Original Article

Turk J Endocrinol Metab 2020;24:1-8

Comparison of New and Old Body Shape Indices to Estimate Body Fat in Obese and Morbid Obese Turkish Females

Obez ve Morbid Obez Türk Kadınlarında Vücut Yağ Oranı Tahmininde Yeni ve Eski Vücut Şekil İndekslerinin Karşılaştırılması

Merve MELİKOĞLU, Can ÖNER, Sabah TÜZÜN, Şule TEMİZKAN*, Ekrem ORBAY

Kartal Dr. Lütfi Kırdar Training and Research Hospital, Department of Family Medicine, İstanbul, Turkey
*Kartal Dr. Lütfi Kırdar Training and Research Hospital, Department of Endocrinology and Metabolism, İstanbul, Turkey

Abstract

Objective: The estimation of fat mass with indirect techniques is beneficial in daily clinical practice. This study aimed to compare new and old body shape indices using bioimpedance analysis for the assessment of body fat mass in obese and morbid obese Turkish females. **Material and Methods:** Four hundred thirty-eight obese and morbid obese females were enrolled in the study. Anthropometric measurements of the study participants were completed using standard techniques. Body mass index (BMI), body adiposity index (BAI), a body shape index, waist to hip ratio and body roundness index (BRI) were calculated. The body fat ratio was evaluated using TANITA-48M. **Results:** All the anthropometric indices except waist circumference, waist-to-hip ratio, and ABSI correlated with body fat (%). BMI and BAI were the best predictors of body fat ratio derived from bioimpedance analysis for all participants. Only for obese females, BAI alone as well as BAI and BMI together were the best predictive methods of body fat (%). In the morbid obese group, BAI alone proved to be the best predictive method for body fat (%) estimation. **Conclusion:** In clinical practice, the determination of body fat ratio with indirect techniques may help physicians estimate the risk of diseases in obese and morbid obese patients. BAI can help estimate body fat ratio easily.

Keywords: Body fat; body mass index; body roundness index; body adiposity index; a body shape index; obesity

Özet

Amaç: Günlük klinik uygulamada vücut yağ oranının direkt ölçümü maliyetli ve zor olduğundan, vücut kompozisyon indeksleri gibi pratik yöntemler kullanılmaktadır. Bu çalışmanın amacı, obez ve morbid obez Türk kadınlarında vücut yağ oranının değerlendirilmesinde yeni ve eski vücut kompozisyon indekslerinin biyolojik empedans analizi ölçümüyle saptanan vücut yağ oranı ile karşılaştırılmasıdır. **Gereç ve Yöntemler:** Çalışmaya 438 obez ve morbid obez kadın alındı. Kadınların antropometrik ölçümleri uygun yöntemlerle yapıldı. Beden kitle indeksi (BKİ), beden adiposite indeksi (BAI), beden şekil indeksi, bel-kalça oranı ve beden yuvarlaklık indeksi hesaplandı. Vücut yağ oranı TANITA-48M ile değerlendirildi. **Bulgular:** Bel çevresi, bel-kalça oranı ve beden şekil indeksi hariç tüm antropometrik ölçümler vücut yağ oranı ile koreledir. Tüm katılımcılar için BKİ ve BAİ biyoelektrik empedans analizinden elde edilen vücut yağ oranını en iyi öngören yöntemlerdi. Obez kadınlar için tek başına BAİ ve BAİ-BKİ vücut yağ oranını en iyi tahmin eden yöntemlerdi. Morbid obez grupta tek başına BAİ, vücut yağ oranı tayini için en iyi öngörücü yöntemdi. **Sonuç:** Klinik pratikte, vücut yağ oranının antropometrik ölçümlerle tahmin edilebilmesi; hekimlerin obezite tanısı koyabilmesi, morbidite riskini değerlendirmesi ve tedavi planlaması için önemlidir. BAİ, obez kadınlarda vücut yağ oranının öngörülmesinde kolay ve etkili bir yöntemdir.

Anahtar kelimeler: Vücut yağ oranı; beden kitle indeksi; beden yuvarlaklık indeksi; beden adipozite indeksi; beden şekil indeksi; obezite

Address for Correspondence: Merve Melikoğlu, Kartal Dr. Lütfi Kırdar Training and Research Hospital, Department of Family Medicine, İstanbul, Turkey
Phone:: +90 216 3776554 **E-mail:** dr.mervemelikoglu@gmail.com

Peer review under responsibility of Turkish Journal of Endocrinology and Metabolism.

