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Anthropometric Markers as a Paradigm for Obesity Risk Assessment

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Abstract

Background: Quantification of obesity/adiposity is feasible with different anthropometric characteristics along with the bioelectrical impedance analysis techniques. Recent advancements are now witnessing development of further computations derived from previously established measures to gauge obesity. **Objective:** Main aim of our study was to evaluate the association of anthropometric determinants of obesity with body compositional adiposity variables, and thus identifying the best marker among them emerging out as the probable predictor for compositional adiposity. **Participants and Setting:** 550 female participants within the age of 18 to 23 years were enrolled under this study attending graduation course at University of Delhi. Ethical clearance was received from the institutional head. Informed written consent was taken from every participant. **Design:** All the body measurements were recorded by trained staff using standard techniques. Derived measurements were calculated further. **Analysis:** Data, hence, gathered was undertaken for descriptive and inferential statistical analysis with SPSS 20.0. **Variables Measured and Results:** WHR over-estimated the count for those at risk compared to waist circumference and WHtR. Skeletal muscle fat associated negatively with all anthropometric adiposity indicators. BMI, BAI, WHtR and waist circumference related closely with all body composition cum obesity markers compared to WHR, CI and ABSI. BAI overrated the risk for fat determining body composition parameters the most followed by BMI. ABSI revealed an underestimated risk for augmenting fat content in body, compared to other markers. **Conclusion and Implications:** It is difficult to establish with compliance as to which of the measures used in the study could better predict the perils of obesity but it could be ascertained that some of the newly verified anthropometric adiposity indicators could be administered for determining clinical situations after further validation.

†Both authors have contributed equally to the work and must be regarded as first and corresponding authors.

Keywords

Adiposity, Anthropometric Markers, Risk, Body Fat, Obesity

1. Introduction

Obesity is a major risk factor associated with numerous lifestyle, chronic and non-communicable disorders, such as cardiovascular diseases and diabetes [1]. The *obesity outbreak* has been estimated by the World Health Organization to surpass even 1 billion of overweight adults in count, 300 millions of which are already clinically obese [1] [2] [3]. Body fat distribution and accumulation in abdominal region confers the highest risk for fatality with varying degrees of obesity [1]; controlled substantially by living trends [4] and familial backdrop [5]; with its stake prognosticated by body's biological age [6]. Abdominal obesity, to be specific, is amongst the most important modifiable risk factors for continual rise in the risk of early onset of several chronic disorders [1]. The *Framingham Heart Study* has also proven abdominal adiposity having a strong association with morbidities and mortalities [7].

Developing appropriate management and preventive strategies to regulate the non-communicable, chronic, lifestyle-related disorders seek for a simple and effective marker of adiposity that could concomitantly assess the risk [8]. Evaluation of intra-abdominal fat mass or visceral fat content before the manifestation of clinical signs, and prediction of associated-risk with great accuracy demands for sophisticated laboratory procedures [9]. However, costs of equipments, sophisticated protocols and diagnostic evaluations become a limiting factor for their unremitting application in research studies. Alternatively, the doubly indirect methods in the form of anthropometric indexes are fast and easy to perform, reproducible and accurate, thus being ideal for obesity detection and body fat localization [1].

Different studies and research work, from time to time, have demanded for the need to establish and apply anthropometric techniques to detect the risk of chronic degenerative diseases much earlier; apart from being accurate, reproducible and easy-to-perform [1]. Due to its simple utilization and reasonable association with body fat, BMI is a widely used and highly acceptable measure of obesity by various scientific communities [1] [8]. It is further employed for prediction of developmental chances of metabolic disorders and several other diseases. It is, also, the most commonly used index for evaluating the nutritional status of individuals as well as populations [1] and the most extensively studied phenotypic marker of generalized obesity, among adults [1] [10].

