The Validity of Body Adiposity Indices in Predicting Metabolic Syndrome and Its Components among Egyptian Women

Moushiria Erfan Zaki1*, Sanaa Kamal1, Hanaa Reyad1, Walaa Yousef1, Naglaa Hassan1, Iman Helwa2, Shams Kholoussi2

1*Biological Anthropology Department, Medical Division, National Research Centre, Giza, Egypt; 2Immunogenetics Department, Human Genetics and Genome Research Division, National Research, Centre, Giza, Egypt

Abstract

AIM: To assess the associations between the body adiposity indices and risk of metabolic syndrome (MS) and its components in Egyptian women and to evaluate their predictive power.

MATERIALS AND METHODS: This was a cross-sectional analysis performed on 180 Egyptian women aged between 25-35 years. They were 90 women with MS diagnosed by International Diabetes Federation (IDF) and 90 healthy age matched controls. Body adiposity index (BAI), body mass index (BMI), waist to hip ratio (WHR) and waist to height ratio (WHtR) were calculated and serum samples were analyzed for metabolic parameters. Receiver operating characteristic curves (ROC) was used to determine the discriminatory capacity of BAI, WHR WHtR and BMI for MS.

RESULTS: Area under the curve (AUC) was highest for BIA, followed by WHR, WHtR and then BMI. All adiposity indices were significantly correlated with metabolic components and BAI had the highest correlation coefficients compared to other indices.

CONCLUSION: BAI is a practical predictor for MS and has satisfactory diagnostic accuracy for diagnosing MS among Egyptian women and can be used in addition to WHR, WHtR and BMI for identifying MS in the field studies.

Introduction

Obesity has become one of the most important public health problems. The increase in prevalence of obesity involves an increase in the prevalence of several obesity-related diseases [1–3]. Several studies show the relation between the adipose tissue accumulation and the incidence of adverse metabolic events and, also, with a higher risk for developing metabolic diseases [4-10]. The metabolic syndrome (MS) is a set of interrelated risk factors such as hypertension, dyslipidemia, obesity and high blood glucose.

Insulin resistance together with central/abdominal or visceral obesity has been proposed as the key factors in the development of the MS. Several authors have tested the correlations between the indices of adiposity and several health outcomes [11-13]. There is no universally agreed definition for MS. Despite the use of the same index for central obesity assessment, the National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III) [14] and International Diabetes Federation (IDF) [15] differed in the waist circumference (WC) cut-off points. ATPIII proposed WC more than or equals 88 cm for women, whereas IDF proposed WC cut-off points based on population estimates. Body mass index (BMI), WC, and waist to hip ratio has all been tested for their relation to MS, but with no consistent results across the globe. The prevalence also varies by ethnicity. In the National Health and Nutrition Examination Survey III (NHANES III) [16], the age-adjusted prevalence was 30–40% higher in people of Mexican–American origin than in persons of White and African–American origin.

The highest prevalence is found in the Middle East region, where more than every third person...
above the age of 20 fulfills the criteria for having the metabolic syndrome. The syndrome is common and has a rising prevalence worldwide, relating largely to a complex interplay of rapid nutritional alterations, sedentary lifestyle and socioeconomic evolution, increasing affluence, rural-to urban migration, leading to obesity.

This study aims to evaluate the predictive power of adiposity indices as predictors for MS in the sample of Egyptian women.

Material and Methods

The present cross-sectional study was carried out on 90 obese Egyptian women (aged 25-35 years old) recruited from obesity clinic National Research Centre with MS having the presence of 3 or more criteria/parameters according to the International Diabetes Federation (IDF) and 90 healthy controls without or even have a single parameter of metabolic syndrome. A written informed consent was obtained from each study subject.

