Correlation between Body Fat Estimated from BMI and Bio Impedance Analysis among Population Working in IT Sector in Bangalore City - A Cross-Sectional Study

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ABSTRACT

BACKGROUND
With the availability of more sophisticated methods, the utility of body mass index (BMI) as a measure of obesity and body fat estimation is being questioned. The current study aims to compare the estimation of body fat derived from BMI to that of directly measured bio impedance analysis (BIA).

METHODS
This is a cross sectional study conducted among IT employees of Bangalore City. Body fat % estimated from BMI using formula (adult BF = (1.20 x BMI) + (0.23 x age) - (10.8 x sex) - 5.4 where value for male = 1 & female = 0) and bioimpedance analysis (BIA) was compared using Bland-Altman analysis.

RESULTS
A total of 6901 participants were included and out of 6901 participants, 67.63 % were women. The mean age was 29.6 ± 6.68 years. The mean of the difference in body fat % calculated from BMI and estimated by BIA was 3.29, (- 9.99 to + 16.58 %). The mean difference was 3.43, (- 9.58 to + 16.45 %) and 2.89, (- 10.90 to + 16.68 %) among men and women respectively.

CONCLUSIONS
The results showed that the body fat estimated by BMI varies significantly from body fat estimated from BIA.

KEYWORDS
Obesity, Body Mass Index**,** Body Fat Percentage, Bioelectrical Impedance

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BACKGROUND

Obesity is an established risk factor for multiple chronic diseases including diabetes and cardiovascular diseases.[1,2] Body mass index (BMI), waist circumference and skinfold thickness are the commonly used anthropometric measurements of obesity. Hydrostatic weighing, air displacement plethysmography (Bod Pod), bioimpedance spectroscopy (BIS) bioelectrical impedance analysis (BIA) and electrical impedance myography (EIM) have evolved as new methods of body fat estimation, recently. Even more objective methods like densitometry, computed x-ray tomography (CT), magnetic resonance imaging (MRI), and dual-energy x-ray absorptiometry (DEXA) are also available for use in clinical settings.[3] These tests have varied precision, cost and handiness.[4]

Body mass index (BMI) had been extensively used in epidemiological studies to diagnose overweight and obesity. The guidelines for ideal body weight have also been suggested in the past research using BMI.[5] However, BMI has been criticized for its weight component not being distinguished between muscle, fat, bone or vital organs.[6] Also, there is ambiguity on whether BMI is related to body fat % in linear,[7] or curvilinear[8,9] manner. There is further uncertainty about the difference in % of fat with age, gender, physically active individuals and pregnancy after controlling for BMI.[9] Following reports of possibility of paradoxically high body fat % in low BMI / waist circumference subjects and vice versa, questions are being raised about its appropriateness as a proxy for body fat proportion.[10] Hence, increasing number of researchers are recommending more reliable methods of estimation of body fat. Bioelectrical impedance analysis (BIA) has been proposed as one such alternative.

Bioelectrical impedance analysis (BIA) works on a principle of assessing electrical impedance of a small constant alternating current when it passes through the body. There are many variety of devices available for working on this principle.[11] Past studies have determined BIA value to estimate percentage body fat with precision. Since BIA is simple, portable, non-invasive and cost effective, it is now emerging as a valuable screening method in body measures.[12]

An effective index of body composition that can easily classify the at-risk individuals for emerging obesity-related diseases, can be deemed important for the health professionals. The present study was conducted to compare the body fat estimation derived from BMI and that of directly measured using BIA among adult population working in IT sector.

METHODS

The study was a cross sectional study conducted in various IT companies across Bangalore City. The participants included were IT sector employees aged above 18 years, belonging to both genders. Participants on long term steroid therapy and participants who underwent any surgical intervention for weight loss were excluded from the study.