BMI values, however, do not differentiate body composition of various kinds; and their cut-offs among distinct populations influence obesity prevalence [1]. It is not able to differentiate between lean mass and fat mass. It, hence, limits differentiating body adiposity across age, gender and ethnicity for a given BMI value

[11]. Under this impression, we have assessed different indirect anthropometric variables in our study to confirm the best adiposity anthropometric marker better than or even similar to BMI.

2. Methods

2.1. Study Design

550 female participants attending graduation course at University of Delhi were enrolled under the current study. Their ages ranged between 18 to 23 years. Multi-stratified sampling technique had been used for this present cross-sectional investigation. Data was gathered after receiving an ethical clearance from the head of the institution and participants gave their informed-written consent. Anthropometric measurements were noted by trained personnel. As put forth by Weiner & Lourie [12] and Shavers [13], standard techniques were employed for this.

2.2. Anthropometric and Compositional Evaluation

All measurements were recorded barefoot with participants wearing minimal clothing, exclusive of unnecessary accessories, standing with both feet close together forming a V-shape and arms raised/hanging by sides of body with body weight being evenly distributed over both feet. Stature was determined raising and placing crossbar of anthropometer upon vertex, in mid-sagital plane, with head oriented in Frankfurt Horizontal Plane, to nearest 0.1 cm. Weight was measured to the nearest 0.1 kg using the Omron Karada Scan (Model HBF-362), that also ascertained the compositional details of body for all participants including subcutaneous fat, skeletal muscle fat and visceral fat counts, and total body fat percentage. Along with this, minimum waist and maximum hip girths were noted to the nearest 0.1 cm. For minimum waist circumference, a stretch-resistant tape was placed at the point midway of lower margin of the least palpable rib and the top of iliac crest to measure the circumference, while maximum hip circumference was recorded around the widest portion of buttocks placing the tape parallel to standing surface.

2.3. Calculation of Anthropometric Obesity Indicators

Following derived-measurements/indices were further calculated with the above mentioned measurements:

$$\text{Body mass index}\left(\text{BMI}\right) = \text{weight }\left(\text{kg}\right)/\text{height}\left(\text{m}^2\right)$$

$$\text{Waist hip ratio}\left(\text{WHR}\right) = \frac{\text{minimum waist circumference}\left(\text{cm}\right)}{\text{maximum hip circumference}\left(\text{cm}\right)}$$

$$\text{Waist height ratio}\left(\text{WHtR}\right) = \frac{\text{minimum waist circumference}\left(\text{cm}\right)}{\text{height}\left(\text{cm}\right)}$$

$$\text{Body adiposity index}\left(\text{BAI}\right) = \frac{\text{maximum hip circumference}\left(\text{cm}\right)}{\text{height}\left(\text{m}\right)^{1.5}} \text{ minus } 18$$

$$\text{A body shape index}\left(\text{ABSI}\right)=\frac{\text{minimum waist circumference}\left(\text{m}\right)}{\text{BMI}^{2/3}\times\text{height}\left(\text{m}\right)^{1/2}}$$

$$\text{Conicity index}\left(\text{CI}\right)=\frac{\text{minimum waist circumference}\left(\text{m}\right)}{0.109\times\sqrt{\dfrac{\text{weight}\left(\text{kg}\right)}{\text{height}\left(\text{m}\right)}}}$$

BMI [14], WHR [15], WHtR [16], waist circumference [17] and total body fat percentage [18] were described as per globally acceptable obesity-defining cut-offs.

2.4. Statistical Analysis

Data analysis was carried out using descriptive and inferential statistics in SPSS 20.0. Continuous variables were assayed descriptively for measure of central tendency (here, mean) and dispersion value (standard deviation). Receiver Operating Characteristic (ROC) analysis was used to calculate the area under the ROC curves so as to identify cut-off values that best balanced sensitivity and specificity for different measures with respect to increasing risk factor for advancing obesity. Association between anthropometric and body composition variables used to determine adiposity/obesity was first evaluated using Pearson correlation coefficient values. Following that, risk assessment among these variables was carried out by logistic regression.

