Original Article

Correlation between the percentage of body fat and surrogate indices of obesity among adult population in rural block of Haryana

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Abstract

Introduction: The increasing prevalence of overweight and obesity has raised concerns regarding the importance of different techniques, which are used to assess body growth composition that can be used at the level of primary health care settings with minimal knowledge. The purpose of this study was to evaluate the relationship between different surrogate indices of fatness (body mass index [BMI], waist circumference [WC], waist-to-hip ratio [WHR], waist-to-height ratio [WHtR], and body fat percentage [BF%]) with the percentage of body fat and their usefulness as a predictor of obesity among adult population. **Materials and Methods:** The community-based cross-sectional study done over a period of 1-year involved 1080 adult participants from a rural area in Haryana. Anthropometry, along with BF% (using hand held analyzer) were recorded using standard procedures. **Results:** The prevalence of overweight and obesity as per the modified criteria of BMI for the Asian Indians was found to be 15.0% and 34.6%, respectively. Positive correlation was seen among all the indices except between the WHR and body adiposity index (BAI) using Pearson's correlation analysis. Maximum correlation was seen between WHtR and WC ($r = 0.923$), whereas WHtR depicted maximum correlation ($r = 0.810$) with BF%. Receiver operating characteristic curve analysis revealed that the WHtR was the most sensitive and specific indicator for the study population to predict overweight and obesity comparable to that calculated by body fat analyser followed by BAI, BMI, and WHR. **Conclusion:** A single value of WHtR irrespective of gender and the area of residence can be used as a universal screening tool for the identification of individuals at high risk of development of metabolic complications.

Keywords: Body adiposity index, body fat percentage, obesity, receiver operating characteristic curve, rural, surrogate indices of fatness

Introduction

The World Health Organization (WHO) describes overweight and obesity as today's most important public health problem, which is escalating as a global pandemic. Worldwide, the proportion of adults with a body mass index (BMI) of 25 kg/m^2 or greater increased between 1980 and 2013 from 28.8% (95% confidence interval 28.4–29.3) to 36.9% (36.3–37.4) in men, and from 29.8% (29.3–30.2) to 38.0% (37.5–38.5) in women. In absolute terms, in 2014, more than 1.9 billion adults, 18 years and older, were overweight. Of these, over 600 million were obese. Thirty-nine percent of adults aged 18 years and above were overweight in 2014, and 13% were obese.[1] Obesity being long considered as a problem of developed countries, now it is increasingly recognized as a significant problem in developing

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Access this article online

Quick Response Code:

Website: www.jfmpc.com

DOI: 10.4103/2249-4863.184642

How to cite this article: Verma M, Rajput M, Sahoo SS, Kaur N, Rohilla R. Correlation between the percentage of body fat and surrogate indices of obesity among adult population in rural block of Haryana. J Family Med Prim Care 2016;5:154-9.

countries and countries undergoing economic transition and is no more considered as a future tense for them.[2]

It is important to have valid and reliable tools to assess the body growth and composition. Techniques that accurately depict body fat percentage (BF%) can be used as a tool to evaluate an individual's weight loss or gain over a period of time. While direct assessment of fat mass may be a better index of obesity, routine evaluation of regional fat distribution on a wide scale requires methods that are simpler than dual energy X-ray absorptiometry, computed tomography, or magnetic resonance imaging due to their various limitations. Body impedance analysis is a relatively simple but reliable, quick, and noninvasive method, and it is widely used to evaluate body composition.[3] However, anthropometry still remains the most widely used method for clinical and epidemiological purposes,[4] out of which BMI is the parameter most frequently used for the screening of overweight and obesity because it is easy to determine and it tends to correlate well with body fat. On the other hand, there are also data indicating that BMI provides misleading results concerning body fat content in different ethnic groups.[5,6] Since BMI depends on both weight and height, it is expected to depend on both genetic and environmental factors.