The stored data (height, weight and body fat percentage) was collected and analysed from the authenticated cloud platform. These physical parameters were measured (height, weight and body fat percentage) in their respective institutions from May 2018 to November 2018. A standard, calibrated weighing scale and wall-mounted stadiometer were used to measure weight and height. Participant's weight was recorded with minimal clothing to the nearest 0.5 kg and height were assessed to the nearest 0.5 cm. Body fat % (BF %) was also determined using bioelectrical impendence analysis using Mi body composition scale. The instrument records impedance from foot to foot via electrodes. Based on the personal data such as age, height, weight, and sex entered into the device before performing the test, it determines the BF % directly obtained from the device readings by using the pre-entered data. The direct value of body fat percentage using BIA was retrieved and the parameters for BMI was deidentified and analysed as follows. BMI was calculated as the quotient ratio of weight (kg) / height $(m)^2$. Body fat was estimated from BMI based on the following formula proposed by Deurenberg, P., et al.[13]

Adult Body Fat

(1.20 x BMI) + (0.23 x age) - (10.8 x sex) - 5.4

[male = 1, female = 0]

No standardized definition was available for defining paradoxically high and low-fat percentage. For the purpose of this study, these terms were defined as follows:

Paradoxically high body fat %: The proportion of subjects who are either underweight or normal by BMI category having high or very high body fat % as estimated by BIA.

Paradoxically low body %: The proportion of people classified as overweight to obese by BMI, having very low to normal body fat %, as estimated by BIA. Considering the mean value of percentage body fat as estimated by BMI as 24.3 ± 7.19 (mean and SD) and percentage body fat as calculated by BIA as 27.6 ± 7.96 with 5 % two-sided alpha error, the study had attained 100 % power.

Ethical Consideration

Authenticated cloud platform hosted on servers located in India, was used to securely store the data of the participants. To ensure security of the data, all the institutional mechanisms were in place as per the required standards. The data was deidentified, anonymized by the institution and deidentified data was analyzed by the collaborating agency within the premises of the "mfine" on dedicated and secure platforms belonging to the organizations. Consent to waiver was obtained from ethical committee and the study was approved by the Digital Health Research Independent Ethics Committee (approval number: DHRIEC / SAL01 / 21052020, dated: 21.5.2020)

Statistical Analysis

Body fat by BIA method and BMI method were outcome variables of interest. Visual inspection of histograms and normality Q-Q plots were done to assess compliance of quantitative variables with normal distribution. P-values of statistical tests like Shapiro-Wilk test and Kolmogorov Smirnov test were also calculated. Mean ± SD, median (IQR) were used to summarize normally and non-normally distributed quantitative variables. Categorical variables were summarized by number and proportion. The level of agreement between the body fat calculated from BMI and body fat assessed by BIA were assessed by Bland-Altmann analysis. The mean of the differences and it's 95 % CI were plotted in the y-axis against the mean of the two methods. The risk of proportion bias was calculated using T-test. P value < 0.05 was considered statistically significant. Co Guide version V.1.0 was used for statistical analysis.

RESULTS

A total of 6901 subjects were analysed in this study. The mean age of the study population was 29.6 ± 6.68 years with 67.63 % of the population being women. The number of people with overweight were 1306 (18.92 %). Pre-obesity and obesity were observed in 2489 (36.07 %) and 913 (13.23 %) people respectively. The mean body fat by electrical impedance method and BMI was also determined. (Table 1)

	Parameter	Statistics
	Age (Mean ± SD)	29.6 ± 6.68
Age group N (%)	< 25	2078 (30.11 %)
	26 - 30	2400 (34.78 %)
	31 - 35	1311 (19.00 %)
	> 35	1112 (16.11 %)
Gender	Female	2234 (32.37 %)
	Male	4667 (67.63 %)
	BMI (mean ± SD)	25.16 ± 4.56
BMI categories	< 18.5 (underweight)	384 (5.56 %)
	!8.5- 22.99 (normal)	1809 (26.21 %)
	23 - 24.99 (over weight)	1306 (18.92 %)
	25 - 29.9 (pre-obese)	2489 (36.07 %)
	> = 30 (obese)	913 (13.23 %)
Body fat categories by BIA (WHO categories)	Very low	289 (4.2 %)
	Low	740 (10.70 %)
	Normal	1589 (23.0 %)
	High	2023 (29.3 %)
	Very high	2260 (32.7 %) (39.52 %)
Body fat categories calculated from BMI (WHO cut off levels)	Very low	204 (2.96 %)
	Low	1664 (24.11 %)
	Normal	2560 (37.1 %)
	High	1636 (23.71 %)
	Very high	837 (12.13 %)

Table 1. Descriptive Analysis of Socio-Demographic Parameters in the Study Population (N = 6901)

In the overall study population, paradoxically high body fat % was observed in 748 (34.1 %) of the study population. This proportion was 43.16 % among male population and 21.11 % among women. Paradoxically low body fat % was observed in 27.66 % of the subjects in overall study population 21.78 % of the male and 42.5 % of the females (Table 2).

