

The accuracy of currently used WHO's Body Mass Index cut-off points to measure Overweight and Obesity in Syrian women: A correlation study

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ABSTRACT

Purpose: Obesity is a common health problem in both developed and developing countries. BMI is commonly used to identify obesity. However, there is increasing evidence that the relationship between BMI and BF% differs among various ethnicities. The main objectives of this study are (1) to evaluate the correlation between BF% as determined by BIA, DEXA, Deuterium oxide (D2O) and BMI, (2) to assess the accuracy of currently used WHO's BMI cut-off points to identify overweight and obesity among Syrian women.

Material and Methods: A total of 908 healthy Syrian women aged 18-60 years participated in this study. Weight, height, BMI, BF% assessed by BIA and DEXA, and D2O have been determined.

Results: BF% results obtained by BIA and DEXA, and D2O revealed strong correlations. BMI showed a statistically significant correlation with BF% determined by BIA, DEXA and D2O. Obesity when defined as BMI ≥ 30 and as BF% $> 35\%$ (derived from BIA, DEXA and D2O) classified 43%, 52.5%, 75.9% and 72.7% of women as obese, respectively. ROC analysis defined BMI cut-off points for overweight and obesity of 22.5 and 25.7, respectively. Using the new BMI cut-off point, the prevalence of obesity among Syrian women was increased by 24%.

Conclusions: The current BMI cut-off points recommended by WHO underestimate the prevalence of overweight and obesity among Syrian women. Our data suggests that it is important to lower the proposed WHO's BMI cut-off points for the Syrian women.

Key words: Obesity, BMI, DEXA, BIA, D2O

INTRODUCTION

Overweight and obesity are important health issues globally and their prevalence is rapidly escalating in both developed and developing countries [1-3]. The WHO has defined obesity as a condition with excessive fat accumulation in the body, to the extent that health is adversely affected [4]. Obesity is measured by various methods such as body mass index (BMI), waist circumference (WC), waist-hip ratio (WHR) and skin fold thickness. However, obesity is commonly defined by the measurement of BMI (weight/height²) [1,5]. This approach is simple, safe and practical, but its main limitation is that it cannot differentiate between fat mass (FM) and lean body mass (LBM) and it may misclassify people with high muscle mass into overweight or obese. Hence, an accurate evaluation of obesity should be based on the measurement of body FM. The upper limits of FM for defining obesity have been set as FM>25% in males and > 35% in females, corresponding to a BMI of 30 kg/m² in Caucasians [6]. However, in vivo, the amount of FM can be measured by a number of techniques including: underwater weighing (hydro densitometry), air displacement (bod pod), bioelectrical impedance analysis (BIA), dual energy X-ray absorptiometry (DEXA), computerised tomography (CT) and magnetic resonance imaging (MRI) and isotope dilution technique (deuterium oxide, D2O). Most of these techniques have proven their validity in determining FM [1, 7, 8-10].

There is increasing evidence that the relationship between BMI and BF% differs among various ethnicities. It has been demonstrated that Asians have a higher BF% in lower BMI points compared to Caucasians, while Blacks and Polynesians have a low BF% at any given BMI point compared to Caucasians [11-12]. Therefore, the BMI classification of obesity in Asians has been controversial and there has been growing investigation on whether the accepted BMI cut-off points are suitable for identifying increased health risks for Asian population. The WHO considered this issue and proposed that Asians have different association between BMI, BF% and health risks than the Europeans, and they concluded that the proportion of Asians with a high risk of developing obesity related morbidity is substantial at BMIs lower than existing WHO cut-off points for overweight and obesity (BMI values of 23 and 25 kg/m² as the cut-off points for overweight and obesity) [13-16]. Consequently, WHO proposed developing country-specific BMI cut-off point for public health intervention [17]. Since 2002, several studies have attempted to identify an appropriate BMI cut-off point for Asian populations [18-21]. Therefore, data on accurate BMI cut-off points based on BF% to define overweight and obesity of different ethnicities are required for more accurate assessment of risk of obesity related morbidity and mortality.

The main objectives of current study were to evaluate

the correlation between BF%, as determined by BIA and DEXA, D2O, and BMI, and to assess the accuracy of currently used WHO's BMI cut-off points to identify overweight and obesity among Syria women. Receiver Operating Characteristic Curves (ROC) analysis has been used in the present study to propose new cut-off points for BMI for overweight and obesity in Syrian women.

