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Visceral Fat Cut-off Points for a Sample of Egyptian Adults

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Key words: Obesity; Visceral fat; Waist circumference; Body mass index, Ultrasound.

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Abstract

Objective: To determine appropriate visceral fat cut-off values using ultrasound (USVF); for obesity according to existing waist circumference (WC), waist/hip ratio (WHR) and BMI cut-off levels.

Methods: 998 Egyptian adults, aged 25- 55 years, were studied in a cross-sectional survey for evaluation of “Visceral and Central Obesity as an Early Estimator for Obesity Health Risk”.

Results: Using WC as standard for classification of central obesity, cut-off points of USVF were found to be 6.5 cm for men and 5 cm for women; using ROC analysis; with 76 % sensitivity, 83% specificity, 1.06 PPV/NPV, and 81% accuracy for men, and with 77 % sensitivity, 76% specificity, 0.99 PPV/NPV, and 76% accuracy for women. Same cut-off points of USVF were detected using BMI as standard; with 71 % sensitivity, 77% specificity, 1.04 PPV/NPV, and 75% accuracy for men, and 74% sensitivity, 79% specificity, 1.03 PPV/NPV, and 77% accuracy for women. Even by using WHR as standard, these cut-offs increased 0.5 cm only for both men and women (7 and 5.5 cm respectively).

Conclusion: The best cut-off points of visceral fat; using US in Egyptian adults; is 6.5 cm for men and 5 cm for women.

Introduction

Pattern of fat distribution rather than obesity is of importance for co-morbidity and mortality [1]. Abdominal obesity, known as belly fat or clinically as central obesity, is the accumulation of abdominal fat. Visceral fat is also, known as organ fat or intra-abdominal fat. It is located inside the peritoneal cavity packed in between internal organs resulting in an increase in waist size. In contrast to the accumulation of subcutaneous fat in the gluteo-femoral region, the accumulation of visceral fat around abdominal viscera and inside intra-abdominal solid organs is strongly associated with obesity-related complications like Type 2 diabetes and coronary artery disease [2]. However, some who are obese have no metabolic abnormalities. Recent studies found that, approximately 10-25% of obese individuals are metabolically healthy most likely due to preserved insulin sensitivity [3]. So, it is not adipose tissue per se, but perhaps where it is located that is important for determining metabolic consequences [4, 5].

According to the individual's gender and ethnic background, the rate of visceral fat accumulation differ; being more prominent in white men, African American women and Asian Indian and Japanese men and women [2]. Such differences may explain the variation in the cardiometabolic risk at different waist measurements between different populations [6]. While central obesity can be obvious just by looking at the naked body, the severity of central obesity is determined by taking waist and hip measurements [7].

Visceral fat is harder to lose than subcutaneous fat because it is more deeply embedded in the body's tissues. It is only measured accurately by an imaging machine (as Abdominal Ultrasound, Computerized Tomography CT, and Magnetic Resonance Imaging MRI) that can see how much of the abdomen is made up of visceral fat. A person may be within a healthy weight range, but still have too much intra-abdominal fat around the internal organs [8]. Ultrasonography (US) is a low cost and useful method besides not requiring radiation for evaluating visceral fat tissue. It distinctively quantifies visceral fat and subcutaneous fat [9].

Determination of accurate criteria for the diagnosis of 'obesity related disease' among Egyptian subjects is an urgent priority. The published criteria, for visceral fat area cut-off points, developed were based on Western patients; therefore, generalization to Egyptian subjects requires modification. Thus, the aim of this study was to define visceral fat; measured by US; cut-off levels for obesity according to existing waist circumference, waist/ hip ratio and BMI cut-off levels as criteria for diagnosis of obesity related diseases.

Subjects and Methods

Between October 2011 and December 2012, 998 Egyptian adults (400 men and 598 women), with age ranged between 25- 55 years, were studied in a cross-sectional survey for evaluation of "Visceral and Central Obesity as an Early Estimator for Obesity Health Risk: Management and Intervention". These participants were recruited from the employee in the "National Research Centre"; situated in Giza governorate. Participants were informed about the purpose of the study and their permission in the form of written consent was obtained. The protocol was approved by the "Ethical Committee" of the "National Research Centre". The agreement reference number is 10/119.