IDF criteria are: central obesity (defined as waist circumference >80 cm). If BMI is > 30 Kg/m², central obesity can be assumed and waist circumference does not need to be measured, BMI has no relation with central obesity measured by WC, as there are some bodies have BMI > 30 Kg/m² and WC less than 88 cm, triglycerides >150 mg/dL or specific treatment for this lipid abnormality, HDL-cholesterol < 50 mg/dL and blood pressure >130/85 mmHg or treatment of previously diagnosed hypertension, fasting plasma glucose >100 mg/dL or previously diagnosed type 2 diabetes. When central obesity plus two of the four previous criteria are met, a diagnosis of metabolic syndrome can be made [17]. BMI was calculated as weight (kg) divided by height (m) squared (kg/m²). BAI was calculated using the equation ((hip circumference)/((height) 1.5)-18) [18].

WC and hip circumference (HC) were measured using inelastic tape at the level midway between the lateral lower rib margin and iliac crest as well as at the levels of trochanters. WHR was calculated as WC divided by HC and WHtR was calculated as WC divided by height in centimeters.

Serum analysis

Blood samples were collected after a 12-h overnight fast and stored at < 80°C until analyzed. An Olympus AU400 automatic analyzer (Olympus Corporation, Tokyo, Japan) was used to measure serum total cholesterol (TC), High Density Lipoprotein cholesterol (HDL-C), triglycerides (TG) and low Density Lipoprotein cholesterol (LDL-C) was calculated. Fasting blood glucose (FBG) was measured with commercial kits (Roche Diagnostics, Indianapolis, IN, USA) and fasting blood insulin (FBI) were determined with the Phadebas Insulin Test (Pharmacia, Uppsala, Sweden) using a radioimmunosorbent technique. The insulin sensitivity was then calculated using Homeostasis Model Assessment (HOMA-IR) according to the following formula: \( \text{HOMA-IR} = \frac{\text{FBG} \times \text{FBI}}{22.5} \).

Table 1: Age, anthropometric, clinical and biochemical indices characteristics of the study participants

| Characteristics | MS | Non-MS |
|-----------------|----|--------|
| Age             | 28.42 ± 2.45 | 29.42 ± 3.56 |
| BMI (kg/m²)     | 33.42 ± 3.70 | 23.51 ± 2.91 *** |
| Waist circumference (cm) | 106.42 ± 10.00 | 99.46 ± 17.395 *** |
| Hip circumference (cm) | 125.22 ± 12.89 | 119.01 ± 10.78 *** |
| WHR             | 0.89 ± 0.05 | 0.80 ± 0.13 *** |
| WHtR            | 0.72 ± 0.01 | 0.59 ± 0.01 *** |
| BAI (kg²/m⁴)    | 35.75 ± 4.22 | 25.65 ± 3.31 *** |
| Systolic BP (mmHg) | 120.00 ± 12.6 | 115.71 ± 18.44 *** |
| Diastolic BP (mmHg) | 94.54 ± 6.87 | 73.83 ± 10.43 *** |
| FBG (mg/dL)     | 112.52 ± 8.22 | 90.52 ± 5.22 *** |
| FBI (μU/mL)     | 18.20 ± 0.85 | 8.20 ± 0.65 *** |
| HOMA-IR         | 6.88 ± 1.29 | 2.39 ± 0.99 *** |
| Triglycerides (mg/dL) | 145.65 ± 20.61 | 100.41 ± 33.29 *** |
| Total cholesterol (mg/dL) | 174.71 ± 30.81 | 124.71 ± 23.81 *** |
| LDL-C (mg/dL)   | 163.71 ± 35.890 | 112.81 ± 29.381 *** |
| HDL-C (mg/dL)   | 45.44 ± 15.217 | 47.96 ± 14.560 *** |

BMI: body mass index; WHR: waist to hip ratio; WHtR: waist to height ratio; BAI: body adiposity Index; FBG: fasting blood glucose; FBI: fasting blood insulin; HOMA-IR: homeostasis model assessment of Insulin Resistance; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol. *** Significant at p-value < 0.001.