Received: 14 Jun 2019 **Received in revised form:** 17 Nov 2019 **Accepted:** 02 Jan 2020 **Available online:** 20 Jan 2020

DOI: 10.25179/tjem.2019-66730

Introduction

Obese and overweight individuals pose a significant and widespread health problem all over the world. Nearly 1.9 billion adults throughout the world are overweight or obese (1). According to the national statistics, 1 in every 3 adults is obese and this ratio reaches up to 35.8-44.0% in females (2). Body fat amounting to more than 25% of body weight in males and more than 35% in females is classified as obesity in adults. Many in-vivo techniques for the determination of body fat and diagnosis of obesity exist and many new indices are still being developed to obtain results that are more accurate. The most common and popularly used index is body mass index [BMI=weight (kg)/height (m^2)]. World Health Organization defines overweight as a BMI ≥25 and obesity ≥30 (kg/m^2) (3).

The body fat percentage and distribution are important because of their relationship with chronic diseases, especially cardiac diseases and diabetes. The techniques determining body fat percentage may be studied as direct and indirect ones. Several direct techniques are employed for the evaluation of body fat percentage and distribution including bioimpedance analysis (BIA), air displacement plethysmography (ADP) and dual-energy X-ray absorptiometry (DEXA) (4). DEXA and magnetic resonance imaging (MRI) are considered the gold standard for determining body fat; yet, the requirement of equipment, trained personnel, and the involved cost limits the use of these techniques. For that reason, bioimpedance analysis is more convenient and is employed more often.

Indirect techniques of determination of body fat percentage are easy to use, involve low cost and do not require auxiliary staff; thereby becoming the most recommended and widely used. The most popular indirect technique for body fat measurement that has been accepted as a tool for defining obesity is Body Mass Index (BMI). Although BMI is very easy to calculate and use, the limitations of this index are well documented; it includes the inability to distinguish the level of fat-free mass and scarce information about fat distribution (5). In order to overcome these limitations, new indices have been developed. Waist circumference (WC) and waist to hip ratio (WtHR) have been introduced as an alternative to BMI, and many studies have confirmed that these indices are superior to BMI in indicating cardio-metabolic diseases (6). In 2011, Body Adiposity Index (BAI) was developed, which use hip circumference and height as the basic anthropometric measures and estimates the body adipose tissue in percentage (7). BAI has been reported to be useful in both genders and in all ethnicities and is strongly correlated with adiposity, in contrast to BMI (4). In 2012, A Body Shape Index (ABSI) was developed in which waist circumference, body weight and height are used as basic measures (8). Although ABSI measurements correlate positively with abdominal adipose tissue deposition, but it is weaker in estimating cardiovascular diseases as compared to BMI (9).

In 2013, a new geometric model, Body Roundness Index (BRI) was developed (5). It is based on the assumption that the body is an ellipse which has two lengths; body height is accepted as major and the diameter of hip or waist circumference as minor axes. The degree of body roundness is characterized by a non-dimensional value called as "eccentricity". BRI ranges between 1 and 16; a larger value is associated with rounder individuals whereas a value closer to 1 is related to more narrowly shaped individuals (5). It was shown that BRI can predict cardiovascular risk and diabetes mellitus, although it is not superior to BMI and WC (10,11).

Accurate estimation of body fat percentage and its distribution through a numerical value proves very advantageous for clinical practice. Therefore, the aim of this study was to assess the concordance of indirect techniques (BMI, BAI, ABSI, BRI, WC and WtHR) via measured body fat (%) using bioimpedance analysis in obese and morbid obese Turkish women to determine the best indicator index for body fat (%).

Material and Methods

This study was conducted in Kartal Dr. Lutfi Kirdar Education and Training Hospital obesity outpatient clinic between 1 January and 30 June 2016 retrospectively. Women with a BMI of 30 or above were included in the study. Pregnancy, age <18 years, secondary obesity, thyroid and adrenal diseases were the exclusion criteria. The study was approved by the local Ethics Committee of Kartal Dr. Lutfi Kirdar Training and Research Hospital (No: 2016/514/83/6).

