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Comparison between Anthropometry, Ultrasonography and Under Water Weighing for Prediction of Body Fat and Metabolic Syndrome in Adult Indians

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Abstract

Introduction: Obesity is a major public health problem. We evaluated the accuracy of various anthropometric variables among waist circumference (WC), waist: hip ratio (W:H), waist: height ratio (W:Ht), skin fold thickness (STs) that are used to predict body fat in obese middle age Indians.

Methodology: A cross sectional study was undertaken on 51 individuals aged (30-55 years), with body mass index (BMI) of 23 or above (22 males and 29 females). Waist, hip circumference were measured by tape at specific levels. Biceps, triceps, subscapular, suprailiac and abdominal STs were measured by Harpenden calipers. Total body fat (TBF) was calculated using underwater weighing machine and intraabdominal fat (IAF) and subcutaneous body fat (SC) were estimated using ultrasonography. The status of metabolic syndrome was also determined in each subject.

Result: WC showed significant association ($p < 0.01$) with SC in both males and females. W:H ratio showed significant correlation with ultrasound measures of IAF

and metabolic syndrome ($p < 0.01$) in men. W: Ht ratio also showed significant correlation ($p < 0.01$) with SC in both males and females and TBF in females. **Conclusions:** The ultrasonography measurements of IAF estimate visceral obesity and metabolic syndrome better than other anthropometric measurements and the effectiveness of other anthropometry indices requires reference to gender, TBF, IAF and SC.

Keywords: Anthropometric measurements, intra-abdominal fat, metabolic syndrome, Obesity, Ultrasonography, Hydrostatic under water weighing.

Introduction

Obesity in India is increasing at a steady rate. About 5% of the total population is affected with morbid obesity (1). Obesity is an important risk factor for diabetes mellitus, hypertension, hyperlipidemia, development and progression of coronary heart disease, and various other cardiovascular

diseases (2). Indians are genetically more susceptible to weight accumulation especially around their waist area (1). Intra-abdominal fat probably is more important than overall body weight as a risk factor for developing cardiovascular diseases (CVD) (3,4). Intra-abdominal fat increases insulin resistance, glucose intolerance, and diabetes mellitus. It also causes low HDL-cholesterol concentrations, elevated triacylglycerides, hypertension and obesity (5-7). The cluster of these metabolic risk factors was first described as “syndrome X” (5) and is also referred to as the “insulin resistance syndrome” or “metabolic syndrome” (5-7). American College of Sports Medicine described obesity as an excessive amount of adipose tissue in body, which is >25% in adult males and >32% in adult females (8). Much of the available statistical data for estimation of body fat and body composition is based on body mass index (BMI). WHO recently set the cut off BMI value of 23 kg/m² and 25 kg/m² for overweight and obese respectively for Asian Indians (9) As BMI does not differentiate between total body fat mass and lean mass tissues (10) hence recognizing the relevance of body composition and anatomical distribution of fat with various cardiovascular and chronic diseases (11). Following this need many techniques have been developed to assess body composition of adipose and lean body mass as well as total body fat. The gold standard of body composition in a two compartmental model has been hydrostatic under water weighing (12). The accurate quantification of intra-abdominal fat is done by imaging technique such as magnetic resonance imaging, computed tomography (13,14). However, these techniques are relatively expensive and complex, and are impractical for routine clinical purposes as well as large scale studies. Ultrasonography has been proven to be a useful alternative to computed tomography in measuring intra-abdominal fat and predicting visceral obesity (15). Simpler clinical anthropometric measures commonly used for the same purpose are waist circumference (WC), waist hip ratio (W: H), waist height ratio (W: Ht), weight, skinfold thickness (STs) and BMI (16,17). However how well these various anthropometric measures predict total body fat as well as intra-abdominal fat remains unclear. Therefore the present study was undertaken to relate the various anthropometric measurements (weight, BMI, WC, W: H, W: Ht and STs) to total body fat and intraabdominal body fat measured by hydrostatic underwater weighing and ultrasonography respectively and to identify the best anthropometric index which can be used as a predictor of total body fat and intraabdominal body fat in obese middle age men and women in India and also to verify if these comparisons vary

between men and women.