Statistical Analyses

All the data were tested for their normal distribution (Kolmogorov–Smirnov test). Results are expressed as means and standard deviations (SD). Student t test for unpaired data was used to evaluate differences in anthropometric and biochemical characteristics between cases and controls.

The existence of significant bivariate correlations between parameters such as BAI, BMI, WHR, WHIR and biochemical parameters and metabolic risk factors was ascertained by determining correlation coefficients. Receiver operating characteristic curves were used to determine discriminatory capacity of BAI, WHR, WHIR and BMI for metabolic syndrome risk.

Statistical analysis was carried out using IBM SPSS Statistics 20.0 software (SPSS/IBM, Chicago, IL, USA). Significance was accepted at p<0.05.

Results

Table 1 shows clinical, biochemical and anthropometric characteristics of the study participants. Statistically significant differences were found between the MS cases and controls in all anthropometric and biochemical parameters. Women with MS showed significant higher values of BMI, WC, HC, WHR, WHIR, BAI, blood pressure levels, LDL-C,
TG, FBI, FBG, HOMA-IR and lower HDL-C than normal controls (p < 0.001).

Figure 1: ROC Curve to determine the diagnostic value of body adiposity indices to predict the metabolic Syndrome

Table 2: Partial correlations between adjusted body adiposity indices and metabolic components; to exclude the effect of age

| Metabolic Component | BAI | WHR | WHitR | BMI |
|---------------------|-----|-----|-------|-----|
| Systolic BP         | 0.727 | 0.590 | 0.461 | 0.361 |
| Diastolic BP        | 0.686 | 0.502 | 0.434 | 0.374 |
| FBG                 | 0.586 | 0.321 | 0.234 | 0.283 |
| HOMA-IR             | 0.486 | 0.482 | 0.464 | 0.253 |
| Triglyceride        | 0.485 | 0.404 | 0.384 | 0.251 |
| LDL-C               | 0.486 | 0.381 | 0.335 | 0.235 |

Table 2 shows the coefficients of partial correlation between anthropometric measures and metabolic risk factors. BAI had the highest correlation coefficients with metabolic components followed by WHR and WHitR and then BMI.

Discussion

The objective of this cross sectional study was to analyze correlation of body adiposity indices with metabolic risk factors among Egyptian women aged 25-35 years old. Adipose tissue accumulation increases the incidence and risk of adverse metabolic events and diseases.

To our knowledge this study is the first study focused on evaluating the applicability of BAI as a method to determine metabolic risk in a sample of Egyptian women and determine the validity of each of BAI, WHR, WHitR and BMI that might have predictive power for the risk of MS. The main finding of the present study is that BAI a good adiposity predictor for MS and overcome the limitations of BMI and the other indices analyzed. Body fat content, fat distribution or adiposity, therefore, could be considered as important indicators of metabolic risk. Body adiposity index has been developed, to overcome the shortcomings of BMI and it can be used to reflect body fat percentage (BF %) in adults [19, 20]. BAI was suggested to have several advantages over BMI, including that it yields similar associations with BF% for men and women and may be more practical to assess in field studies because it does not require a weight measurement and it can be used to reflect body fat percentage (BF %) in adults. It has been suggested that the BAI can be used to mirror %body fat for adult men and women of differing ethnicities without numerical correction.

BAI was suggested to have several advantages over BMI, including that it yields similar associations with BF% for men and women and may be more practical to assess in field studies because it does not require a weight measurement [21].

Current study tested adiposity indices for identifying MS using ROC curves and detect their sensitivity and specificity in the categorization of MS among Egyptian women.