Anthropometric measurements of the study participants were performed. Weight was measured in light clothing using calibrated electronic scales to the nearest 0.1 kg. Height was measured barefoot using a stadiometer to the nearest 0.1 cm. Waist circumference was measured over bare skin, midway between the lower rib margin and the iliac crest at the end of expiration while hip circumference was measured as the maximum circumference over the buttocks to the nearest 0.1 cm using a fiberglass measuring tapes. Using these dimensions, BMI, BAI, ABSI, WtHR and BRI were calculated using the formulas summarized in Table 1.

The body composition of the study participants was assessed after overnight fasting. BIA was used for the estimation of the body fat ratio. Bioimpedance measurements of all participants were performed using a TANITA-48M device. The whole body impedance measurements were made using standard positions of outer and inner electrodes on the right hand and right foot. Body fat percentage was obtained according to algorithms developed by the producer (TANITA). Statistical analyses were performed using the Software Statistical Package Sciences (SPSS) for Windows version 17.0. The data were presented as percentages and frequencies, mean±standard deviation. Pearson's correlation or Spearman's correlation test was used to find out the correlation between the variables. Significant indices in correlation tests were assessed via the stepwise linear regression to determine the best index/indices. Statistical analyses were two-sided and a p-value <0.05 was considered significant.

Results

The study sample comprised 438 obese and morbid obese females, out of which 272 (62.1%) were obese and 166 (37.9%) were morbid obese. Mean BMI and mean age of the study participants were 38.84±6.19 kg/m^2 and 42.92±10.78 years, respectively. Nearly 1 in 5 females had diabetes (n=87) and 97 (22.1%) females had hypertension. Anthropometric measures of the participants are presented in Table 2.

The correlation of different body fat (%) measurements were analyzed in all the study participants and the results have been depicted in Table 3. All the anthropometric indices except WC, WtHR and ABSI correlated with body fat (%) as assessed by BIA. Body Roundness Index showed a significant correlation with all the other indices (Table 2).

Stepwise linear regression analysis showed that BMI and BAI were the best predictors of body fat ratio derived from BIA for all the participants (R^2=0.385; p=0.000 for model 1 and R^2=0.412; p=0.000 for model 2) (Table 4).

The participants were divided into two groups: obese and morbid obese according to BMI. In the obese group, waist circumference (r=0.349; p=0.000), BRI (r=0.437;

Table 1. Anthropometric formulas used in the study.

Name	Abbreviation	Formula	Reference
Body Mass Index	BMI	weight (kg)/height ^{2} (m)	(3)
Body Adiposity Index	BAI	$\frac{\text{Hip circumference (cm)}}{\text{height} \times \sqrt{\text{height}}} - 18$	(7)
A Body Shape Index	ABSI	$\frac{\text{Waist circumference (cm)}}{\text{BMI}^{\frac{2}{3}} \times \text{height}^{\frac{1}{2}}}$	(8)
Body Roundness Index	BRI	BRI=364,2-(365,5×Ɛ) $\varepsilon = \sqrt{1 - \frac{(\frac{\text{Waist circumference}}{2\pi})^2}{(0{,}5 \times height)^2}}$	(10)
Waist to Hip Ratio	WtHR	waist circumference (cm)/hip circumference (cm)	(3)

Table 2. Anthropometric measures of the participants.

	Minimum	Maximum	Mean±SD
Weight (kg)	63.6	156.5	95.8±15.9
Height (m)	1.38	1.77	1.57±0.6
Waist circumference (cm)	84	150	110.8±12.2
Hip circumference (cm)	98	203	124.6±12.4
WtHR	0.71	1.23	0.89±0.06
BMI (kg/m²)	30	65.1	38.8±6.1
BAI (fat%)	30.4	77.7	45.4±7.15
ABSI	0.06	0.10	0.07±0.005
BRI	3.92	17.7	8.17±2.25
Body fat (%)	13.7	50.0	41.5±3.99

WtHR: Waist to Hip Ratio; BMI: Body Mass Index; BAI: Body Adiposity Index; ABSI: A Body Shape Index; BRI: Body Roundness Index.

p=0.000), BAI (r=0.546; p=0.000), BMI (r=0,544; p=0,000) were correlated significantly with body fat (%). The stepwise linear regression analysis of only the obese group revealed that BAI alone (r^2=0,298), as well as BAI and BMI together (r2=0.377), were the best predictive methods of body fat (%) in obese patients.