Body fat categories as assessed by BIA across various BMI categories was also determined. There was a statistically significant difference in the proportion of people classified in different body fat categories by two methods (P < 0.001). (Table 3)

	BMI Categories	Body Fat Categories as Assed by BIA Who Categories: Very Low Normal	High & Very High	Chi Square	P Value
Overall	Underweight to normal (N = 2193)	1445 (65.89 %)	748 (34.11 %)	912.886	< 0.001
	Overweight to obese (N = 4708)	1302 (27.66 %)	3406 (72.34 %)		
Male	Underweight to normal (N = 1293)	735 (56.84 %)	558 (43.16 %)	532.541	< 0.001
	Overweight to obese (N = 3374)	735 (21.78 %)	2639 (78.22 %)		
Female	Underweight to normal (N = 900)	710 (78.89 %)	190 (21.11 %)	290.554	< 0.001
	Overweight to obese (N = 1334)	567 (42.5 %)	767 (57.5 %)		

Table 2. Comparison of BMI Across Body Fat Categories (N = 6901)

Body Fat using BMI (WHO) Categories	Body Fat Using Bio Impedance Electrometry (BIE) Method (WHO) Categories: Very High	High	Normal	Low	Very Low	Chi Square	P Value
Very high (N = 837)	568 (67.86 %)	167 (19.95 %)	71 (8.48 %)	26 (3.11 %)	5 (0.6 %)	2540.031	< 0.001
High (N = 1636)	851 (52.02 %)	518 (31.66 %)	169 (10.33 %)	78 (4.77 %)	20 (1.22 %)		
Normal (N = 2560)	570 (22.27 %)	1045 (40.82 %)	720 (28.13 %)	158 (6.17 %)	67 (2.62 %)		
Low (N = 1664)	235 (14.12 %)	263 (15.81 %)	599 (36 %)	443 (26.62 %)	124 (7.45 %)		
Very low (N = 204)	36 (17.65 %)	30 (14.71 %)	30 (14.71 %)	35 (17.16 %)	73 (35.78 %)		

Table 3. Comparison of Body Fat Using BMI (WHO) Categories Across Body Fat Using EI Method (WHO) Categories (N = 6901)

Bland–Altman analysis showed that the mean of the difference in body fat % calculated from BMI and estimated by BIA was 3.29, ranging from - 9.99 to + 16.58 %. Among males, the mean of the difference in body fat % was 3.43, ranging from - 9.58 to + 16.45 % and among females the mean of the difference in body fat % was 2.89, ranging from - 10.90 to + 16.68 %. There was risk of proportional bias (P value < 0.001) (Figure 1). The body fat % differed significantly as determined by unpaired T-test (P = < 0.001) (Table 4).

Methods	Body Fat (Mean ± STD)	Mean Difference	95 % CI of Mean Difference: Lower	Upper	P-Value
Body fat assessed by BIA	27.6 ± 7.96	3.30	3.14	3.46	< 0.001
Body fat derived from BMI	24.3 ± 7.19				

Table 4. Comparison of Mean Body Fat Using Bioelectrical Impedance Method and BMI (N = 6901)