Subjects and Methods

Subjects

The Institutional Ethics Committee of Faculty of Sports Medicine and Physiotherapy, Guru Nanak Dev University, approved the study protocol and written informed consent was obtained from all the subjects. Fifty one overweight or obese individuals aged (30-55 yrs), with BMI value of 23 or above as indicated by World Health Organization volunteered for the study. (Males N= 22; female N= 29). The age [mean± SD (range)] was 44.5±7.0 (30-55) years and 39.5±4.5 (32-47) years for men and women respectively. Subjects with history of any medical or surgical conditions, respiratory illness, pregnancy and hydrophobia were excluded.. The study was conducted in the months of August-October, 2010 with average ambient temperature of 28°C and humidity around 25%.

Anthropometric measurements

The blood pressure of each subject was measured in the supine position; the mean of 2 measurements was used as the final value. Subjects were weighed with minimal clothing, with empty bowel using a digital balance, (Soehnle, West Germany), which has a precision of 0.1 kg. The height of the subjects was recorded without footwear, using a vertically mobile scale (Holtain, Crymych UK) and expressed to nearest 0.1 cm. BMI (kg/m²) was calculated as weight (kg) divided by height² (m²). Waist circumference was measured at the umbilical level in standing and breathing normally during the examination (17), after which W: Ht ratio was calculated. Hip circumference was measured at the level of the trochanter major (18), after which W: H ratio was calculated. Biceps, triceps, Subscapular, suprailiac and abdominal skin fold thickness were measured using Harpenden Calipers (Holtain, Crymych, UK). Three readings of each skin fold thickness were taken and average was taken as the final reading. The prediction equations used to calculate percent fat skin fold (% Fat SF) was Durnin and Womersley's 4-site ST equation as follows (19):

Body density = 1.1631-0.0632(log of sum of 4 SFTs) (male)

Body density = 1.1599-0.0717(log of sum of 4 SFTs) (female)

Body density converted to % BF using Siri's equation

%BF = (495/body density)-450 (19)

Table 1. Characteristics of study subjects for anthropometry, body composition and circulating plasma lipids are presented as mean \pm standard deviation for both men (n=22) and women (n=29) separately.

Parameters	Males		Females	
	Mean \pm S.D.	Range	Mean \pm S.D.	Range
Height (m)	1.71 \pm 0.07	1.61 - 1.85	1.57 \pm 0.05	1.49-1.69
Weight (kg)	81.6 \pm 10.4	66 - 117	68.3 \pm 7.2	55-85
Body mass index (kg/m ²)	27.7 \pm 2.8	23.0 - 34.2	27.8 \pm 2.8	23.0-35.5
Bicep skinfold (mm)	8.4 \pm 3.2	5.0 - 18.1	13.8 \pm 4.8	7.0 - 22.0
Triceps skinfold (mm)	11.9 \pm 4.5	4.0 - 22.3	19.3 \pm 5.1	12 - 23.5
Subscapular skinfold mm)	16.4 \pm 5.3	9 - 30	23.3 \pm 5.5	8.9 - 35.2
Suprailiac skinfold (mm)	15.0 \pm 4.6	7.1 - 23.5	18.1 \pm 5.0	5.9 - 24.4
Skinfold-derived percentage fat	23.8 \pm 3.9	18.2 - 32.2	27.6 \pm 3.4	17.4-31.8
Abdominal skinfold (mm)	35.6 \pm 8.8	23.2 - 5.0	34.4 \pm 8.1	15.3 - 46.2
Waist (cm)	97.1 \pm 6.7	87 - 113	88.0 \pm 5.5	80 - 105
Waist: Hip ratio (W:H)	0.96 \pm 0.08	0.88 - 1.02	0.85 \pm 0.04	0.78 - 0.90
Waist: Height ratio	56.69 \pm 0.04	0.50 - 0.69	56.21 \pm 0.04	0.50 - 0.64
Fat mass (kg)	27.50 \pm 7.48	11.04 - 39.83	25.2 \pm 5.47	14.86 - 36.73
Lean mass (kg)	54.10 \pm 7.73	40.78 - 77.16	43.08 \pm 5.08	32.58 - 51.52
Percentage body fat (%)	33.46 \pm 7.25	16.7 - 42.9	37.20 \pm 5.57	24.5 - 46.0
Intra-abdominal fat (IAF) (mm)	67.9 \pm 17.1	39.3 - 97.0	60.0 \pm 14.2	43.3 - 113.0
Subcutaneous fat (SC) (mm)	19.7 \pm 4.9	12.7 - 31.3	19.0 \pm 4.3	11.7 - 31.7
IAF/SC ratio	3.6 \pm 1.1	2.1 - 7.0	3.4 \pm 0.9	1.7 - 5.1
Serum total cholesterol (mg/dl)	192.9 \pm 29.2	145 - 280	178.7 \pm 34.8	150 - 310
Serum triglycerides (mg/dl)	155.6 \pm 21.0	130 - 210	146.28 \pm 13.25	88 - 165
Serum HDL cholesterol (mg/dl)	43.5 \pm 6.9	32 - 60	49.7 \pm 5.4	41 - 60