Anthropometric evaluation was performed. Height, weight, waist and hip circumferences were measured following the recommendations of the International Biological Program [10]. Height was measured to the nearest 0.1 cm using a Holtain portable anthropometer, and weight was determined to the nearest 0.01 kg using a Seca Scale Balance, with the subject wearing minimal clothing and no shoes. Waist circumference was measured at the level of the umbilicus with the subject standing and breathing normally, hip circumference at the level of the iliac crest, using non-stretchable plastic tape to the nearest 0.1 cm. All circumferences were taken with the subjects standing upright, with the face directed forward and shoulders relaxed. The following adiposity indices were calculated:

- Body mass index (BMI): as weight (in kilograms) divided by height (in meters) squared.

- Waist/ Hip ratio (cm/ cm).

Ultrasound (US) examination to each participant was done to evaluate visceral fat at the umbilicus (USVF) in cm. Intra-abdominal fat thickness measurement was obtained using the "Medison Sonoace X8" ultrasonography equipment. For the visceral fat, a 3.5 MHz transducer was transversely positioned 1 cm above the umbilical scar on the abdominal midline, without exerting any pressure over the abdomen. Visceral fat thickness attempted corresponding to the measurement in centimeters between the internal surface of the abdominal rectus muscle and the posterior aortic wall in the abdominal midline, during expiration.

Definitions

Normal BMI was defined as less than 25 kg/m², overweight as BMI $\geq$ 25 kg/m² and obesity as BMI $\geq$ 30 kg/m² for both men and women [11]. The cut-off points for obesity using waist circumference were defined as 102 cm for men and 88 cm for women [7, 12], Waist/hip ratio (WHR) cut-off was defined as 0.95 for obese men and 0.80 for obese women [7, 12]. True-positive subjects were those with high WC, WHR or BMI and high visceral fat. True-negative subjects were those with low WC, WHR or BMI and low visceral fat. False-positive subjects were those with high visceral fat and low WC, WHR or BMI. False-negative subjects were those with low visceral fat and high WC, WHR or BMI. Sensitivity was calculated as true-positives/(true-positives + false-negatives); specificity as true negatives/(true-negatives + false-positives). Positive predictive value (PPV) was defined as the percentage of subjects with high WC, WHR or BMI who had high visceral fat. Negative predictive value (NPV) was defined as the percentage of subjects with low WC, WHR or BMI who had low visceral fat.

Statistical Analysis

The significance of sex differences in the anthropometric parameters was tested by using the *student t-test*. *Pearson's correlations* between USVF and various variables by sex were done. All tests of significance were two-tailed. To find the optimal, maximal sensitivity and specificity for USVF, the receiver output curve (*ROC*) analysis of cut-off points at intervals of 0.5 or 1cm for USVF against two levels of waist circumference, BMI and waist/hip ratio were performed. Maximal *accuracy and PPV/NPV* closest to 1 were used for cut-off level determination. *P* value of 0.05 was considered significant. Data were analyzed using the SPSS computer program, version 16.0.

Results

In spite of the absence of significant sex difference in the mean age, women were highly significant heavier, had higher value of BMI and larger hip C than men in this sample, and insignificant difference in WC. However, men were highly significant taller and had highly significant higher values of WHR, and significant higher values of USVF (Table1).

Table 1: Characteristics of the sample by sex (using t-test).

	MEN			Women			P
	N	Mean	SD	N	Mean	SD	
Age (years)	400	42.75	11.02	598	41.45	10.30	0.061
Weight (kg)	400	87.89	20.77	596	91.50	20.64	0.007**
Height (cm)	400	169.67	8.04	597	158.24	7.75	0.000**
Waist Circumference (cm)	395	100.48	18.39	598	101.81	14.50	0.224
Hip Circumference (cm)	395	108.37	19.67	598	121.02	15.34	0.000**
BMI (kg/m^2)	400	30.80	7.56	595	36.45	7.384	0.000**
Waist/Hip ratio	395	1.00	0.71	598	.8542	0.25	0.000**
Visceral Fat (cm)	395	6.34	2.53	557	5.95	2.25	0.013*

Partial correlation (to exclude the effect of age) between USVF and various variables revealed highly significant correlation between USVF and weight, waist and hip circumferences, BMI for men and women, and waist/hip ratio for men only (p, 0.0001). The strongest correlation was found between USVF and WC (R = 0.71 for men and 0.66 for women), followed by BMI (R = 0.71 for men and 0.64 for women). While the correlation between USVF and waist/ hip ratio was the least (R = 0.25 for men and 0.07 for women) (Table 2).