The present results demonstrated that BAI has the higher discriminatory capacity (higher area under the curve) than the WHR, WHitR and BMI from ROC curves for identifying MS (IDF criteria). Area Under the Curve (AUC) was 69.8% for BIA, 67.3% for WHR, 65.9% for WHitR and 61.3% for BMI, indicating that BMI has the weakest predictive power as compared to other adiposity indices. Moreover, partial correlation analysis showed that BAI had the highest correlation with metabolic risk factors compared to other adiposity indices. BAI level in subjects with metabolic syndrome was 35.75 ± 4.22 and 25.65 ± 3.31 in healthy controls.

The syndrome is common and has a rising prevalence worldwide, relating largely to a complex interplay of rapid nutritional alterations, sedentary lifestyle and socioeconomic evolution, increasing affluence, rural -tourban migration, leading to obesity [22].

However other studies reported that BAI could be less useful than BMI when the metabolic health risk is evaluated. Furthermore, this study suggested that WC and WHR may be even better candidates than BMI or BAI as simple (only tape measurements are required) and practical indicators of cardiovascular health risk [23].

In the IDF definition for MS, central obesity (increased WC) is a pre-requisite criterion in addition to two or more of the other major risk factors. The IDF
definition was adopted in this study for identifying subjects with MS and studying the relation between different risk factors. Different measures of central obesity have been developed over time including WHR, BMI, WC, and WHtR [22-24]. The first definition of MS by World Health Organization (WHO) used BMI and WHR. The ATPIII used BMI and WC to indicate central obesity, whereas the IDF only used WC in their MS criteria.

Our study showed significant partial correlations between adiposity indices and metabolic syndrome risk factors after controlling for age with highest correlations BAI followed by WHR then WHtR and BMI. In agreement to the current study, several studies have shown that the BAI supposes a new approach in order to determine the adiposity and MS [19-24].

WHR ratio may reflect visceral fat more accurately than WC, since the latter indicator does not reflect visceral fat properly as it may stay the same because WC and hip circumference can increase or decrease proportionately. However, previous study from Iran demonstrated that increased WHR was a better predictor for CVD risk factors than BMI, WC and WHR, in all age groups [25]. BAI has been suggested to have several advantages over BMI. BAI gives similar associations with BF% for men and women and may be more practical to assess in field studies because it does not require a weight measurement. Many techniques have been developed for assessing and/or determining body fat or adiposity. These include the BMI, WC, WHR, skinfold thickness, dual energy X-ray absorption (DXA) and hydrostatic densitometry [22-26].

In our study, BMI, BAI were and WHR were significantly correlated with metabolic parameters; correlations of BAI were stronger than WHR and BMI. ROC analysis revealed also superior discrimination of BAI compared to BMI and WHR.

A recent study done in north India concluded that the correlation of BMI to percentage of body fat was better than that of BAI to percentage of body fat, the sensitivity and specificity of BAI were similar to, if not better than, BMI [27, 28].

The BAI can be measured without weighing, which renders it BAI was developed and validated in studies of Mexican American and African-American adults. Several studies of BAI values for predicting fat content or metabolic disorders in European-American, Mexican-American, Caucasian and Asian subjects have reported controversial results [29-31]. In Caucasians, BAI is a better estimate of adiposity than BMI in non-obese subjects, but less effectively than BMI in obese men and women. Another study reported that BMI more strongly correlated with BF% than BAI, and more highly associated with diabetes risk in Caucasian [32]. BMI was more accurate surrogate for adiposity in American [33, 34], Mexican Americans [35] Caucasian [36, 37] and Asian subjects [38]. Lifestyles have been changed over the preceding decades in developing countries, especially in Egypt. Increase in sedentary lifestyles has been observed that likely contribute to an increased incidence of MS [39]. Moreover, MS and its components (high waist circumference, high triglyceride levels, and low high density lipoprotein cholesterol levels) were significantly associated with menstrual irregularity in women of reproductive age [40].

In conclusion, BAI is practical predictor for MS and has a significant diagnostic accuracy for diagnosing MS among Egyptian women and can be used as a useful predictor in addition to other adiposity indices (WHR, WHtR and BMI) for identifying MS in the field studies.