MATERIALS AND METHODS

Participants

The study subjects were recruited by local advertisement and consisted of 908 healthy women (non-pregnant or lactating) aged 18 to 60 years. The main exclusion criteria were previously known or newly diagnosed diabetes, thyroid, liver or kidney diseases, malignancies, markedly elevated blood pressure and any medication influencing body composition. The study protocol was approved by the scientific research and the ethical committee of the Atomic Energy Commission of Syria (AECS). Each participant provided informed consent prior to participation after a detailed explanation of the study protocol. This study was performed in accordance with guidelines prescribed by Helsinki Declaration of the world Medical association. All of the measurements were done by the same person using the same equipment during morning hours. The participants performed no strenuous physical activity for 24 h, arrived in the morning after an overnight fast at the Human Nutrition Unit, health centre, AECS. Brief clinical examination was performed by specialised medical doctors.

Anthropometric measurements

Body weight was measured using an electronic scale (Seca, Model 7671321004, Germany) and height was measured using a well-mounted stadiometer (Seca, Model 1721009, Germany). Participants were measured barefoot in light underwear. BMI was calculated as weight divided by height squared (kg/m²). Four categories of BMI were classified according to WHO cut-off points as follows: Individuals with a BMI ≤18.5 kg/m² were classified as underweight, individuals with a BMI 18.5–24.9 were classified as normal, overweight (BMI 25–29.9) and obese (BMI ≥ 30).

Percentage body fat determination

Percentage body fat was determined using three major methods:

1. Bioelectrical impedance analysis (BIA):

BF% was estimated using commercially available BIA analyser system (Bodystat Quad scan

4000, British ISLES) in all studied groups in accordance with the manufacturer's instruction manual between 9 and 10 h in the morning. The reliability and validity of this system in measuring BF% has been previously verified in multiple ethnicities [8, 9]. BF% was calculated from the whole body impedance value and the pre-entered personal data (age, gender, height and weight) of the corresponding women. Whole-body composition was estimated using standard equations provided by the manufacturer. WHO classification of overweight and obesity based on BF% (> 30% and >35% as the cut-off points of women overweight and obesity, respectively) was used for interpretation of the findings.

2. Dual energy X-ray absorptiometry (DEXA):

BF% was also measured for all groups using whole body DEXA scan with Lunar Prodigy Advance System (analysis version: 13.20) manufactured by GE Healthcare. Daily quality control was carried out by measurement of a Lunar phantom in accordance with the manufacturer's instruction manual. At the time of the study, phantom measurements showed stable results.

3. Isotope Dilution Technique (Deuterium Oxide, D2O):

Randomly selected 66 women of the participating group were also subjected to BF% determination by deuterium oxide. BF% was estimated from total body water (TBW). TBW was determined according to plateau method [22] and measured with mass spectroscopy [8]. Each woman received orally a dose of D2O (0.05 g/kg body weight) (99.8% atom present excess; Cambridge Isotope D2O laboratories, Inc, United Kingdom). The saliva samples were taken at baseline, after an overnight fast and at 3 h after ingesting the D2O (endpoint), assuming that the plateau was reached at 3 hours [9]. Absorbent salivates (sarstedt, Rommelsdorf, Germany) were used to collect the saliva. The level of D2O in the saliva samples were analysed using Isoprime Ratio Mass Spectrometry (IRMS, GV Instrument). The values obtained were expressed relative to secondary standards. Low-enrichment and high-enrichment standard water were similarly prepared to normalise data against V-SMOW-SLAP-GISP (Vienna Standard Mean Ocean Water/Standard Light Antarctic Precipitation/Greenland Ice Sheet Perception). All samples were prepared and analysed in triplicate. The following equation was used for the calculation D2O dilution space (N) [9]:

$$N = (TA/a) * ((Ea - Et) / (Es - Ep))$$

Where A is the amount of isotope given in grams, a is the portion of the dose in grams

retained for mass spectrometer analysis, T is the amount of tap water in which the portion of a was diluted before analysis, and Ea, Et, Ep and Es are the isotopic enrichments in delta units of the portion of dose, the tap water used, the pre-dose saliva sample, and the post-dose saliva sample, respectively. The D2O dilution space was assumed to overestimate TBW by a factor of 1.04 [10]. Fat free mass (FFM) was calculated from TBW, assuming that FFM has a hydration constant of 0.73 [23]. BFM was calculated as scale weight minus FFM.