BMI classification has been debated in the Asian population. Short stature, stunting of growth, and malnutrition may alter the appropriateness of assessing the relationship between height, weight, and body composition, facts of critical importance for the Asian populations. A WHO study supplemented by many other similar studies done over a period of time have indicated that abdominal adiposity and cardiovascular risk are higher in South-Asians compared to Caucasians at similar BMI and lower average waist circumference (WC) levels that has attributed to the so-called "Asian Indian Phenotype" characterized by less of generalized obesity as measured by BMI, but greater central body obesity as shown by greater WC and waist-to-hip ratio (WHR).[7-10] In a WHO consultation on obesity in Asia Pacific regions in 2000, International Association for the Study of Obesity and the International Obesity Task Force have suggested lower BMI cut-off values for the definitions of overweight and obesity in Asian populations.[11]

There is a paucity of literature concerning the relationship between the measured body fatness using traditional and recently introduced indices of adiposity in adults of South-East Asians. The purpose of this study was to evaluate the relationship between different surrogate indices of fatness (BMI, WC, WHR, waist-to-height ratio [WHtR], and BF%) with the percentage of body fat and their usefulness as a predictor of obesity among adult population in rural area of Haryana.

Materials and Methods

Study area

This study was conducted in block Beri, district Jhajjar, Haryana, a rural field practice area attached to the Department of Community Medicine of a tertiary care teaching hospital.

Study period

This was conducted between September 2013 and August 2014.

Study design

It was a cross-sectional community-based study.

Sample size calculation

The sample size was calculated to be 970, considering the prevalence of overweight 9%[12] with confidence level of 95% and 20% allowable error, but a sample of 1080 study participants were included for the study.

Study participants

Adults >20 years of age.

Inclusion and exclusion criteria

Study subjects who were residing in the study area since 6 months, registered at the subcentre and had given informed written consent were included in the study, whereas migrants, bed ridden patients were excluded from the study. In case, the desired numbers of study subjects were not available in any anganwadi area, subsequent AWC was included in the study.

Ethical consideration

The permission and ethical clearance for the study were obtained from the Institutional Review Board.

Study protocol

The block is served by three primary health centres (PHC), out of which two subcenters were randomly selected from each PHC and from each subcentre area, two anganwadis were also selected by simple random sampling technique that gave us a total of 6 sub-health centers and 12 anganwadis that were included in the study. A sub-health center is the most peripheral health outpost covering a population of 5000 and an anganwadi is a center for comprehensive development of mother and children providing supplementary nutrition and covering a population of 1000. Sex wise enumeration of the study population according to the age groups was done from the anganwadi registers. Nine males and 9 females were selected from each of the five age subgroups (20–29, 30–39, 40–49, 50–59 years, and 60 years and above) by systematic random sampling.

Methodolody

Data were collected on a predesigned, pretested, and semi-structured schedule that included the characteristics of respondents such as caste, education, occupation, socioeconomic status, marital status, and family type by interview technique by the investigator himself after ensuring the confidentiality of the information. After filling the questionnaire, the respondents were called to a separate room for anthropometric measurements and variables such as weight (kg), height (cm), WC (cm), hip circumference (HC in cm), BF%, BMI (kg/m^2), WHR, WHtR, and body adiposity index (BAI) were recorded and calculated using standard procedures.[13] In case of female study subjects, privacy was maintained and a female para-medical health worker was present while taking measurements.

The modified classification of BMI for Asian populations was used in this study to define overweight (23–24.99 kg/m^2) and obesity (>25 kg/m^2).[14,15] Cut-off points used to define central obesity were WC ≥ 90 cm for men and ≥80 cm for women. WHR > 0.90 in men and >0.80 in women was taken as high.[16] Similarly, for WHtR, the value 0.5 was chosen as one boundary value.[17] BAI was calculated using a suitable formula (BAI = [HC (cm)/height (m)$^{1.5}$] −18).[18]

BF% was measured using a commercially available bioelectric impedance analyzer (HBF-306, Omron Health Care Co., Kyoto, Japan). Prior information about the protocol for the BF% measurement such as refraining from food and drink for at least 6 h and voiding urine before measurement was given to subjects a day before the scheduled program by our health workers/anganwadi workers. Subjects were requested to moisten the palms with a wet towel before taking the measurement. The study subjects were asked to stand on the flat surface and gently grasp the two handgrips with arms held straight forward. BF% >25% in males and >30% in females was taken as high.[19]

The subjects who were found to have the disease any underlying co-morbidities were referred to PGIMS, Rohtak, after counseling for further intervention.