References

1. Dietz WH, Robinson TN. Clinical practice. Overweight children and adolescents. N Engl J Med. 2005; 352: 2100–2109. http://dx.doi.org/10.1056/NEJMcp043052 PMid:15901863

2. Must A, Spadano J, Coakley EH, Field AE, Colditz G, et al. The disease burden associated with overweight and obesity. JAMA. 1999:282:1523–1529. http://dx.doi.org/10.1001/jama.282.16.1523 PMid:10546691

3. Ross R, Berentzen T, Bradshaw AJ, Janssen I, Kahn HS, et al. Does the relationship between waist circumference, morbidity and mortality depend on measurement protocol for waist circumference? Obes Rev. 2008;9:312–325. http://dx.doi.org/10.1111/j.1467-789X.2007.00411.x PMid:17956544

4. Eckel RH, Alberti KG, Grundy SM, Zimet PZ. The metabolic syndrome. Lancet. 2010;375: 181–183. http://dx.doi.org/10.1016/S0140-6736(09)61794-3

5. Mathieu P, Poirier P, Pibarot P, Lemieux I, Despres JP. Visceral obesity: the link among inflammation, hypertension, and cardiovascular disease. Hypertension. 2009;53:577–584. http://dx.doi.org/10.1161/HYPERTENSIONAHA.108.110320 PMid:19237885

6. Whillock G, Lewington S, Sherliker P, Clarke R, Emberson J, et al. Body mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. Lancet. 2009;373:1083–1096. http://dx.doi.org/10.1016/S0140-6736(09)60318-4

7. Huffman KM, Sun JL, Thomas L, Bales CW, Califf RM, Yates T, et al. Impact of baseline physical activity and diet behavior on metabolic syndrome in a pharmaceutical trial: results from NAVIGATOR. Metabolism. 2014;63: 1511–1521. http://dx.doi.org/10.1016/j.metabol.2014.01.002 PMid:24559843 PMCID:PMC4103164

8. Hamaans N, Noda M, Moriyama S, Yoshikawa K, Katsuyama H, Sako A, Mishima S, Kakei M, Ezaki O, Yanai H. Daily Physical Activity Assessed by a Triaxial Accelerometer Is Beneficially Associated with Waist Circumference, Serum Triglycerides, and Insulin Resistance in Japanese Patients with Prediabetes or Untreated Early Type 2 Diabetes. J Diabetes Res. 2015:2015:526201. http://dx.doi.org/10.1155/2015/526201 PMid:26064983 PMCID:PMC4441997

9. Preis SR, Massaro JM, Robins SJ et al. Abdominal subcutaneous and visceral adipose tissue and insulin resistance in
the Framingham heart study. Obesity. 2010;18:2191–2198. http://dx.doi.org/10.1038/oby.2010.59 PMid:20339361 PMCid:PMC3033570

10. Shay CM, Carnethon MR, Church TR et al. Lower extremity fat mass is associated with insulin resistance in overweight and obese individuals: The CARDIA Study Obesity. 2011;19:2248–2253. http://dx.doi.org/10.1038/oby.2011.113 PMid:21617639 PMCid:PMC3203327

11. Goedette JH, Levitt NS, Lambert EV et al. Differential effects of adiponectin and tissue distribution on insulin sensitivity in black and white South African women. Obesity. 2009;17:1506–1512. http://dx.doi.org/10.1038/oby.2009.73 PMid:19300428

12. Katzmarzyk PT, Gagnon J, Leon AS, Skinner JS, Wilmore JH, et al. Fitness, fatness, and estimated coronary heart disease risk: the HERITAGE Family Study. Med Sci Sports Exerc. 2001;33:585–590. http://dx.doi.org/10.1097/00005768-200104000-00012 PMid:11283434

13. Tanaka H, Clevering CM, Jones PP, Seals DR, Desouza CA. Influence of body fatness on the coronary risk profile of physically active postmenopausal women. Metabolism. 1998;47:1112–1120. http://dx.doi.org/10.1016/S0026-0495(98)00286-4

14. National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation. 2002;106:3143–3421. PMid:12485966

15. IDF. The IDF consensus worldwide definition of the metabolic syndrome (booklet online). 2005. Available from: http://www.idf.org/webdata/docs/IDF_Meta_def_final.pdf. Accessed 15 Sept 2013.