In the morbid obese group, BAI (r=0.268; p=0.000), BMI (r=0.191; p=0.000) and hip circumference (r=0.174; p=0.025) were significantly correlated with body fat (%). The stepwise linear regression analysis in the morbid obese group showed that BAI alone (r^2=0.72) was the best predictive method for body fat (%).

Discussion

It is well known that higher body fat ratio (%) is associated with coronary artery diseases, cardiovascular events and mortality (12). The amount of adipose tissue forms an important part of the body weight and includes a large quantity of fluid in its interstitial space which plays a critical role in heart failure. The stroke volume, cardiac output and left ventricular mass are related to fat-free mass. Furthermore, fat tissue acts as an endocrine organ that synthesizes and releases a variety of peptidases and non-peptides playing a role in cardiovascular homeostasis (13). Recent studies have also established the relationship between insulin resistance, diabetes and body fat ratio (14,15). Lipolysis of adipose tissue produces free fatty acids which in turn increases lipid synthesis and gluconeogenesis, resulting in peripheral insulin resistance. This process ends with hyperlipidemia, glucose intoler-

Table 3. Correlation coefficients (r*) of different anthropometric indices with each other and bioimpedance analyses (fat%).

	BRI	ABSI	BAI	BMI	WtHR	HC	WC	BIA (fat%)
BIA (fat%)	0.548	-0.052	0.621	0.610	0.009	0.551	0.493	1
WC	0.929	0.444	0.637	0.763	0.498	0.755	1	
HC	0.685	-0.049	0.830	0.831	-0.188	1		
WtHR	0.481	0.736	-0.142	0.042	1			
BMI	0.793	-0.204	0.838	1				
BAI	0.778	-0.077	1					
ABSI	0.395	1						
BRI	1							

BIA: Bioimpedance Analyses; WC: Waist Circumference; HC: Hip Circumference; WtHR: Waist to Hip Ratio; BMI: Body Mass Index; BAI: Body Adiposity Index; ABSI: A Body Shape Index; BRI: Body Roundness Index.
* r values with statistically significant (p<0.05) are written in bold.

Table 4. Stepwise regression analysis of the indices.

		ß	Confidence interval	p-value
Model 1	BAI	0.621	0.305-0.388	0.000
Model 2	BAI	0.368	0.131-0.279	0.000
	BMI	0.301	0.109-0.280	0.000

ance, hypertension and atherosclerosis (16). Because of these relationships between obesity, fat ratio and chronic metabolic diseases, it is important for the physicians to determine body fat ratio. The direct methods of estimation of body fat involve higher costs and require equipment and personnel. Estimation of body fat ratio (%) using indirect measures is therefore feasible in daily clinical practice. World Health Organization recommends the use of BMI for the determination of obesity. However, as the ability of BMI to determine body fat percentage is debatable, new indices like WC, WtHR, BAI, ABSI and BRI have been developed.

In this research, the anthropometric indices were compared with body fat ratio and all anthropometric indices except waist circumference, WtHR and ABSI showed a statistically significant correlation with body fat ratio (%) in both, obese and morbid obese females. The strongest correlation between these indices and body fat ratio was observed between BAI (r=0.621) and BMI (r=0.610). In the obese females, BAI and BMI were almost equally effective in predicting body fat; however, in morbid obese females, the value of BMI decreased and BAI was the only index that could determine body fat (%).

Bergman et al. established an easily measured anthropometric index; BAI, for determining body fat ratio. They reported a higher correlation of BAI with body fat ratio (r=0.790) than with BMI (r=0.569). The conformity of BAI and body fat ratio is poor at lower levels of adiposity. BAI predicts body fat optimally if the body adiposity is >20% (7). Sun et al. carried out a research on the concordance of BAI and BMI with DEXA. They found that BAI significantly correlated with body fat in the entire cohort (r=0.78). According to gender, BAI was more consistent with the body fat ratio in the females as compared to the males and the entire cohort (r=0.74 vs. r=0.67). Nevertheless, in obese females, such as those in the present study, the correlations of BMI and BAI with body fat were almost equal (r=0.58 vs. r=0.54) (17). On the other hand, one study showed that BAI overestimates body fat at lower levels of adiposity (<20%) and provides 5-10% underestimates at higher adiposity (>40%) (18). In morbid obese females, BMI has been observed to be the single best predictor of body fat (4). This difference could be due to the BAI formula that includes hip circumference and height, which are both related to bone structure. Turkish women are mostly short in stature and have a smaller waist, but larger hip circumference (19). Moreover, in some ethnic groups weight gain is not related to increased hip circumference, but waist circumference (20).