Statistical analysis

Analysis of the data was carried out using Statistical package for social sciences (SPSS) for Windows version 17.0, Released 2008 (SPSS Inc., Chicago, IL).

Results

Body mass index and the percentage of body fat

Mean age of the study participants was 44.55 ± 15.65 years, being more in the males (45.06 ± 16.17 years) as compared to females (44.04 ± 15.13). The mean height and BMI of males were more than the females, whereas the mean weight, BF%, WC, HC, WHR, WHtR, and BAI were more in the females [Table 1].

As per the Quetelet's index, the prevalence of overweight as per the modified criteria for the Asian Indians was found to be 15.0%, and it was higher among males (15.4%) as compared to females (14.6%). Overweight men were maximum in >60 years of age group (24.1%) and minimum in 30–39 years age group (14.5%), whereas among females, it was maximum in 40–49 years age group (22.8%) and minimum in 50–59 years age group (16.5%).

The prevalence of obesity was 34.6%, and it was higher among females (36.9%) as compared to males (32.4%). Among males, proportion increased from 14.9% in 20–29 years age group to 28.60% in >60 years age group. Among females, it was maximum in 30–39 years age group (23.1%) and minimum in 20–29 years age group (14.6%). The overall prevalence of overweight and obesity was found to be 49.62% (females - 51.48%; males - 47.77%).

Table 1: Anthropometric characteristics of the study participants (n=1080)

Quantitative parameters	Mean±SD			t	P
	Male (n=540)	Female (n=540)	Total (n=1080)		
Age (years)	45.06±16.17	44.04±15.13	44.55±15.65	1.099	0.283
Weight (kg)	60.70±12.91	60.98±13.79	60.84±13.35	0.059	0.000
Height (cm)	161.76±9.72	160.24±9.58	161.00±9.67	3.282	0.000
BMI (kg/m^2)	23.71±4.82	23.19±4.53	23.45±4.68	28.524	0.000
BF%	26.02±8.51	28.69±8.25	27.36±8.48	1078	0.000
WC (cm)	84.97±12.31	87.40±13.53	86.19±12.99	24.454	0.628
HC (cm)	92.73±9.21	93.65±10.54	93.18±9.91	14.797	0.003
WHR	0.91±0.08	0.95±0.46	0.93±0.33	2.127	0.840
WHtR	0.52±0.08	0.54±0.08	0.53±0.08	3.866	0.000
BAI	27.34±5.9	28.41±6.33	27.88±6.16	2.87	0.004

SD: Standard deviation; WC: Waist circumference; BMI: Body mass index; BAI: Body adiposity index; BF%: Body fat percentage; HC: Hip circumference; WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio

Surrogate indices of adiposity

High WHR was observed in 76.57% (827/1080) study participants affecting 62.22% males and 90.92% females, whereas 47.50% participants (513/1080) had high BF%, 49.72% (537/1080) participants had central obesity (32.59% males and 66.85% females), and 38.24% (413/1080) participants had an increased WHtR with 34.81% (188/540) males and 20.83% (225/540) females [Table 2]. Positive correlation was seen among all the indices except between the WHR and BAI using Pearson's correlation analysis. Maximum correlation was seen between WHtR and WC (r = 0.923), whereas WHtR also depicted maximum correlation (r = 0.810) with BF% [Table 3].