16. Ford ES, Gles WS, Dietz WH. Prevalence of the metabolic syndrome among US adults: findings from the third National Health and Nutrition Examination Survey. JAMA. 2002;287:356–359. http://dx.doi.org/10.1001/jama.287.3.356 PMid:11790215

17. Grundy SM. Metabolic syndrome pandemic. Arterioscler Thromb Vasc. 2008;28:629–636. http://dx.doi.org/10.1161/ATVBAHA.107.151092 PMid:18174459

18. Bergman RN, Stefanovski D, Buchanan TA, Sumner AE, Reynolds JC, et al. A better index of body adiposity. Obesity (Silver Spring). 2001;9:1035–1055. http://dx.doi.org/10.1038/oby.2001.133 PMid:11321607

19. Bennasar AH, Sung J, Ah Sung, Jee-Young Oh, Hyejin Lee. Comparison of the Body Adiposity Index to Body Mass Index in Korean Women. Yonsei Med J. 2014;55:1028–1035. http://dx.doi.org/10.3349/yjm.2014.55.4.1028 PMid:24954333 PMCid:PMC4075363

20. Appelhans BM, Kazlauski R, Karavolos K, Janssen I, Kravitz ML, Vicente T, et al. Body adiposity index, body adiposity index, and percent body fat in Asians. Am J Clin Nutr. 2012;96:299–305. http://dx.doi.org/10.1002/ajpa.22341

21. Yeon-Chul Ha, Hye Jin Lee, Sung Lee, Chang-ae Kwon. Comparison of the Body Adiposity Index to Body Mass Index in Korean Women. Yonsei Med J. 2014;55:1028–1035. http://dx.doi.org/10.3349/yjm.2014.55.4.1028 PMid:24954333 PMCid:PMC4075363

22. Snijder MB, Nicolaou M, van Valkengoed IG, Brewster LM, Stroons K. Newly proposed body adiposity index (bai) by Bergman et al. is not strongly related to cardiovascular health risk. Obesity (Silver Spring). 2012;20:1138–1139. http://dx.doi.org/10.1038/oby.2011.338 PMid:22627979

23. Romo I, Roth J. Genetic and environmental interactions in obesity and type 2 diabetes. J Am Diet Assoc. 2008;108: S24–S28. http://dx.doi.org/10.1016/j.jada.2008.01.022 PMid:18358250

24. Lee K, Song Y, Sung J. Which obesity indicators are better predictors of metabolic risk? Healthy twin study. Obesity. 2008;16:834–840. http://dx.doi.org/10.1038/oby.2007.109 PMid:18295959

25. Esmailzadeh A, Mirmiran P, Azizi F. Waist-to-hip ratio is a better screening measure for cardiovascular risk factors than other anthropometric indicators in Tehranian adult men. Int J Obes Relat Metab Disord. 2004;28:1325–1332. http://dx.doi.org/10.1016/j.ijobm.2003.09.003 PMid:15314626

26. Goran MI, Driscoll P, Johnson R, Nagy TR, Hunter G. Cross-calibration of body-composition techniques against dual-energy X-ray absorptiometry in young children. Am J Clin Nutr. 1996;63:299–305. PMid:8602584

27. Piers LS, Soares MJ, Frandsen SL, O’Dea K. Indirect estimates of body composition are useful for groups but unreliable in individuals. Int J Obes Relat Metab Disord. 2000;24:1145–1152. http://dx.doi.org/10.1038/ijobm.110033983 PMid:110033983