In this work we aim to investigate: 1) the association of anthropometric adiposity/obesity markers with body composition determining adiposity/obesity variables; and 2) to evaluate the best adiposity/obesity marker among them appearing as better predictor of compositional adiposity/obesity.

3. Results

Baseline features of the studied sample, encompassing their stature, body mass, circumferences, derived indices and body composition factors are represented in **Table 1**. From **Figure 1**, it is noted 20.4% participants were underweight, 63.8% were normal weight and 15.8% participants were overweight/obese for BMI. **Figure 2** gives distribution of participants for waist circumference, WHR and WHtR in different categories. Here, WHR is found over-estimating the count for those at risk compared to waist circumference and WHtR (44.0% vs 22.9% vs 25.8%). 77.1%, 56.0% and 74.2% participants were normal for waist circumference, WHR and WHtR.

Skeletal muscle fat is negatively associated with all anthropometric adiposity indicators, unlike other compositional indicators that are suggestive of adipose count in profusion. BMI, BAI, WHtR and waist circumference are more closely related with all body composition cum obesity markers than WHR, CI and ABSI. Also, BMI and BAI have the highest positive association with visceral fat, followed by subcutaneous and total fat count; while waist circumference and waist height ratio correlate the most with subcutaneous fat, followed by visceral fat and total fat count (**Table 2**). Except for ABSI, all associations hold high statistical significance ($p \leq 0.001$).

Table 1. Baseline characteristics of considered sample.

Variable	Mean ± SD	Minimum	Maximum
Height (cm)	157.4 ± 6.13	139.5	177.8
Weight (kg)	53.4 ± 9.49	31.7	87.9
Subcutaneous fat (%)	24.7 ± 4.80	12.3	39.8
Skeletal muscle fat (%)	26.0 ± 1.99	20.5	36.6
Total fat (%)	29.4 ± 5.09	13.5	43.0
Body mass index	21.6 ± 3.59	15.0	34.0
Visceral fat	3.2 ± 2.38	1.0	13.0
Maximum hip circumference (cm)	92.8 ± 7.64	74.0	124.0
Minimum waist circumference (cm)	73.8 ± 9.33	53.0	112.0
Waist hip ratio	0.79 ± 0.065	0.63	1.06
Waist height ratio	0.46 ± 0.058	0.33	0.69
Body adiposity index (%)	29.0 ± 4.11	19.4	42.4
Body shape index ($m^{11/6}$ $kg^{-2/3}$)	0.076 ± 0.0056	0.05901	0.09447
Conicity index	1.16 ± 0.093	0.92	1.80

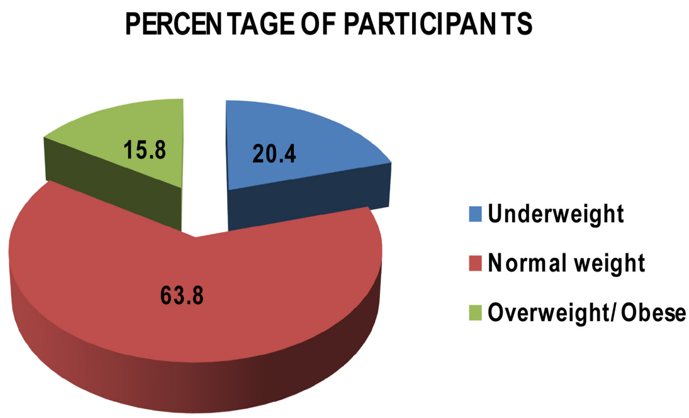

Figure 1. Distribution of participants in different categories for body mass index.