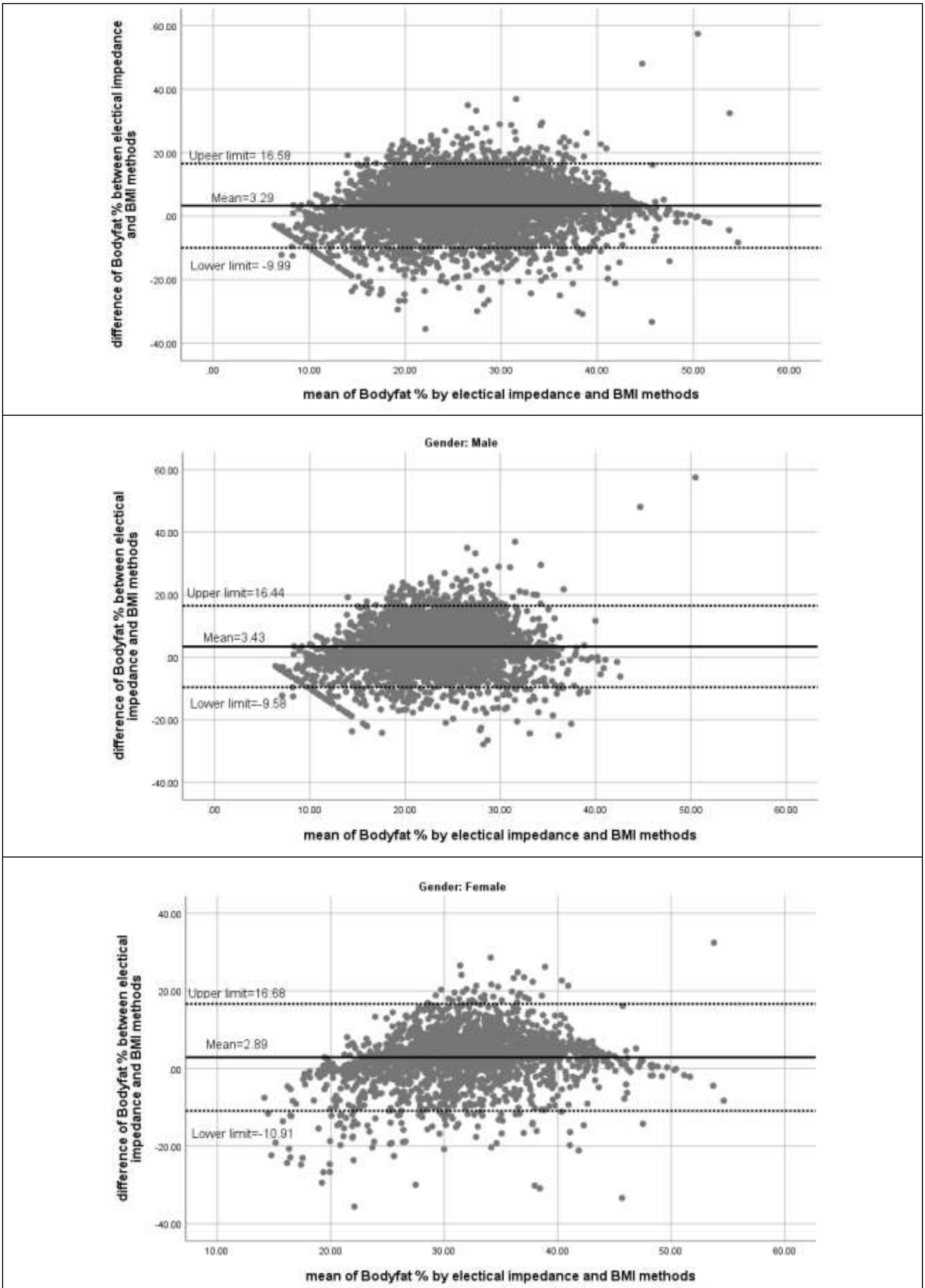

Figure 1. Bland-Altmann Plots of Difference in Body Fat between BMI and Electrical Impedance Methods against Mean Body Fat of BMI and Electrical Impedance Methods (N = 6901)

DISCUSSION

Body mass index (BMI) is most widely used as a surrogate marker of body fat in epidemiological studies. However, its ability to diagnose obesity can vary considerably by predictors of muscle mass, such as age, sex and race.[14] With the availability of simple and more objective body fat measurements like bioimpedance electrometry the validity of BMI as an indicator of body fat is being questioned in recent times. It has been proved by previous studies, that BIA based fat estimation correlates better with more objective body fat % measurements like DEXA and MRI based assessments.[3] Level of agreement between BMI and BIA based body fat estimation and the extent of paradoxical relationship between BMI and body fat % is the focus of the current study.

In the current study, the underweight population was found to have "high" and "very high" body fat in 47 (12.23 %) and 94 (24.47 %) participants respectively. Conversely in the overweight, pre-obese and obese population, about 5 to 7 % subjects had low fat. Deurenberg-Yap, M., et al.[15] studied the paradox in detail among Chinese, Malays and Indians residing in Singapore and the results showed that BF % for was under-predicted by BMI. In a large population-based cohort study, there was a poor correlation between BMI and body fat % among adults. Low BMI and high body fat % were both independently associated with overall mortality. Increasing trend of mortality was observed with decreasing BMI and increasing BF %, suggesting higher adiposity can adversely affect survival independent of BMI.[16] BMI was reported to accurately identify only 44 % & 52 % of men and women with obesity.[6] In contrast Porto, L.G., et al.[4] reported excellent agreement between BMI and BF % among physically active people. Similar findings were seen in the study by Bradbury, K.E., et al.[17] and Santi, A., et al.[18] There are many uncertainties about the influence of race, age, gender, physically active status etc. on the association between BMI and body fat percentage.[15] Also there are propositions of linear[7] and curvilinear[8,9] nature of this relationship.

