitness Assessment Manual 2008 is widely used and referred to[11]. The standards are different for men and women and again vary for different age groups within each gender. The categories in each group have a scaling approach starting from the best end of the spectrum labeled as 'Essential fat' followed by 'Excellent', 'Good', 'Average', 'Below average', and the worst being ' Poor'.

For our analysis, the value of 22.4 was used as the upper limit for BF% in males and 27.7% for females as they correspond to the upper limit for the age group 20—29 years which includes most of our study subjects. For subjects below 20 years, no separate standards were available in the ACSM guidelines, hence the 20—29 year

was used as default. It is worthwhile to note that many research studies take an average of both 22.4% and 27.7% instead and use BF% >25% as a universal cutoff to define obesity for both males and females.

The analysis of the BF% (Table 3) of the students shows that 266 (63.3%) students have BF% higher than the cutoff value for their respective sex and age (i,e obese) whereas the remaining 154 (36.7%) have BF% within limits. Further analysis reveals that the agreement between BF% and BMI in identifying the 'high risk' is the highest in the 'obesity' category (93.3%) followed by the 'overweight' category (67.1%). The startling finding is that students who were labeled as 'Normal' using the BMI criterion were found to be obese by BF% assessment (43%) and even 'Underweight' students were found to have more than normal levels of BF% (15.2%). Thus the BF% was found to be a more sensitive indicator of obesity compared to BMI.

The study of the linear relationship between BF% and BMI reveals (Table 3) that there is a statistically significant ($p<0.00$) strong positive correlation (0.57) between BF% and BMI. However sub-group analysis shows a weak correlation in the underweight, normal, and overweight categories and a modestly positive correlation in the obese category. This also underscores the fact that the linear relationship of BF% is independent of BMI, especially in the lower BMI ranges of 'underweight' and 'normal' where the person is considered as having a low risk. Thus a person could well be at high risk because of higher than normal body fat percentage and yet remain in the false realm of normalcy if only BMI is used as the clinical criterion to define or screen obesity.

The measurement of the waist circumference (WC) is an important marker of cardiovascular risk since it overtly measures abdominal girth which is the principal site for extra fat deposition. The government of India's National Program for Prevention and Control of NCDs has a set limit for WC as a screening tool where more than 90 cm in males and more than 80 cm in females is considered a risk for NCDs. The analysis of the anthropometric data in (Table 4), shows that 146 (34.8%) of the students had WC higher than normal which puts them at risk of NCDs. The breakup of the data shows that 55.3% of the female students had a higher than normal WC compared to only 22.3% of the male students, which was statistically significant. Likewise, the distribution of the WHR across the different BMI categories is summarized in (Table 5) which was also statistically significant.

The waist circumference to hip circumference ratio (W/H ratio) is also an important predictor of cardiovascular risk vis-a-vis its ability to measure abdominal obesity. The WHO criterion upper limit for the W/H ratio is 0.9 for males and 0.85 for females.[12] Any value above these two is considered a high-risk category. The analysis of the anthropometric data in (Table 4), shows that 145 (34.5%) of the students had WHR higher than normal which puts them at risk of NCDs. The breakup of the data shows that 35.8% of the female students had a higher than normal WHR compared to 33.5 % of the male students. However, the distribution of the WHR across the different BMI categories (Table 5), was statistically significant.

Discussion

Medical undergraduate students are more prone to obesity due to their extended hours spent on the study table as well as very little time for physical activity within their packed course schedule. In several studies done across India, it has been reported that the burden of overweight and obese is high in medical students.[13-15] In one study done in Gwalior by Tiwari et al showed a prevalence of overweight at 9.93% and that of obesity at 1.53%. Deotale et al in Gran Medical College, Mumbai have reported a prevalence of 14.33% and 3.34% respectively for overweight and obesity. Likewise, Fernandez from Pune reported a combined proportion of 13.2% among medical students for overweight and obesity together.[15] Khan et al in a study in our neighboring country Pakistan reported that 30.5% of males and 16% of females had a BMI exceeding 25 kg/ m^2.[16] However most of the studies have used the WHO global BMI criterion which has 25 kg/m^2 as a cut-off. In one of the few studies that used the modified WHO criteria (for Asians and Indians) by KK Manojan et al done in a medical college in Kerala, the prevalence of obesity was 25.7% and overweight was 24.5%.[17] Our study which also uses the modified WHO criterion affirms the findings with the burden of overweight at 18.8% and obesity at 35.7% among the students of our college.

One of the research objectives of the present study was to explore the validity of the measurement of body fat percentage (BF%) as a marker of obesity compared to the often-used BMI. The relationship between BMI and BF% has been studied across various ethnic groups, particularly in Western countries.[18-21] The Body composition of Indians is different from other ethnic groups around the world. From the very few studies that have been published in India, it has been reported that for the same degree of obesity measured by BMI, the BF% among South Asians particularly Indians may be much more than other ethnic populations.[22-25] This was also established in our analysis where students who were labeled as 'Normal' using the BMI criterion were found to be obese by BF% assessment (43%) and even 'Underweight' students were found to have more than normal levels of BF% (15.2%). Thus the use of BMI alone as a screening tool in clinical practice to detect or rule out obesity can be fallacious and dangerous as people who are indeed at risk' may be given the false impression of 'normalcy'.

Earlier research has indicated a positive correlation between BMI and BF% in various populations.[18,19, 22] Although our study shows a strong positive correlation in the overall population (r^2=0.57) between BF% and BMI which was also statistically significant, the linear relationship was not uniform across all categories of BMI. It was minimal and negative in the underweight category (r^2= - 0.24) and gradually increased to a positive correlation as one moved up the BMI categories from 'Normal' to 'Obese' through 'overweight'. In the 'Normal' and 'Obese' categories the correlation was positive and statistically significant as well. Similar findings have also been reported from a study in British adults (correlation between BF% and BMI).[11, 17]

Conclusion

The present research work was designed as a simple observational descriptive study to give a picture of the burden of overweight and obesity among UG medical students of our college. The study findings of a high burden of overweight and obesity in medical students will hopefully convince research institutions like ICMR to establish a demographic health surveillance system for medical students. Indian medical students can be subjected to annual or semi-annual health assessment and their clinical and other parameters can be logged and they can be followed up (in a longitudinal format) to study the burden of risk factors and outcomes for various health conditions especially NCDs among them. [similar to the famous British Doctors study of Doll and Hill].

The country's medical regulator—the National Medical Commission (NMC) can be also motivated to include mandatory physical activity in the curriculum for all medical students and also endorse the prescription of annual health assessments for all medical students.

That BMI of 23 kg/m^2 is not an effective predictor of obesity particularly in Indians is strikingly borne out in this study. The analysis of the body fat percentage even in this sample of relatively young study subjects reveals the so-called "Indian paradox", that Indians are more prone to obesity (due to their smaller body frame) even at much lower BMI cut-offs compared to their western or Caucasian counterparts. Thus using BF% as a clinical marker of adiposity is more desirable than using BMI only to screen obesity.

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