The authors observed that BMI is the second-best index to determine the body fat ratio in obese women. A study including 12901 adults showed that BMI significantly correlates with body fat, both in men and women, although body fat does not increase linearly with weight. Moreover, in females, body fat percentage correlated with WC in a better way (21). A study comparing BAI, BMI, HC, WC and WtHR for determination of body fat (%) revealed that the highest correlation was 0.78 (r^2=0.60) for BMI and 0.67 for BAI (r^2=0.45) (22). In another study, BMI was significantly correlated with body fat ratio in women (r=0.76) as well as in obese women (r=0.54) (17). Ehrampous et al. speculated that BMI showed the strongest relation with body fat ratio (r=0.868) (23). Similarly, Geliebter et al. reported BMI as the single best predictor of body fat that significantly correlated with BIA (r=0.90) in severely obese women (4). The literature also reports studies presenting significant correlations between BMI and body fat ratio which is similar to the results of the present study (24,25). Lopez et al. compared BAI and BMI in the determination of body fat ratio and found that BAI is advantageous over BMI, as it does not use weight; however, in general, the BAI does not overcome the limitation of BMI (26). Some researchers suggest that BMI is well correlated with body fat ratio and is a powerful indicator of cardiac events. However, the literature also quotes studies that questioned the adequacy of BMI in measuring body fat ratio (27,28). The relationship between BMI and body fat percentage varies according to age, sex and ethnicity (21). Moreover, its weight dependence and inability to determine the distribution of body fat could be the reasons for this discordance observed in the literature.

ABSI is weakly correlated with height and weight, so its correlation with BMI is poor but on the other hand, it shows a strong correlation with mortality rates (8). In the present study, ABSI was unable to predict body fat (r=-0.052, p>0.05). Ehrampoush et al. found a weak correlation between body fat and ABSI, which is in accordance with the results of the present study (23). The height differences between varied ethnic groups may decrease the ability of ABSI in determining body fat.

The authors observed that after BAI and BMI, the new index, BRI was the third-best method that correlated with body fat ratio. It was also strongly correlated with BAI and BMI. BRI could determine body fat ratio and it was possible to obtain a better correlation coefficient when hip circumference rather than waist circumference was used for the calculation of the eccentricity coefficient. Santos et al. reported that BRI could be used for estimating body fat ratio although it has a lower correlation than BMI (29).

Waist circumference and WtHR were not correlated with body fat ratio in the present study. Jablonowska et al. also found that WtHR and WC have a non-significant correlation with body fat, as assessed by BIA (30). On the other hand, literature reports studies indicating WC and WtHR as effective methods for determining body fat indirectly (21,23). The authors deliberate that variations between study groups could be the reason for this discrepancy. The study group in the present research includes obese and morbidly obese, middle-aged Turkish women. The amount and distribution of body fat have been found to be directly related to age and ethnicity.

This study poses some limitations. A cross-sectional design and small sample size are the major limitations. The study group included only those patients who were followed up in the author's hospital-based outpatient clinics (only obese/morbid obese women), thereby rendering it impossible to use these results when evaluating the entire population. Another limitation of this study is the non-homogenous distribution of age in the study group. Menopause is an important factor in body fat distribution. Postmenopausal women have higher amounts of body fat and reduced muscle mass. BAI underestimates body fat ratio measured by DXA in white postmenopausal women (31).

Conclusion

In clinical practice, the determination of body fat ratio with indirect techniques could help physicians estimate the risk of diseases in obese and morbid obese patients. In conclusion, it was found that BAI and BMI are the best indicators of body fat in obese women. On the other hand, BAI is the best predictive method for body fat estimation in morbid obese females. Body Adiposity Index can be easily used in situations when the weight of the patient is not known.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: Merve Melikoğlu, Can Öner; Design: Can Öner, Sabah Tüzün; Control/Supervision: Merve Melikoğlu, Can Öner, Sabah Tüzün, Şule Temizkan, Ekrem Orbay; Data Collection and/or Processing: Merve Melikoğlu, Şule Temizkan; Analysis and/or Interpretation: Can Öner, Sabah Tüzün; Literature Review: Merve Melikoğlu, Can Öner, Sabah Tüzün, Şule Temizkan; Writing the Article: Merve Melikoğlu, Can Öner, Sabah Tüzün; Critical Review: Ekrem Orbay; References and Fundings: Merve Melikoğlu; Materials: Merve Melikoğlu, Can Öner, Sabah Tüzün, Şule Temizkan, Ekrem Orbay.