Receiver operating characteristic (ROC) curve analysis revealed that the WHtR was the most sensitive and specific indicator for the study population [Figure 1] to predict overweight and obesity comparable to that calculated by body fat analyser working on the principle of bio impedance analysis followed by BAI, BMI, BMI, and WHR. However, a difference was observed when male and females were considered separately [Figures 2 and 3], where WHtR was noticed as the most sensitive and specific indicator followed by WC, BMI, BAI, and WHR in males, whereas in females, it was the BAI that was observed to be most sensitive and specific followed by WHtR, BMI, WC, and WHR [Table 4].

Discussion

Despite the use of modified criteria for defining overweight and obesity in the Indian population, its use does not always indicate the degree of obesity. According to this criteria, nearly half of the study participants were either overweight or obese,

Table 2: Prevalence of participants having excessive body fat percentage central obesity and increased waist-to-hip ratio (*n*=1080)

	Increased BF%	Central obesity	Increased WHR	Increased WHtR
Males	280/540 (51.85)	176/540 (32.59)	336/540 (62.22)	188/540 (34.81)
Females	233/540 (43.14)	361/540 (66.85)	491/540 (90.92)	225/540 (41.66)
Total	513/1080 (47.5)	537/1080 (49.72)	827/1080 (76.57)	413/1080 (38.24)

Figures in parentheses indicate percentages. WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio; BF%: Body fat percentage

Table 3: Correlation between different indices of adiposity

	BAI	WC (cm)	BMI	WHR	WHtR	BF%
BAI	1					
WC (cm)	0.561** (0.000)	1				
BMI	0.722** (0.000)	0.813** (0.000)	1			
WHR	−0.175** (0.000)	0.172** (0.000)	0.066* (0.030)	1		
WHtR	0.773** (0.000)	0.923** (0.000)	0.832** (0.000)	0.161** (0.000)	1	
BF%	0.752** (0.000)	0.703** (0.000)	0.747** (0.000)	0.075* (0.014)	0.810** (0.000)	1

Figures in parentheses indicate percentages. **Correlation is significant at the 0.01 level (two-tailed); *Correlation is significant at the 0.05 level (two-tailed). BAI: Body adiposity index; BMI: Body mass index; WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio; WC: Waist circumference; BF%: Body fat percentage