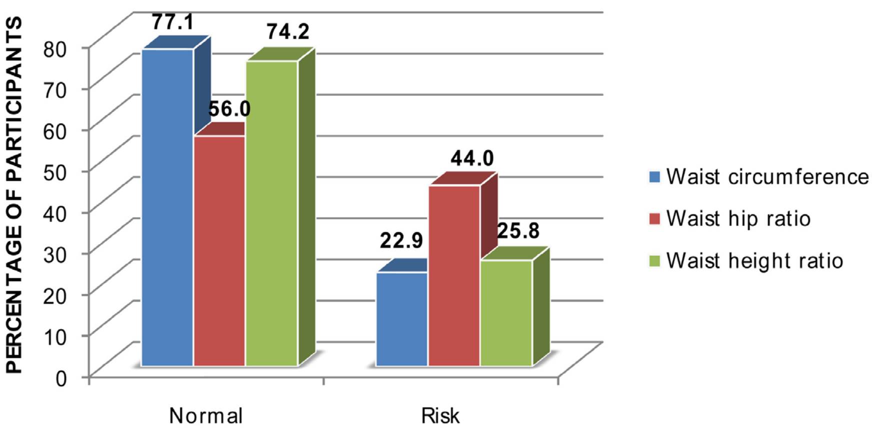

Figure 2. Distribution of participants in different categories for waist circumference, waist hip ratio, weight height ratio.

Table 2. Pearson correlation coefficient between anthropometric and compositional adiposity indicators.

Adiposity indicator	Subcutaneous fat	Skeletal muscle fat	Visceral fat	Total fat
Body mass index	0.930***	−0.706***	0.957***	0.756***
Minimum waist circumference	0.770***	−0.567***	0.747***	0.676***
Waist hip ratio	0.393***	−0.351***	0.356***	0.385***
Waist height ratio	0.812***	−0.683***	0.795***	0.723***
Body adiposity index	0.813***	−0.724***	0.816***	0.700***
Body shape index	−0.023	−0.019	−0.082	0.074
Conicity index	0.284***	−0.193***	0.248***	0.338***

***$p \leq 0.001$.

The ROC curve (**Figure 3** and **Figure 4**) shows that the areas under the curve (AUC) of subcutaneous fat, visceral fat, body shape index, conicity index and body adiposity index have strong prediction for adiposity/obesity. However, subcutaneous fat, visceral fat, conicity index and body adiposity index have better prediction value than body shape index. 25.05 is regarded the best cut-off point for subcutaneous fat with 85.8% sensitivity and 92.7 specificity. For visceral fat, the cut-off point taken at 2.50 has sensitivity point at 85.4% and specificity at 74.3%. With a 72.5% of sensitivity and 60.3% specificity body shape index gets its optimal cut-off value at 0.0760. Conicity index marks the criterion value at 1.18 (sensitivity = 83.1% and specificity = 76.7%). Lastly, cut-off for body adiposity index worked out with 78.9% sensitivity and 78.4% specificity has been found at 29.9 (**Table 3**).

With the ROC derived cut-offs, distribution of participants into different categories has been depicted in **Figure 5** for subcutaneous fat, visceral fat, body shape index, conicity index. Among them, visceral fat seems to be over-estimating the risk condition for developing obesity-related perils and disorders while body adiposity index is under-estimating the condition (subcutaneous fat vs visceral fat vs ABSI vs CIvsBAI: 42.5% vs 52.5% vs 48.4% vs 41.1% vs 36.4%).

Of all fat indicating measures taken in consideration for the presented work, BAI provides the most overrated values of vulnerability to fall into perilous state for fat determining body composition parameters, followed by BMI; at statistically significant levels. In contrast, ABSI tends to underestimate the risk for augmenting fat content in body. Increased waistline seems to be posing risk for high subcutaneous fat only, while CI could predict the risk for increasing visceral and total fat count. WHR gives the highest OR count for subcutaneous fat and WHtR for visceral fat content (**Table 4**).

4. Discussion

Metabolic syndrome associates positively with visceral fat [17] [19] [20] [21] but it is negatively associated with muscle mass and gluteofemoral fat [22] [23].