References

1. World Health Organization (WHO). Obesity and overweight Fact Sheet no 311.2016. Geneva: World Health Organization; 2018. Date of access: 22.07.2019. [Link]
2. Satman I, Omer B, Tutuncu Y, Kalaca S, Gedik S, Dinccag N, Karsidag K, Genc S, Telci A, Canbaz B, Turker F, Yilmaz T, Cakir B, Tuomilehto J. Twelve year trends in the prevalence and risk factors of diabetes and prediabetes in Turkish adults. Eur J Epidemiol. 2013;28:169-180. [Crossref] [PubMed] [PMC]
3. World Health Organization (WHO). Physical Status: The use and interpreation of anthropometry. Technical Report Series 854, Geneva: WHO Press; 1995. p.439. Date of access: 22.07.2019. [Link]
4. Geliebter A, Atalayer D, Flancbaum L, Gibson CD. Comparision of body adiposity index (BAI) and BMI with estimations of % body fat in clinicall severe obese women. Obesity (Silver Spring). 2013;21:493-498. [Crossref] [PubMed]
5. Thomas DM, Bredlau C, Bosy-Westphal A, Mueller M, Shen W, Gallagher D, Maeda Y, McDougall A, Peterson CM, Ravussin E, Heymsfield SB. Relationships between body roundness with body fat and visceral adipose tissue emerging from a new geometrical model. Obesity (Silver Spring). 2013;21:2264-2271. [Crossref] [PubMed] [PMC]
6. Chang Y, Guo X, Chen Y, Guo L, Li Z, Yu S, Yang H, Sun Y. A body shape index and body roundness index: two new body indices to identify diabetes mellitus among rural populations in northeast China. BMC Public Health. 2015;15:794. [Crossref] [PubMed] [PMC]
7. Bergman RN, Stefanovski D, Buchanan TA, Summer AE, Reynolds JC, Sebring NG, Xiang AH, Watanabe RM. A beter index of body adiposity. Obesity (Silver Spring). 2011;19:1083-1089. [Crossref] [PubMed] [PMC]
8. Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. PloS One. 2012;7:e39504. [Crossref] [PubMed] [PMC]
9. Haghighatdoost F, Sarrafzadegan N, Mohammadifard N, Asgary S, Boshtam M, Azadbakht L. Assessing body shape index as a risk predictor for cardiovascular diseases and metabolic syndrome among Iranian adults. Nutrition. 2014;30:636-644. [Crossref] [PubMed]
10. Maessen MF, Eijvogels TM, Verhegen RJ, Hopman MT, Verbeek AL, de Vegt F. Entering new era of body indices: the feasibility of a body shape index and body roundness index to indentify cardiovascular health status. PloS One. 2014;9:e107212. [Crossref] [PubMed] [PMC]
11. Chang Y, Guo X, Chen Y, Guo L, Li Z, Yu S, Yang H, Sun Y. A body shape index and body roundness index: two new body indices to identify diabetes mellitus among rural population in northeast China. BMC Public Health. 2015;15:794-802. [Crossref] [PubMed] [PMC]
12. Lee WS. Body fatness charts based on BMI and waist circumference. Obesity (Silver Spring). 2016;24:245-249. [Crossref] [PubMed]
13. Poirier P, Giles TD, Bray GA, Hong Y, Stern JS, Pi-Sunyer X, Eckel RH. Obesity and cardiovascular disease: pathophysiology, evaluation, and effect of weight loss an update of the 1997 American Heart Association Scientific Statement on Obesity and Heart Disease from the Obesity Committee of the Council on Nutrition, Physical Activity, and Metabolism. Circulation. 2006;113:898-918. [Crossref] [PubMed]
14. Patel P, Abate N. Body fat distribution and insulin resistance. Nutrients. 2013;5:2019-2027. [Crossref] [PubMed] [PMC]
15. Al-Goblan AS, Al-Alfi MA, Khan MZ. Mechanism linking diabetes mellitus and obesity. Diabetes Metab Syndr Obes. 2014;7:587-591. [Crossref] [PubMed] [PMC]
16. Matsuzawa Y, Shimomura, I, Nakamura T, Keno Y, Kotani K, Tokunaga K. Pathophysiology and pathogenesis of visceral fat obesity. Obes Res. 1995;2:187S-194S. [Crossref] [PubMed]
17. Sun G, Cahill F, Gulliver W, Yi Y, Xie Y, Bridger T, Pace D, Zhang H. Concordance of BAI and BMI with DXA in Newfoukland population. Obesity (Silver Spring). 2013;21:499-503. [Crossref] [PubMed]
18. Johnson W, Chumlea WC, Czerwinski SA, Demerath EW. Concordance of the recently published body adiposity index with measured body fat percent in European-American adults. Obesity (Silver Spring). 2012;20:900-903. [Crossref] [PubMed] [PMC]
19. Can AS, Bersot TP, Gönen M, Pekcan G, Rakıcıoğlu N, Samur G, Yıldız EA. Anthropometric indices and their relationship with cardiometabolic risk factors in a sample of Turkish adults. Public Health Nutr. 2008;12:538-546. [Crossref] [PubMed]
20. Vinknes KJ, Elshorbagy AK, Drevon CA, Gjesdal CG, Tell GS, Nygård O, Vollset SE, Refsum H. Evaluation of the body adiposity index in a caucasian population: the Hordaland health study. Am J Epidemiol. 2013;177:586-592. [Crossref] [PubMed]
21. Flegal KM, Shepherd JA, Looker AC, Graubard BI, Barrud LG, Ogden CL, Harris TB, Evehart JE, Schenker N. Comparisions of percentage body fat, body mass index, waist circumference, and waist stature ratio in adults. Am J Clin Nutr. 2009;89:500-508. [Crossref] [PubMed] [PMC]
22. Suchanek P, Kralova Lesna I, Mengerova O, Mrazkova J, Lanska V, Stavek P. Which index best correlates with body fat mass: BAI, BMI, waist or WHR? Neuro Endocrinol Lett. 2012;33:78-82. [PubMed]
23. Ehrampoush E, Arasteh P, Homayounfar R, Cheraghpour M, Alipour M, Naghizadeh MM, Hadibarhaghtalab M, Davoodi SH, Askari A, Razaz JM. New anthropometric indices or old ones: which is the better predictor of body fat? Diabetes Metab Syndr. 2017;11:257-263. [Crossref] [PubMed]
24. Gallagher D, Visser M, Sepúlveda D, Pierson RN, Harris T, Heymsfield SB. How useful is body mass index for comparision of body fatness across age, sex and ethnic groups? Am J Epidemiol. 1996;143:228-239. [Crossref] [PubMed]
25. Gallagher D, Hemysfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamato Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. Am J Clin Nutr. 2000;72:694-701. [Crossref] [PubMed]