Table 2: Partial correlation between visceral fat and various variables and their statistical significance by sex.

Variables	Visceral fat			
	Men (n=400)		Women (n=598)	
	r	p	r	p
Weight (Kg)	0.689**	0.000	0.563**	0.000
Waist Circumference (cm)	0.706**	0.000	0.661**	0.000
Hip Circumference (cm)	0.324**	0.000	0.520**	0.000
BMI (Kg/m²)	0.706**	0.000	0.638**	0.000
Waist/Hip ratio(cm/ cm)	0.249**	0.000	0.066	0.118

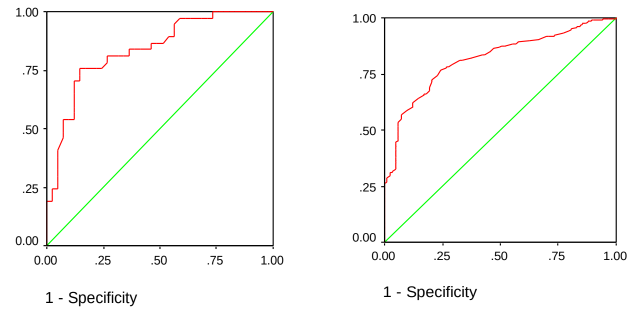
N.B.: p< 0.000 = highly significant difference.

Using WC as standard for classification of central obesity (WC > 102 cm for men and > 88cm for women), the cut-off points of USVF were found to be 6.5 cm for centrally obese men and 5 cm for centrally obese women; using ROC analysis; with 76 % sensitivity, 83% specificity, 1.06 PPV/NPV, and 81% accuracy for centrally obese men , and with 77 % sensitivity, 76% specificity, 0.99 PPV/NPV, and 76% accuracy for the centrally obese women (Table 3, Figure 1).

Table 3: Visceral fat (cm) cutoff levels for determining subjects with visceral obesity depending on waist circumference (WC≥ 88 and ≥ 102 cm) using ROC analysis.

Cut-off (cm)	Waist Circumference (cm) Men (N = 395) Sensi-tivity (%)	1 – Speci-ficity (%)	PPV/ NPV	Accu-racy (%)	Women (N = 598) Sensi-tivity (%)	1 – Speci-ficity (%)	PPV/ NPV	Accu-racy (%)
2	100	98	0.51	51	99	90	0.57	54
2.5	100	93	0.52	54	98	86	0.62	56
3	100	83	0.55	59	97	84	0.65	56
3.5	100	73	0.58	63	90	63	0.75	64
4	97	63	0.65	67	86	47	0.81	70
4.5	97	59	0.67	69	81	33	0.91	74
5	86	46	0.82	70	77	24	0.99	76
5.5	81	37	0.89	72	62	12	1.20	75
6	78	27	0.97	76	53	6	1.35	74
6.5	76	17	1.06	81	44	5	1.43	70
7	65	12	1.18	76	35	5	1.48	65
7.5	54	10	1.28	72	27	1	1.67	63
8	49	7	1.35	71	21	0	1.79	60
8.5	38	5	1.46	66	15	0	1.85	57
9	27	5	1.50	61	11	0	1.89	55
9.5	22	2	1.62	60	8	0	1.92	54
10	16	0	1.84	58	6	0	1.94	53
11	8	0	1.92	54	3	0	1.97	52
12	5	0	1.95	53	1	0	1.99	51

N.B.: Sensitivity was calculated as true-positives/ (true-positives + false-negatives). Specificity was calculated as true negatives/ (true-negatives + false-positives). Positive predictive value (PPV) was defined as the percentage of subjects with high WC, who had high visceral fat. Negative predictive value (NPV) was defined as the percentage of subjects with low WC, who had low visceral fat.