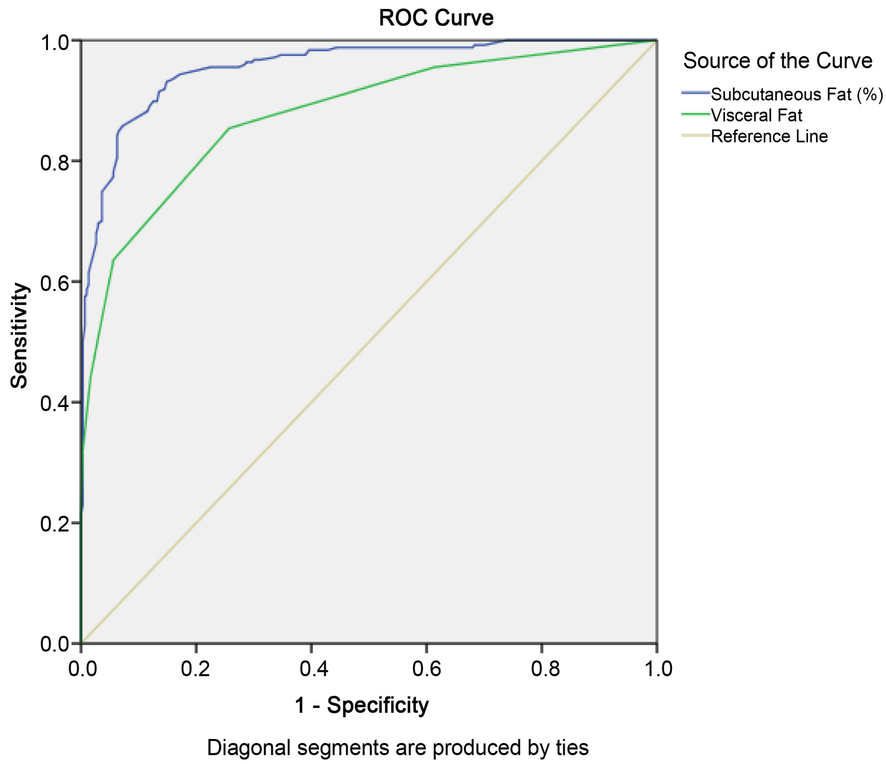

Figure 3. ROC curve for subcutaneous fat and visceral fat as predictor of adiposity.