Biochemical studies

Venous blood samples were taken in the morning after overnight fasting of all subjects. Plasma levels of total cholesterol, triglycerides, high density Lipoprotein-cholesterol (HDL-C), low density lipoprotein-cholesterol (LDL-C) and very low density lipoprotein (VLDL) were determined with RA-50, Semi-auto Chemistry Analyzer,

Thyrocare India Ltd., India. The presence of metabolic syndrome in each subject was determined by the existence of ≥ 3 of the following conditions: diabetes mellitus (glucose concentration ≥ 7 mmol/L or physician's diagnosis), hypercholesterolemia (total cholesterol concentration ≥ 6.5 mmol/L), hypertriglyceridemia (triacylglycerol concentration ≥ 2 mmol/L), hypertension (blood pressure \geq

Table 2. Partial Pearson's correlation between one and two dimension study parameters and intra-abdominal fat measurements by ultrasonography in all study subjects (males 22 and females 29).

Parameters	Intra-abdominal fat (mm)		Subcutaneous abdominal fat (mm)		Intra-abdominal/subcutaneous abdominal fat ratio	
	Male	Female	Male	Female	Male	Female
Age	0.550**	-0.055	0.360	0.328	0.091	-0.225
Height	0.198	-0.119	0.158	-0.061	0.026	-0.013
Weight	0.304	-0.150	0.393	0.134	-0.144	-0.123
Biceps	0.239	-0.189	0.253	0.100	0.054	-0.124
Triceps	0.270	-0.181	0.393	0.037	-0.069	0.041
Subscapularis	0.112	0.254	0.074	0.200	0.125	-0.068
Suprailiac	0.273	-0.124	-0.138	0.300	0.270	-0.358
Abdominal	0.045	0.315	-0.116	0.033	0.006	0.184
Waist	0.315	0.094	0.848**	0.571**	-0.350	-0.253
Body mass index	0.199	-0.076	0.372	0.185	-0.227	-0.116
Skinfold sum	0.274	-0.072	0.165	0.225	0.165	-0.176
Percent fat [4 site skinfold]	0.537**	-0.255	0.238	0.365	0.302	-0.394*
Waist : Hip Ratio	0.559**	0.009	0.427*	0.517**	0.047	-0.410*
Waist : Height Ratio	0.193	0.093	0.729**	0.499**	-0.351	-0.230

* denotes $p < 0.05$, ** denotes $p < 0.01$

135/85 mm Hg or physician's diagnosis), and obesity (BMI ≥ 25) (20).

Body composition estimations

The amount of abdominal adipose tissue was determined by the procedure given by Armellini *et al.* (21). Ultrasonography measurements were taken by a single experienced operator using real time US scanner (Sonoline 20, Siemens, Germany). The subcutaneous fat thickness (SC) was measured as the distance between the skin fat and

fat muscle interfaces and the intraabdominal fat thickness (IAF) was measured as the distance between the internal face of the rectus abdominis muscle and the rear wall of aorta (22). An ultrasound determined intraabdominal- to-subcutaneous fat ratio (IA: SC) of 2.50 was established as cut off value to define subjects with abdominal visceral obesity (23,24). Percent total body fat (TBF) was measured using the hydrostatic underwater weighing machine "Vacumed Turbofit 5.10" (www.vacumed.com). The vital

Table 3. Partial Pearson correlation between one and two dimension study parameters and total body fat measured by underwater weight^a.