Men **Women**

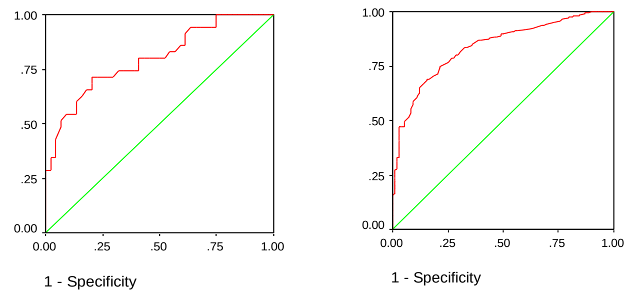
Figure 1: ROC curve for prediction of visceral fat cut off points depending on WC as standard.

The same cut-off points of USVF (6.5 cm for obese men and 5 cm for obese women) were detected using BMI (≥ 30 kg/m²); using ROC analysis; with 71 % sensitivity, 77% specificity, 1.04 PPV/NPV, and 75% accuracy for men, and 74% sensitivity, 79% specificity,1.03 PPV/NPV, and 77% accuracy for women (Table 4, Figure 2).

Table 4: Visceral fat (cm) cutoff levels for determining subjects with visceral obesity depending on BMI (BMI ≥ 30 Kg/m²) using ROC analysis.

Cut-off Level (cm)	BMI (Kg/cm) Men (N= 400) Sensi-tivity (%)	1 - Speci ficity (%)	PPV/ NPV	Accu-racy (%)	Women (N=595) Sensi-tivity (%)	1 – Speci-ficity (%)	PPV/N PV	Accura cy (%)
2	100	98	0.51	51	100	90	0.54	55
2.5	100	93	0.52	53	99	84	0.59	57
3	100	89	0.53	56	96	77	0.64	60
3.5	100	77	0.56	61	92	63	0.72	65
4	94	68	0.68	63	89	49	0.78	70
4.5	94	64	0.69	64	84	32	0.89	76
5	83	55	0.83	64	74	21	1.03	77
5.5	80	41	0.89	70	65	12	1.18	76
6	74	32	0.96	71	55	8	1.29	73
6.5	71	23	1.04	75	47	3	1.46	72
7	66	18	1.11	74	37	3	1.53	67
7.5	54	14	1.22	70	28	2	1.63	63
8	51	7	1.34	72	21	1	1.72	60
8.5	40	5	1.46	68	15	0	1.85	58
9	31	2	1.59	65	11	0	1.89	56
9.5	26	0	1.74	63	8	0	1.92	54
10	20	0	1.80	60	6	0	1.94	53
11	9	0	1.91	54	3	0	1.97	52
12	6	0	1.94	53	1	0	1.99	51
13	3	0	1.97	51				

N.B.: Sensitivity was calculated as true-positives/ (true-positives + false-negatives). Specificity was calculated as true negatives/ (true-negatives + false-positives). Positive predictive value (PPV) was defined as the percentage of subjects with high BMI, who had high visceral fat. Negative predictive value (NPV) was defined as the percentage of subjects with low BMI, who had low visceral fat.



Men **Women**

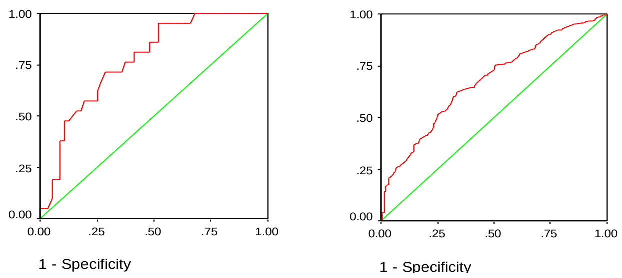
Figure 2: ROC curve for prediction of visceral fat cut off points depending on BMI as standard.

In spite of the finding that the correlation between USVF and WHR was weak for men (R=0.25), and women (R= 0.07), a trial was done using WHR as standard for determining USVF cut-off point for visceral obesity. It was found that USVF 7 cm for obese men and 5.5 cm for obese women); using ROC analysis; with 71 % sensitivity, 71% specificity, 1.00 PPV/NPV, and 71% accuracy for men, and 62% sensitivity, 66% specificity,1.02 PPV/NPV, and 64% accuracy for women (Table 5, Figure 3).