28. Yeon-Ah Sung, Jee-Young Oh, Hyejin Lee. Comparison of the Body Adiposity Index to Body Mass Index in Korean Women. Yonsei Med J. 2014;55:1028–1035. http://dx.doi.org/10.3349/yjm.2014.55.4.1028 PMid:24954333 PMCid:PMC4075363

29. Zhao D, Li Y, Zheng L, Yu K. Brief communication: body mass index, body adiposity index, and percent body fat in Asians. Am J Phys Anthropol. 2013;152:294–299. http://dx.doi.org/10.1002/ajpa.22341

30. Johnson W, Chunleewa 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;20:900–9003. http://dx.doi.org/10.1038/oby.2011.346 PMid:22095112 PMCid:PMC3988697

31. Lopez AA, Cespedes ML, Vicente T, Tomas M, Bennasar-Veny M, Tauler P, et al. Body adiposity index utilization in a Spanish population. Obes Res. 2002;10:388–399. http://dx.doi.org/10.1038/oby.2002.33 PMid:12044721

32. Sun G, Cahill F, Gilliver W, Yi Y, Xie Y, Bridger T, et al. Concordance of BAI and BMI with DXA in the Newfoundland population. Obesity (Silver Spring). 2012;20:1138–1139. http://dx.doi.org/10.1038/oby.2011.346 PMid:22095112 PMCid:PMC3988697

33. Schulze MB, Thorand B, Fritsche A, Haring HU, SchickF, Zierer M, Tauler P, et al. Body adiposity index utilization in a Spanish Mediterranean population: comparison with the body mass index. PLoS One. 2012;7:e35281. http://dx.doi.org/10.1371/journal.pone.0035281 PMid:22496915 PMCid:PMC3322155

34. Sun G, Cahill F, Gilliver W, Yi Y, Xie Y, Bridger T, et al. Concordance of BAI and BMI with DXA in the Newfoundland population. Obesity (Silver Spring). 2013;21:499–503. http://dx.doi.org/10.1002/oby.202009 PMid:23049692
severely obese women. Int J Body Compos Res. 2012;10:9-14. PMid:23243391 PMCid:PMC3520094

36. Lichtash CT, Cui J, Guo X, Chen YD, Hsueh WA, Rotter JI, et al. Body adiposity index versus body mass index and other anthropometric traits as correlates of cardiometabolic risk factors. PLoS One. 2013;8:e65954. http://dx.doi.org/10.1371/journal.pone.0065954 PMid:23776578 PMCid:PMC3679008

37. López AA, Cespedes ML, Vicente T, Tomas M, Bensusar - Veny M, Tauler P, et al. Body adiposity index utilization in a Spanish Mediterranean population: comparison with the body mass index. PLoS One. 2012; 7:e35281. http://dx.doi.org/10.1371/journal.pone.0035281 PMid:22496915 PMCid:PMC3322155

38. Zhao D, Li Y, Zheng L, Yu K. Brief communication: body mass index, body adiposity index, and percent body fat in Asians. Am J Phys Anthropol. 2013;152:294-299. http://dx.doi.org/10.1002/ajpa.22341

39. Hastert TA, Gong J, Campos H, Baylin A. Physical activity patterns and metabolic syndrome in Costa Rica. Prev Med. 2015;70:39–45. http://dx.doi.org/10.1016/j.ypmed.2014.11.006 PMid:25445330 PMCid:PMC4341893

40. Lee SS, Kim do H, Nam GE, Nam HY, Kim YE, Lee SH, Han KD, Park YG. Association between Metabolic Syndrome and Menstrual Irregularity in Middle-Aged Korean Women Korean J Fam Med. 2016;37:31–36. http://dx.doi.org/10.4082/kjfm.2016.37.1.31 PMid:26885320 PMCid:PMC4754284