26. López AA, Cespedes ML, Vicente T, Tomas M, Bennasar-Veny M, Tauler P, Aguilo A. Body adiposity index utilization in a Spanish Mediterranean population: comparison with the body mass index. PloS One. 2012;7:e35281. [Crossref] [PubMed] [PMC]
27. Jahanlou AS, Kouzekanani K. The interaction effect of body mass index and age on fat-free mass, waist-to-hip ratio, and soft lean mass. J Res Med Sci. 2017;22:86. [Crossref] [PubMed] [PMC]
28. Bosy-Westphal A, Geisler C, Onur S, Korth O, Selberg O, Schrezenmeir J, Müller MJ. Value of body fat mass vs anthropometric obesity indices in the assessment of metabolic risk factors. Int J Obes (Lond). 2006;30:475-483. [Crossref] [PubMed]
29. Santos DA, Silva AM, Matias CN, Magalhães JP, Minderico C, Thomas DM, Sardinha LB. Utility of novel body indices in predicting fat mass in elite athletes. Nutrition. 2015;31:948-954. [Crossref] [PubMed]
30. Jabłonowska-Lietz B, Wrozesek M, Włodarczyk M, Nowicka G. New indexes of body fat distribution, visceral adiposity index, body adiposity index, waist to height ratio and metabolic disturbances in the obese. Kardiol Pol. 2017;75:1185-1191. [Crossref] [PubMed]
31. Cerqueira M, Amorim P, Magalhães F, Castro E, Franco F, Franceschini S, Cerqueira L, Marins J, Doimo L. Validity of body adiposity index in predicting body fat in a sample of Brazilian women. Obesity (Silver Spring). 2013;21:E696-699. [Crossref] [PubMed]