Parameters	Total fat mass		Lean body mass		Percentage body fat	
	Male	Female	Male	Female	Male	Female
Age	0.035	0.189	0.399	-0.002	-0.109	0.116
Height	0.402	0.032	0.391	0.415*	0.143	-0.092
Weight	0.669**	0.661**	0.695**	0.645**	0.274	0.310
Biceps	0.259	0.276	-0.077	0.301	0.278	0.053
Triceps	0.306	0.398*	-0.108	0.144	0.312	0.307
Subscapularis	0.437*	0.197	0.193	0.101	0.458*	0.093
Suprailiac	-0.145	0.062	-0.091	-0.030	-0.127	0.039
Abdominal	0.074	0.056	0.077	-0.094	0.026	-0.070
Waist	0.556**	0.437*	0.067	0.145	0.434*	0.270
Body mass index	0.503*	0.604**	0.520*	0.390*	0.235	0.367
Skinfold Sum	0.274	0.305	-0.094	0.150	0.294	0.173
Percent body fat ^b	0.210	0.229	-0.028	0.238	0.220	0.113
Waist: Hip ratio	0.358	0.400*	0.603**	0.054	0.051	0.310
Waist: Height	0.315	-0.368*	0.149	0.410*	0.339	0.292

a. data derived from 22 males and 29 females. *b.* derived for 4 site skin folds

* indicates $p < 0.05$, ** indicates $p < 0.01$

capacity was calculated by using Rolex Spiro meter (Rolex scientific engineers Ltd, Ambala Cantt, India). The software estimated the residual lung volume using the following equations: Male residual lung volume = Vital Capacity \times 0.24 and Female residual lung volume = Vital Capacity \times 0.28 (25). The subjects were directed to slowly expel the inhaled air prior to submerging in water and continue until complete exhalation. They were instructed to move slowly into the tank to reduce the dynamic effect of possibly moving water. The total body was submerged and no part of the body was allowed to touch the bottom or the sides of the tank. The underwater weight was entered automatically in the computer when the standstill on the indicator lighted up. An average of three readings was taken as the final reading. Final percentage total body fat, total body fat (in kg) and lean body mass (in kg) was automatically calculated by the

software using Brozek's formula (26).

Statistical analysis

SPSS software (version 16.0; SPSS, Inc.) was used for statistical analysis. The characteristics of study subjects are represented as mean \pm standard deviation. Partial Pearson correlation coefficient test was used to explore relations between variables. Differences between groups were tested using T test in both male and female group separately. Significant level was set at $p < 0.05$.

Results

The mean values and standard deviation for selected attributes of the study subjects for body composition and lipid metabolism are presented in table 1 for males and females separately. Both the groups were obese in terms of

Table 4. Relation between metabolic syndrome and intra-abdominal fat and total body fat measured by various anthropometric indices

Parameters	Metabolic syndrome (present)		Metabolic syndrome (absent)	
	Males = 10	Females = 9	Males = 12	Females = 20
Age (years)	49.8 ± 5.3	39.7 ± 3.1	40.1 ± 4.5	39.4 ± 5.1
Body mass index (kg/m ²)	29.1 ± 2.8*	27.9 ± 3.8	26.6 ± 2.2*	27.7 ± 2.3
Intra-abdominal fat (mm)	76.36 ± 15.63*	74.92 ± 15.14*	60.85 ± 15.55*	54.71 ± 8.26*
Subcutaneous abdominal fat (mm)	21.95 ± 5.05	19.61 ± 2.55	17.86 ± 4.11	18.77 ± 4.90
Percent total body fat	34.03 ± 7.33	37.05 ± 6.84	32.98 ± 7.47	37.27 ± 5.10
% FAT Skinfold	25.57 ± 4.53*	27.06 ± 2.87	22.33 ± 2.51*	27.88 ± 3.58
Waist circumference (cm)	99.3 ± 7.2	89.8 ± 6.9	95.3 ± 5.9	87.2 ± 4.7
Waist: Hip ratio	0.99 ± 0.10*	0.85 ± 0.04	0.93 ± 0.03*	0.84 ± 0.04
Waist: Height ratio	0.579 ± 0.05	0.577 ± 0.05	0.556 ± 0.04	0.555 ± 0.04
* indicates $p < 0.05$, ** indicates $p < 0.01$				

Table 5. Association between intra-abdomen and metabolic syndrome (Present=1, absent=2) cross tabulation

Present		Metabolic syndrome		Total
		Absent	Present	
Intra-abdominal fat	≤ 60	2	24	26
	> 60	17	8	25
Total		19	32	51
<i>Odds ratio = 0.039 (95% CI, Odds ratio = 0.007–0.208, $p < 0.001$, Association is significant)</i>				

high body mass index percentage body fat.