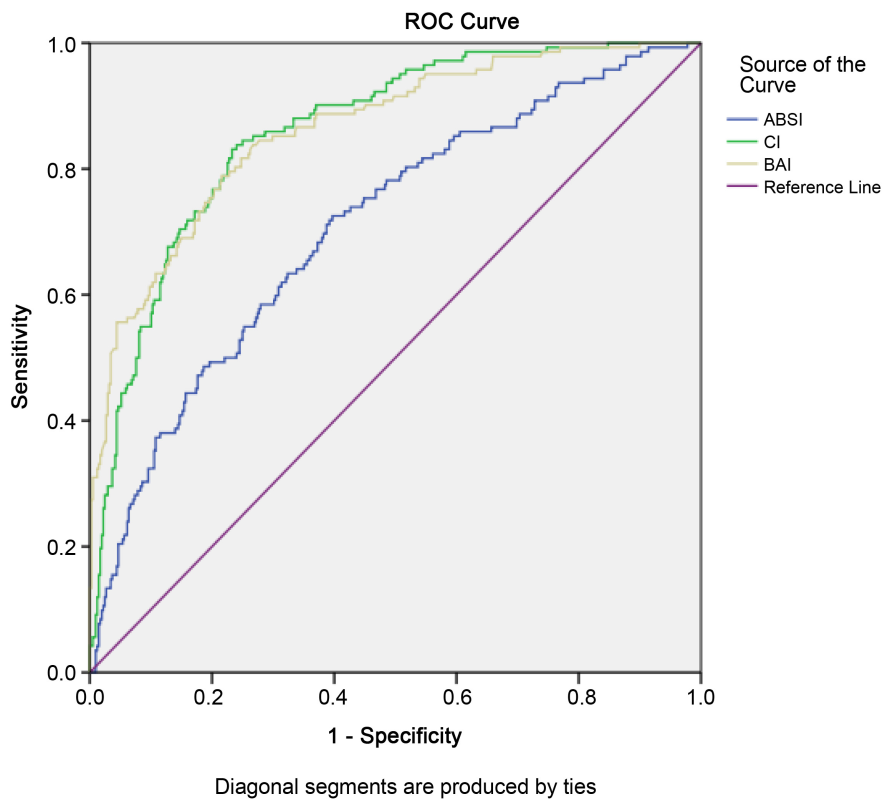

Figure 4. ROC curve for ABSI, CI and BAI as predictor of adiposity. ABSI = body shape index, CI = conicity index, BAI = body adiposity index.

Table 3. AUC, sensitivity and specificity giving the most optimal cut-off point for different parameters predicting adiposity.

Variables	AUC (95% CI)	Sensitivity	Specificity	Cut-off point
Subcutaneous fat	0.955 (0.939 - 0.971)	0.858	0.927	25.05
Visceral fat	0.877 (0.848 - 0.907)	0.854	0.743	2.50
Body shape index	0.708 (0.658 - 0.758)	0.725	0.603	0.0760
Conicity index	0.860 (0.827 - 0.894)	0.831	0.767	1.18
Body adiposity index	0.862 (0.827 - 0.898)	0.789	0.784	29.934

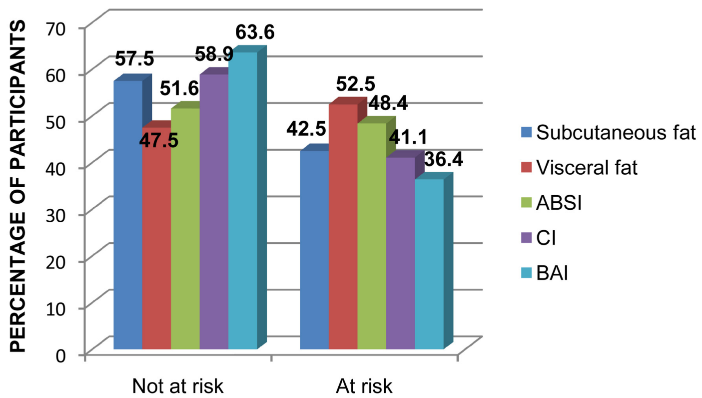

Figure 5. Distribution of participants in different categories for subcutaneous fat, visceral fat, ABSI, CI, BAI (ABSI = body shape index, CI = conicity index, BAI = body adiposity index).

Table 4. Regression analysis for predicting increase in body composition fat count.

Variables	SFC	VFC OR (95% CI)	TFC
BMI	7.4* (1.59, 34.36)	8.3* (1.04, 66.62)	15.1** (3.29, 69.33)
WC	1.4 (0.53, 3.75)	1.0 (0.33, 3.07)	0.9 (0.35, 2.28)
WHR	2.1* (1.02, 4.56)	1.3 (0.66, 2.73)	1.8 (0.94, 3.51)
WHtR	3.4** (1.30, 9.21)	5.3** (1.71, 16.4)	2.9* (1.18, 7.59)
BAI	18.2*** (11.66, 28.45)	26.8*** (15.33, 46.96)	10.5*** (6.97, 15.95)
ABSI	0.4* (0.17, 0.99)	0.3* (0.16, 0.83)	0.7 (0.35, 1.57)
CI	1.0 (0.40, 2.69)	1.7 (0.72, 4.26)	1.4 (0.65, 3.29)

*p < 0.05, **p < 0.01, ***p < 0.001 (SFC = subcutaneous fat count, VFC = visceral fat count, TFC = total fat count).

Likewise, metabolic complications of obesity are more closely related to visceral adiposity than overall adiposity, while BMI does not consider body fat distribution at all [24]. It is for this reason that other measures of adiposity considering body fat distribution such as waist circumference, waist-hip ratio and waist-height ratio were developed and studied extensively [8]. Central adiposity measures are good indicators of visceral adiposity [8]—waist circumference, waist-hip ratio, waist-height ratio, conicity index, body adiposity index, body shape index; to name a few central adiposity indicators.