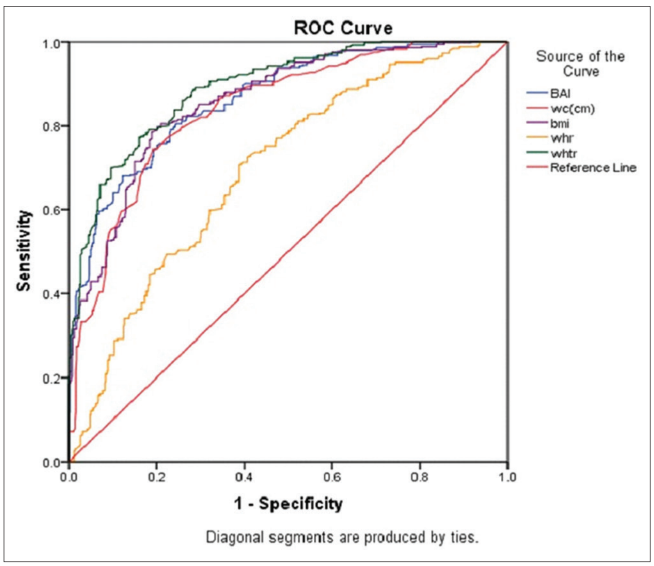

Figure 1: Receiver operating characteristic curve of the study population

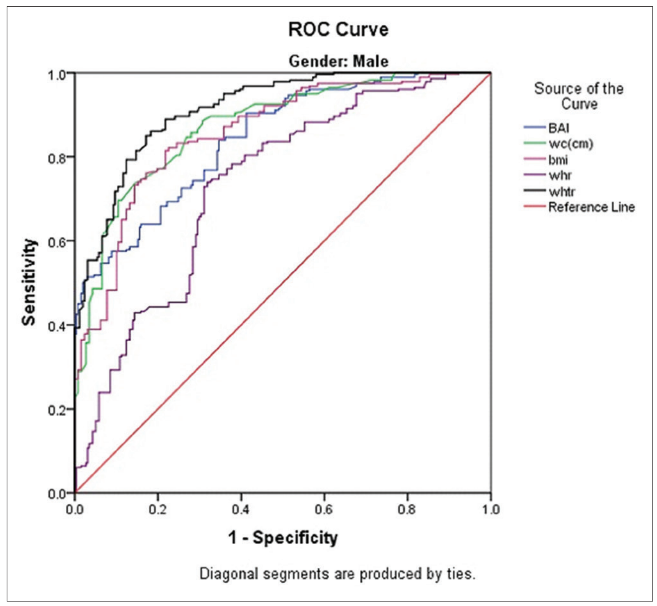

Figure 2: Receiver operating characteristic curve of the male study population

with males having a higher BMI (23.71 ± 4.82 kg/m^2) than the females (23.19 ± 4.53 kg/m^2). Sangeeta *et al.* also observed a higher BMI in the males as compared to the females of Haryana.[20]

On the other hand, mean BF% was higher in female participants (28.69 ± 8.25%) as compared to males (26.02 ± 8.51%) that is in accordance with gender selective morphological differences in the body composition.[21] It has also been suggested that the BMI overestimates body fat in males mostly due to their higher muscles and bone mass.[22,23]

WC and WHR have been used as measures of central adiposity and evidences suggest a greater association of these anthropometric variables with the future metabolic syndrome (MetS) in comparing BMI. Between WC and WHR, several studies have shown that that WC is a better predictor of MetS because of variations in the level of hip measurements, differences in cut-off values between men and women and among different ethnic groups, and the possibility of embarrassment to both examiner and examinee when measuring HC.[24,25] Wang *et al.*, in their study of Chinese population, found that BMI and WC are more useful than WHR for predicting complications arising as a result of overweight and obesity.[25] However, the ability of WC to be used as a universal predictor of central adiposity is limited by the use of different methods for the measurement of WC and different cut-offs used for men and women in different ethnic groups.

Recently, in various studies, WHtR has been found to be a better predictor of metabolic complications.[17] This is because the height of an individual influences the distribution of body fat, and this

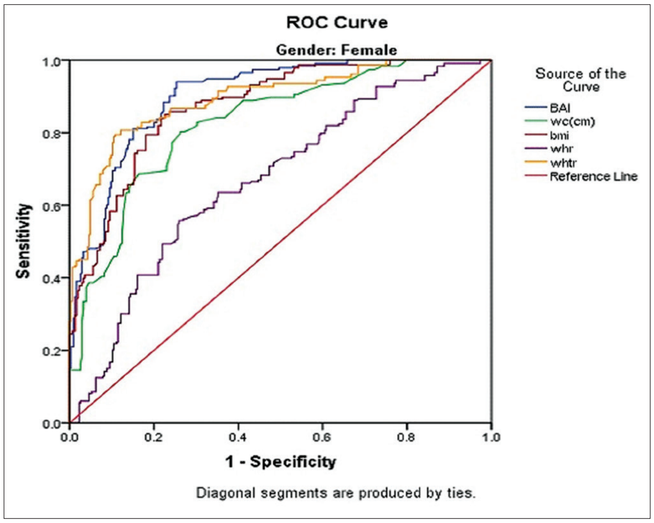

Figure 3: Receiver operating characteristic curve of the female study population

Table 4: Gender wise area under the curve of different indices of adiposity using receiver operating characteristic analysis