The partial Pearson's correlation between one and two dimension study parameters and intra-abdominal fat measurements by ultrasonography in all study subjects (males 22 and females 29) are given table 2. In males, a significant direct correlation ($p < 0.01$) was observed between age and intraabdominal fat ($r = 0.550$). A significant positive correlation ($p < 0.01$) was also found between waist circumference and subcutaneous abdominal fat ($r = 0.848$), percentage fat skin fold and intraabdominal fat mass ($r = 0.537$), waist hip ratio and intraabdominal fat ($r = 0.537$), waist hip ratio and subcutaneous abdominal fat ($r = 0.427$), ($p < 0.05$) and waist: height ratio and subcutaneous

abdominal fat ($r = 0.729$). In females, a significant direct correlation ($p < 0.01$) was observed between waist and subcutaneous abdominal fat ($r = 0.571$), waist hip ratio and subcutaneous abdominal fat ($r = 0.517$) and waist: height ratio and subcutaneous abdominal fat mass ($r = 0.499$).

Partial Pearson correlation data between one and two dimension study parameters and total body fat measured by underwater weight are presented in Table 3. In men, a significant positive correlation ($p < 0.01$) was seen between weight and total fat mass ($r = 0.669$), weight and lean body mass ($r = 0.695$), waist and total fat mass ($r = 0.556$), BMI and total body fat ($r = 0.503$), ($p < 0.05$), BMI and lean body mass ($r = 0.520$), ($p < 0.05$) and waist hip ratio and lean body mass

($r = -0.603$). In females, a significant positive correlation ($p < 0.05$) was observed between weight and total body fat ($r = 0.661$), triceps and total body fat ($r = 0.398$), waist and total body fat ($r = 0.437$), BMI and total fat mass ($r = 0.604$), ($p < 0.01$), BMI and lean body mass ($r = 0.390$), ($p < 0.05$), waist hip ratio and total fat mass ($r = 0.400$), ($p < 0.05$), waist: height ratio and lean body mass ($r = 0.410$), ($p < 0.01$). A significant inverse correlation ($p < 0.05$) was observed between waist: height ratio and total body fat ($r = 0.368$).

Relations between metabolic syndrome and intra-abdominal fat and total body fat measured by various anthropometric indices are presented in table 4. In males a significant difference ($p < 0.05$) was observed between the mean values of intraabdominal fat in two subgroups in which metabolic syndrome was present and in those it was absent. A significant difference was also present in mean values of BMI, percentage fat skinfold and waist hip ratio in the two subgroups respectively. In females a significant difference ($p < 0.05$) was observed between mean values of intraabdominal fat in groups in which metabolic syndrome was present and in those it was not evident. However, in case of BMI, percentage fat skin fold and total body fat percentage both the subgroups had similar values of BMI, percentage fat skin fold and total body fat percentage respectively.

Discussion

The present study results of our study showed an association between intra-abdominal fat area and various conventional anthropometric measures of visceral abdominal obesity differ by gender. The well known association between intraabdominal fat and metabolic risk factors as well as metabolic syndrome was more pronounced with ultrasound measurements of intraabdominal fat than with other conventional anthropometric measurements (Waist circumference, waist hip ratio, waist: Height ratio and skin folds measurements) in both middle age obese men and women. Limitation of our study is relative small sample size and narrower age range, we have attempted overcoming this by the extensive assessment within the small population studied.

A strong age association relative to the subcutaneous fat area:intra-abdominal fat area ratio has been reported in a study on 130 subjects of mixed gender and a wide age range of 20-60 years who had been referred for diagnostic computed tomography ($r > 0.6$ for both sexes) (27). In our study, age strongly correlated with intraabdominal fat area

in males but not in females and age did not correlate with total body fat in either gender. The possible cause might be a much narrower age range (30-55 years) in our group, with a potentially narrower range of estrogen and testosterone levels which has its well known influence on body fat accumulation and distribution (28).