Amongst these measures, waist circumference is regarded the best representing excellent correlation with abdominal adiposity; and resultantly with cardiovascular diseases and diabetes [24] [25] [26]. However, it is not able to account for differences in height, therefore, potentially over-and under-evaluating risk for tall and short individuals, respectively [27]. This has been confirmed by our study, where we traced an exceptionally well association of the measure with different body composition fat predictors however, its overall role in risk prediction could not be documented satisfactorily. Many researchers have consequently, proposed the ratio of waist to height as an alternative to waist circumference that has also proven to be a good indicator of abdominal adiposity, like waist girth [28]. Multiple systematic reviews and meta-analyses have encouraged the use of WHtR as a better predictor of CVD risk factors [27] [29] [30] [31].

There are many systematic reviews and meta-analysis studies that have reported association of cases much strongly with WHtR [29] [31]. However, these studies had more Asians than Caucasians as sample, so the sub-group assessment showed more positive results for WHtR in the Asian group than the Caucasian group with cases [29] [31]. Similar to these findings, individual studies carried out among Western populations presented waist circumference to be a reliable adiposity measure that could further predict CVD-related risk factors, better [32] [33] [34]. On the other hand, other researchers have continued to stress upon the importance of BMI for being the consistent adiposity indicator [35] [36]. Moreover, studies conducted exclusively upon the Caucasian population, which used WHtR as another comparator, concluded waist circumference to be more efficient measure of adiposity and other related risk for CVD conditions than waist-height ratio, further recommending use of waist circumference in clinical and other research studies [37]. Our study presented a very strong relationship of all compositional fat markers with BMI, WHR and WHtR; and also displayed substantial count of odd's ratio for the same.

Another obesity indicator is conicity index works on the presumption that when morphological profile of a human body represents higher fat concentration in the central region, then it displays the shape of double cone with a common base while lower fat quantities over the same site of body lead to a cylinder-like appearance [38]. With this, CI has been proposed to be revealing three different body types as-biconcave, cylindrical and biconic, depicted as in **Figure 6**.

Currently, CI is being recognized as a good indicator of central obesity [1]. Conicity index could compare body fat distribution patterns among individuals presenting differences in weight and height [40]. However, the greatest limitation associated with its use is the inexistence of cutoffs to discriminate those at higher risk for metabolic disorders than rest [1]. This drove us to determine the best cutoffs for it identified at optimum sensitivity and specificity.

Based on its high correlation with abdominal adiposity, Valdez [41] proposed the conicity index (CI). Many studies have demonstrated the high potential of CI for being employed as a righteous visceral fat marker of central obesity, thus

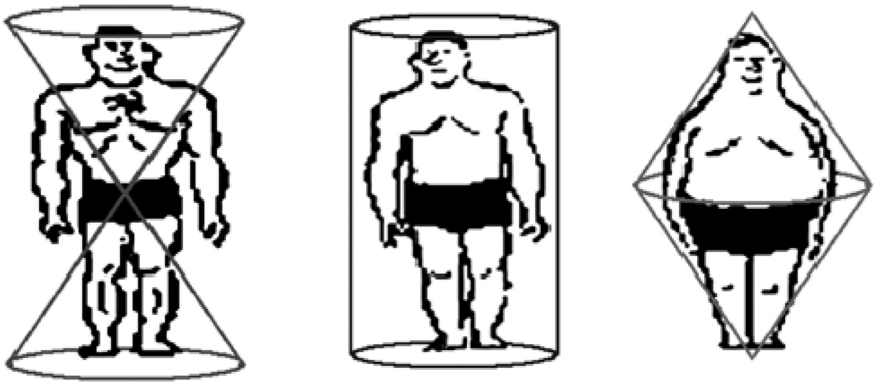

Figure 6. Different body types as per conicity index (source: Mueller *et al.* 1996 [39], Rossi and Freiberg, 2012 [1]).

making it an acceptable predictor for cardiovascular risks, even better than the indicators of generalized obesity such as BMI [1] [42] [43] [44]. CI values are strongly associated with risk factors predisposing to metabolic and cardiovascular diseases than other anthropometric indicators of abdominal obesity [40]. Using CI for body composition analysis is based on its supreme correlation with most diseases and disorders associated with obesity [1]. Our study reconfirmed this fact, whereby promising association of CI became evident with body composition obesity markers, with a confidence score of 99.9% level.