Table 5: Visceral fat (cm) cut-off levels for determining subjects with visceral obesity depending on waist/ Hip ratio (WHR≥ 0.80 and > 0.95 cm/cm) using ROC analysis.

Cut-off Level (cm)	Waist/ Hip ratio (cm/cm)							
	Men (N= 395)				Women (N=598)			
	Sensi-tivity (%)	1 – Speci-ficity (%)	PPV/ NPV	Accu-racy (%)	Sensi-tivity (%)	1 – Speci-ficity (%)	PPV/N PV	Accu-racy (%)
2	100	98	0.50	51	99	97	0.73	51
2.5	100	95	0.51	53	97	93	0.75	52
3	100	91	0.52	54	95	86	0.71	55
3.5	100	82	0.55	59	90	75	0.76	58
4	100	71	0.58	64	86	69	0.81	58
4.5	100	68	0.60	66	79	60	0.87	60
5	95	55	0.70	67	70	47	0.94	62
5.5	86	48	0.82	68	62	34	1.02	64
6	76	41	0.91	68	53	27	1.09	63
6.5	71	36	0.96	68	44	23	1.14	61
7	71	29	1.00	71	37	14	1.25	61
7.5	57	23	1.11	67	28	10	1.34	59
8	52	18	1.18	67	22	5	1.49	59
8.5	48	11	1.30	68	16	2	1.65	57
9	33	9	1.37	62	12	1	1.70	55
9.5	19	9	1.29	55	9	1	1.67	54
10	14	5	1.39	54	7	1	1.61	53
11	5	4	1.14	51	3	1	1.64	51
12	5	2	1.43	51	1	1	1.17	50
13	5	0	1.95	52				

N.B.: Sensitivity was calculated as true-positives/ (true-positives + false-negatives). Specificity was calculated as true negatives/ (true-negatives + false-positives). Positive predictive value (PPV) was defined as the percentage of subjects with high WHR, who had high visceral fat. Negative predictive value (NPV) was defined as the percentage of subjects with low WHR, who had low visceral fat.



Men **Women**

Figure 3: ROC curve for prediction of visceral fat cut off points depending on WHR as standard.

Discussion

Fat tissue is part of a system of neuroendocrine regulation of body mass and metabolism. It is an organ with intensive metabolic activity whose function is to store unused energy. It is also a gland with internal secretion which secretes cytokines (adipokines) which have an endocrine, paracrine and autocrine functions. Receptors for numerous hormones and cytokines are found on adipocytes. Functional connection between fat tissue and other tissues and organs is ensured. Increase in fat tissue, especially in visceral fat, leads to an increase in adipokine blood concentration, which results in changes in the functioning of distant tissues and organs with which fat tissue is hormonally linked. The consequent comprehensive changes in the metabolism are termed metabolic syndrome, and are linked with further complications. The consequences of these complications are a diminished quality of life and a rise in mortality [13].

Proinflamatory cytokines like tumor necrosis factor-alpha (TNF-alpha) and interleukin-6 (IL-6) and less adiponectin were found to be produced more by visceral adipose tissue and its resident macrophages. These cytokines changes induce insulin resistance and play a major role in the pathogenesis of endothelial dysfunction and subsequent atherosclerosis. So, mechanisms beyond a positive caloric balance such as inflammation and adipokine release suggested determining the pathological metabolic consequences in these patients [3].

Regional adiposity can be assessed with anthropometric data and imaging techniques. The former include waist/hip ratio and waist circumference. These measurements are easily obtained and cost-effective, do not involve ionizing radiation, and correlate with metabolic markers and imaging estimates [14]. For these reasons, the measurements have been widely accepted as indicators of intra-abdominal fat deposition [15]. They are characterized, however, by low accuracy and reproducibility [16]. Waist circumference cannot differentiate between the intra abdominal and subcutaneous fat deposits [17].

Various non-invasive imaging techniques, including computed tomography (CT), magnetic resonance imaging (MRI), dual energy X-ray absorptiometry (DEXA) and Ultrasonography, have been used for accurate estimation of regional fat deposits; the intra-abdominal and subcutaneous fat deposits.