Body fat % estimated by BMI and BIA was found to be significantly different in the current study. A study had documented a curvilinear relationship between BMI and body fat % in normal BMI range.[9] As per Romero-Corral, A., et al.[19] BMI was not accurate in diagnosing obesity more in intermediate BMI ranges, among men and elderly population. On the contrary few studies reported a strong correlate between BMI and BF % when determined by BIA.[4,8] Adams, T.D., et al.[20] conducted a study that included a large cohort of severely obese individuals and demonstrated a linear association between BMI and % fat for men and a curvilinear association between BMI and % fat for women.

In the present study, the paradoxically high body fat % was observed in 748 (34.1 %) of the study population. This proportion was 43.16 % among male population and 21.11 % among women. Paradoxically low body fat % was observed in 27.66 % of the subjects in overall study population 21.78 % of the male and 42.5 % of the females. Gartner et al.[21] reported a high correlation between % BF and BMI and documented sensitivity and specificity of BMI < 18.5 kg / m2 (i.e., cut-off point for thinness) in relation to % BF which was 58.5 and 93.6 %, respectively. Romero-Corral, A., et al.[19] reported BMI could identify only 19.1 % of men and 24.7 % of women as obese, while BF % had classified 43.9 % of men and 52.3 % of women as obese. In study by Mullie, P., et al.[22] it was seen that 29 (6.5 %) had overweight scores for BMI with normal impedance values and 47 (10.5 %) had normal scores for BMI with high BF %. The study showed that the BMI can underestimate or overestimate body fat % even in physically active individuals.

Prentice, A. M.[23] in their review argued that BMI can often provide misleading estimation of body fat content and recommended direct measurement of body fat by more objective methods. The BMI significantly varies between age, gender, ethnicity, pregnancy and physically active individuals as determined by many previous studies.[24-27] We must know the average body fat mass in our population and the range between individuals and relationship between excess body fat and the comorbidities. And how does this vary with age, gender and ethnicity is what is unknown. The more appropriate method of BF % other than BMI must be employed to measure this. Bland-Altman analysis was done to determine the agreement between the two tests in measuring the BF %. The study results showed that there was risk of proportional bias overall as well as with respect to either of the genders (P-value < 0.001). The B & A analysis only determines if the two tests are in prefect agreement or not and if the difference exists, limits are acceptable or not. The B & A plot cannot determine if the difference between the tests is a statistically significant one.[28] Existence of proportional bias reaffirms the different levels of disagreement between both methods through the range of measurements.

The BIA has been found to be a fairly accurate and easy method to determine the BF %.[29] However, there is no gold standard method to determine BF %. Even though previous research has illustrated that BIA is a valid measure of % fat when compared with BMI,[9] other previous research has illustrated the use of DEXA and BOD POD as a valid measure of % fat.[30] Future studies must focus on comparing all the techniques, so as to find the easiest and quickest method to determine the BF %.

CONCLUSIONS

BMI is to this day an easy and largely used measure in determining the body fat. However, our study showed that the BMI is a poor surrogate in determining the BF %. In our study, a good proportion of subjects who are either underweight or normal by BMI category were found to have high or very high body fat % as estimated by BIA and vice versa. Furthermore, methods determining the % body fat were not in agreement through the range of measurements. This highlights the need to move towards the more precise, alternative measure to determine the internal body fat. Moreover, the findings from this study can be useful in implementation of specific population-based cost-effective lifestyle intervention programs or preventive programs to reduce the obesity burden and optimize patient care.

Limitations

One of the limitations of the present study is the usage of retrospective records and convenience sampling, which affects the external validity of the study. Moreover, the cross-sectional nature of the study may lead to some kind of bias such as information bias, selection bias etc. Also, the study population included in the present study were the IT population which belongs to a higher socioeconomic stratum and is basically well educated, which also reduces the generalizability of our study population. Physical activity levels, dietary habits, nutritional intake and general lifestyle habits of the included population were not determined, which accounts to another potential limitation of this study. Large sample size could have resulted in proportional bias. In spite of these limitations, the study was well structured and results can be generalized with caution.

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