A new composite index was proposed in 2011 known as the body adiposity index (BAI) [45] based on hip circumference and height with the intention to provide a direct estimate of percent body adiposity. According to some researchers, BAI is unlikely to be better than BMI though it is an acceptable measure of overall adiposity [8]. Different studies done to validate BAI among different populations from various ethnic identities have consistently demonstrated that BAI tends to overestimate or underestimate adiposity at extreme ends of percent body fat [46]. In agreement with these results, our study recorded similar trends where BAI has put forth as much as 18, 26 and 10 times the chances for leading to a dangerously elevated levels of subcutaneous, visceral and total fat, respectively.

Notion behind developing ABSI was to get hold of a measure that is minimally associated with weight, height and body mass index so that it can be used to disentangle the independent contribution of waist circumference and BMI towards gauging cardio-metabolic outcomes arising out of increased obesity [47] [48] [49]. Findings from our work are suggestive of ABSI, compared to other anthropometric variables and indices used to assess obesity risk, being least satisfactory to be employed for this purpose, to recommend its application above any other measure. However, on divergent lines, some studies have proposed ABSI to predict CVD and mortality risks and thence holding potential for getting employed into clinical realm along with or in place of waist circumference and BMI [50] [51].

Study undertaken by Bertoli *et al.* [52] confirms ABSI to be directly associated with visceral adiposity, thus formulating it to be another surrogate measure of abdominal adiposity, other than waist circumference. Body compositional studies have deduced ABSI to be positively associated with fat mass and negatively associated with fat-free mass [53]. Also, in patients with type 2 diabetes mellitus, ABSI is positively associated with visceral fat [54]. It is suggested, contrary to waist circumference ABSI is a much useful index to evaluate the relative contribution of central obesity to clinical outcomes [52]. This was not consistent with our results where ABSI correlated negatively with subcutaneous and visceral fat matter. Based on all such outcomes, we doubt its role in prognosis of adiposity and related-risk assessment. There are other studies which focus on using ABSI so as to complement BMI and not as an alternative to it as they deduced ABSI is less strongly associated with BMI and waist-height ratio in predicting CVD risk factors-ensued from escalating fat content and body masses [55] [56] [57].

5. Conclusion

Assessing fat and its distribution in various regions of body hold great significance in prediction of several health-risk factors. Here, the current work ensures that non-invasive techniques comprising of bunch of anthropometric measurements and indices play crucial role in detecting, evaluating and determining body adiposity, body fatness and its distribution; thus confirming the manifestation of obesity. Different adiposity indices and anthropometric measures hold varying degrees of association with body fat proportions and related aspects. However, in order to reach a consensus as to which of the measure is a better predictor of obesity jeopardy and affecting longevity requires an outsized study sample, aspect that is still under consideration of our core study which is yet to be presented. It is, thus, concluded that apart from the conventional adiposity indices-such as body mass index, waist circumference and waist-to-hip ratio other much recently developed anthropometric adiposity indicators: waist-to-height ratio, body adiposity index and conicity index could be used as additional markers for screening populations in compliance to their health evaluations. Validation of the risk condition as demonstrated by one of the adiposity deciding markers must/could however be further confirmed by other sets of measures/indices in order to accept one of the mat predicting health risks accurately. In this direction, we suggest and expect further research to be undertaken with a substantial sample size confirming with findings about the best predictor that could detect and ascertain the incidence of obesity among different populations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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