Computed tomography (CT), magnetic resonance imaging (MRI) and dual energy X-ray absorptiometry (DEXA) are complicated and expensive methods of analyzing body fat, and require expert skills, so it is difficult to apply those methods to a wide range of people. Their accuracy for assessing body composition has proven to be superior to the results of anthropometry. Overall, CT seems to be the best method used in body fat research with its ability to pin-point differences between visceral fat and subcutaneous fat in the abdominal region. It is known to be the most accurate among obesity confirmation methods using direct bodily measurements [18, 19].

Among these techniques, Ultrasonography has attracted considerable attention because it combines safety, cost-effectiveness, and accuracy [20]. Additionally, Pineau et al [21] have demonstrated similar effectiveness of both ultra-sonography and computed tomography in the quantification of visceral fat.

Armellini et al [22] introduced e use of Ultrasonography for the determination of fat distribution**.** Investigators studying obese women, found a strong correlation between visceral fat thickness estimated with Ultrasonography and visceral adipose tissue area measured with CT. Further studies established the accuracy and repeatability of Ultrasonographic measurement of visceral thickness in various patient groups [23- 25], and the correlation of US measurements with CT and MRI based estimates [24, 25]. Tornaghi et al [24], Pontiroli et al [26] and Minocci et al [27] reported that the association between ultrasonographic measurements with metabolic values and central adiposity were stronger than that between anthropometric data and central adiposity.

In general, intra-abdominal fat thickness is related to cardiovascular risk in specific subgroups of healthy volunteers and diabetic patients [28- 31], although it is more sensitive than waist circumference in screening of men and women at high risk and of women at moderate risk [32].

However, no definite values for US were established to be used to estimate visceral adiposity. In a multivariate analysis by Leite et al [32] intra-abdominal fat thickness was found to be the most significant marker of CVD in both sexes. Cut-off values of 7 and 9 cm successfully differentiated men at moderate and high risk, respectively, of CVD. The corresponding values for women were 7 and 8 cm. Stolk and his colleagues, [28] stated that the mean (± SD) intra-abdominal fat distances in the men and the women were 9.5 ± 2.5 cm (range: 4.1–17.8 cm) and 8.2 ± 2.5 cm (range: 3.5–15.1 cm), respectively, could be considered as markers for metabolic syndrome. Kim and his colleagues [30] found that visceral fat thickness of 4.8 and 3.6 cm in the men and the women, respectively, was a cut-off for predicting the presence of CVD and various metabolic diseases. Hamaqawa et al [33] in Japan concluded that assessment of abdominal visceral fat by US gives us incremental information beyond conventional risk factors for predicting CVD in routine clinical practice. Xu et al [5] in China indicated that higher visceral fat was associated with an adverse lipid and glucose profile. Waist circumference can be a moderate predictor for visceral fat and provides a feasible measurement to estimate glucose metabolic risks.

Reviewing literatures, this research can be considered the first one regarding evaluating cut-off values of visceral fat for identifying obese subjects; in general not only related to certain disease; at high risk for co-morbidity among Egyptian adults, depending on WC or BMI as standards. The best cut-off points of USVF for visceral obesity were found to be 6.5 cm for men and 5 cm for women.

In summary, depending on WC or BMI as standards, the best cut-off points of USVF for visceral obesity are 6.5 cm for men and 5 cm for women. Even by using WHR as standard, these cut-off points increased 0.5 cm only for both men and women (7 and 5.5 cm respectively).

Statement of authorship

Nayera E. Hassan: Conception and design of the study, share in drafting the article and final approval of the version to be submitted. She is the PI of the project from which this data was derived. Sahar A. El-Masry: Analysis and interpretation of the data, share in drafting the article and final approval of the version to be submitted. She is the Co-PI of the project from which this data was derived. Mohamed S. El Hussieny and Rokia El-Banna: Share in drafting the article and final approval of the version to be submitted. Safenaz Y. El Sherity: Responsible of the ultrasound and data collection. Ebrahim A. Ebrahim: Responsible of the ultrasound and data collection. Mohamed K. Metkees: Responsible of the ultrasound and data collection. Wesam A. El Sayed: Responsible of the ultrasound and data collection.

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