Indices of fatness	Males (540)		Females (540)		Total (1080)	
	AUC	95% CI	AUC	95% CI	AUC	95% CI
BAI	0.843	0.812-0.875	0.902	0.877-0.927	0.864	0.843-0.885
WC (cm)	0.873	0.844-0.902	0.826	0.792-0.861	0.840	0.817-0.864
BMI	0.858	0.827-0.889	0.874	0.845-0.902	0.859	0.837-0.880
WHR	0.732	0.690-0.775	0.669	0.624-0.715	0.695	0.664-0.726
WHtR	0.914	0.891-0.936	0.894	0.867-0.921	0.891	0.872-0.909

CI: Confidence interval; AUC: Area under the curve; BAI: Body adiposity index; BMI: Body mass index; WHR: Waist-to-hip ratio; WHtR: Waist-to-height ratio; WC: Waist circumference

factor should be taken into consideration before adopting any anthropometric variable as a measure of adiposity. As explained by Ashwell, men on average are taller than women and have larger WCs. This means that average WHtR values are closer for men and women than average WC values because of adjustments for height, and the same value can be used for both genders to indicate increased risk.[26] Parikh *et al.* earlier reported that WHtR is a better parameter of central obesity and deflects the need for numerous WC cut-offs; it may be useful in children where existing parameters are not useful.[27] BAI is a relatively new anthropometric variable, which is used to calculate BF% through complex calculations.

In our study analysis, WHtR was the most sensitive parameter in males that portrays high body fat in concordance with BF% followed by WC (cm) and BAI as depicted by the high values of area under the curve seen in the ROC analysis. BMI and WHR were least sensitive in showing adiposity in males. In females, the most sensitive indicator was found to be BAI followed by WHtR, BMI, WC, and WHR provide evidence that they are not reliable indices for the assessment of body fat among female participants in our study area. WHtR was observed to be most sensitive for all the study participants when taken together followed by BAI, BMI, WC, and WHR.

Data related to surrogate indices of fatness provide evidence that they were all positively correlated to each other in a statistically significant manner except the negative correlation seen between BAI and WHtR as seen with Pearson's correlation matrix. BF% was more strongly correlated with the WHtR as compared to the BAI. Gupta *et al.* also reported a stronger correlation of BF% with BMI (men: $r = 0.83$; women: $r = 0.71$) than those with BAI (men: $r = 0.66$; women: $r = 0.58$) among the urban population of New Delhi. They also reported that in women, the sensitivity of BAI was higher than BMI and WC.[28] Heish *et al.* observed that in Japanese men and women, WHtR was found to be a better predictor of metabolic risk compared to other anthropometric indices.[29]

Bennasar-Veny *et al.* also indicated that BAI was less correlated with cardiovascular risk factors and metabolic risk factors than other adiposity indexes (BMI, WC, and WHtR). The best correlations were found for WHtR. In addition, the BAI presented lower discriminatory capacity than BMI for diagnosing obesity and MetS associated with it using both International Diabetes Federation and Adult Treatment Panel III criteria. A different behavior of the BAI in men and women when considering the ability to discriminate overweight or obese individuals was also observed.[30]

As suggested by Rajput *et al.* in their rural–urban study, despite the fact that the predictive value of different gender-specific WC values is clearly being superior to other anthropometric measures for predicting two or more nonadipose components of MetS, a single value of WHtR irrespective of gender and the area of residence can be used as a universal screening tool for the identification of individuals at high risk of development of metabolic complications.[31]

Conclusion

Our study gives an insight that WHtR is a reliable and sensitive surrogate index of obesity.

Data pertaining to our study is also having importance since easily measured surrogate indices may contribute to distorted body image and inappropriate dietary habits observed in many young adults who are newly exposed to lifestyle changes such as those living in rural area.

In addition, the calculation of BAI is complex for health workers, so as to use it as a reliable screening tool if we are looking for a better alternative than BMI as a predictor of coronary artery disease. This is also supported by the fact that the reliability of BAI is still to be assessed in different ethnic groups and compared to more accurate means of BF% measurement before it can be used a means of screening the population in resource scarce countries.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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