Waist hip ratio is the most popular index for assessing visceral abdominal obesity for clinical as well as laboratory purposes. However, variations in measurement levels, differences in cut-off values between males and females and among various ethnic groups, and the possibility of embarrassment to examiners and examinees of different genders when measuring the hip area may limit its global prevalence. Some workers found a significant correlation between waist hip ratio and IAF in both sexes (29,30). In our results (Table 2) we found that waist hip ratio was significantly correlated with intraabdominal fat measured by ultrasound measures ($r = 0.559$, $p < 0.01$) in men and not significantly correlated in women ($r = 0.009$). Waist hip ratio showed a significant difference ($p < 0.05$) between two subgroups of male group in whom the metabolic syndrome was either absent or present (Table 4). These results were similar to findings of Kamel *et al.* (31) which showed that in men, waist circumference, waist hip ratio, and dual x-ray absorptiometry (DXA) predicted IAF equally well while in women DXA was the best predictor of IAF followed by waist circumference, whereas waist hip ratio had no predictive power and Seidell *et al.*, in which waist hip ratio was highly correlated with intra-abdominal fat area ($r = 0.88$) (32).

Recently, some organizations have proposed usefulness of waist circumference to measure visceral abdominal obesity. However, measurement methods and cut-off values differ by each ethnic groups and gender (33-35). In the present study, waist circumference showed significant association with subcutaneous abdominal fat in both males ($r = 0.848$, $p < 0.01$) and females ($r = 0.571$, $p < 0.01$) but was not significantly correlated with intraabdominal fat in both genders ($r = 0.315$, 0.094 respectively) (Table 2). Waist circumference was also significantly correlated with total body fat in both male ($r = 0.556$, $p < 0.01$) and females ($r = 0.437$, $p < 0.05$) (Table 3). However, the waist circumference did not showed any significant difference ($p > 0.05$) between subjects with or without metabolic syndrome (Table 4). A potential explanation may be that waist circumference, which captures the intraabdominal region, also measures subcutaneous abdominal fat, underestimating the effect

of intra-abdominal fat on metabolic risk factors and cardiovascular outcomes (36). Other published studies support the finding of this study that waist circumference is not a useful predictor for IAF, Ross et al., 1994 found no significant correlation between waist circumference and IAF in 17 obese men (37). Though the same group had shown previously a moderate correlation ($r=0.58$) between waist circumference and IAF in men (38).

Reports from Asia indicate that waist: height ratio corresponds better to metabolic syndrome and its risk factors than BMI, waist circumference, waist hip ratio and skinfold measures (based on investigations on data gathered on over 48000 persons) (39, 40). In our study waist : Height ratio showed significant correlation ($p<0.01$) with subcutaneous abdominal fat ($r=0.729$, $r=0.499$ respectively) in both males and females (table 1) and significantly correlated ($p<0.05$) with total body fat and lean body fat in females ($r=-0.431$, $r=0.410$). However waist: height ratio had weak correlation with intra-abdominal fat mass and metabolic syndrome (Tables 3 and 4). Thus as Intra-abdominal fat is the component of android fat which has well known association with metabolic risks such as hyperinsulinemia and risk of developing cardiovascular diseases, a direct measure of visceral fat area would be expected to improve the accuracy of associations with metabolic syndrome and cardiovascular risk factors. In male subgroups divided according to the presence or absence of metabolic syndrome (Table 4) significant difference ($p<0.05$) was seen between both BMI and percentage fat skin fold. Also BMI showed significant correlation ($p<0.05$) with total body fat ($r=0.503$, 0.604) and lean body mass ($r=0.520$, 0.390) in both males and females (Table 3). Seidell *et al.* in their study also showed that BMI was significantly correlated with peripheral fat measured by computed tomography ($r=0.91$) (32).

In conclusion, we observed that as ultrasonography measurements of intraabdominal fat estimate visceral obesity as well as metabolic syndrome better than do measurements of waist circumference, waist hip ratio and waist height ratio. The results of this study suggest that it is not possible to generalize the effectiveness and use of anthropometry indices to predict IAF without reference to gender, degree of obesity, and the amount of abdominal subcutaneous fat. However, in obese men and women, waist circumference, and waist hip ratio and waist height ratio was equally useful in predicting abdominal subcutaneous fat, whereas waist hip ratio was useful in predicting IAF

and metabolic syndrome in men. We suggest caution may be required in the use of anthropometric measurements in prediction of intra-abdominal fat and metabolic risks in case of women. Additional research in much larger groups of both obese and non-obese women and men may be needed to fully assess the validity and usefulness of anthropometry in the prediction of intrabdominal fat and metabolic syndrome.

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