Statistical analysis

All analyses were performed by using the Statistical Package for Social Science SPSS (version 17). Means and standard deviations have been calculated for all measures of body composition. Multiple regression analysis was performed to detect the relationship between the variables; the coefficients of determination (R2) for each regression model were calculated. Comparison between the different methods of body composition was performed using the statistical analysis of Bland and Altman [24]. The mean difference between methods and the 2 SDs of the difference between methods were calculated, and the level of significance was determined as a P value < 0.05.

BMI cut-off points for overweight and obesity in Syrian women have been evaluated using ROC. Analysis using ROC curves involves calculation of sensitivity and specificity rates corresponding to various BMI cut-off points. The ROC statistical results and ROC curves were used to determine which BMI value provides maximum classification accuracy, defined as sensitivity and specificity. The area under the curve (AUC) statistic is a global measure of the overall diagnostic accuracy of BMI to determine the obesity status.

RESULTS

In total, 908 women met the inclusion criteria and provided informed consent to participate in the study. The characteristics of volunteer's sample included in the study are shown in table 1 and 2. The mean age, weight, height and BMI (SD) of the studied group were 42.3 (10.89) years, 73.34 (15.62) kg, 157.7 (5.49) cm and 29.5 (5.5) kg/m² within age range of 18-60 years. All these values increased progressively across age groups, except the height. BF% as measured by BIA, DEXA, D2O in Syrian women are shown in table 1 and 2. BF% was significantly increased in the age group 31-40 years, followed by moderate increase in the age group 41-50 years and minimal increase in the age group 51-60 years.

The total BF% (38.65±5.06) derived from

TABLE 1. The characteristics of women sample and BF% ($m \pm SD$) as measured by BIA and DEXA in various age groups.

AGE	NO (%)	WEIGHT KG M(SD)	HEIGHT CM M(SD)	BMI KG/M ² M(SD)	BF% BIA M(SD)	BF% DEXA M(SD)	BMI, BF% CORRELATION	
							BF% BIA	BF% DEXA
18-30	155 (17.07%)	61.70 (12.28)	158.99 (5.20)	24.40 (4.73)	29.18 (6.59)	39.22 (7.83)	0.74	0.71
31-40	224 (24.67%)	70.92 (14.05)	158.69 (5.48)	28.15 (5.29)	35.32 (6.31)	43.55 (6.19)	0.78	0.66
41-50	291 (32.05%)	76.98 (15.17)	158.04 (5.33)	30.83 (5.95)	39.95 (6.36)	46.11 (6.23)	0.73	0.66
51-60	238 (26.21%)	78.76 (15.10)	155.52 (5.30)	32.57 (6.09)	43.93 (5.86)	47.27 (5.64)	0.71	0.54
All ages	908 (100%)	73.34 (15.62)	157.70 (5.49)	29.53 (6.30)	38.01(8.03)	44.60 (6.96)	0.78	0.69

BIA: Bioelectrical Impedance

DEXA: Dual Energy X-ray Absorptiometry

TABLE 2. The characteristics of women sub-group sample and BF% ($m \pm SD$) as measured by D2O.

AGE GROUP (YEARS)	NO (%)	BF% D2O M(SD)	BMI, %BF CORRELATION
18-30	11 (16.7)	36.94 (6.00)	0.66
31-40	18 (27.3)	40.39 (5.24)	0.67
41-50	23 (34.8)	42.26 (5.32)	0.73
51-60	14 (21.2)	43.64 (5.01)	0.74
All ages	66 (100)	41.25 (5.84)	0.75

D2O: Deuterium Oxide (isotope dilution technique)

D2O method, in randomly selected 66 women of the participating group, was higher than BF% derived from BIA and lower than that of DEXA (32.36 ± 6.30), (41.29 ± 6.14), respectively, in the same group of 66 women. The mean differences were +6.29%, -2.64%, respectively. However, the BF% results obtained by BIA, DEXA and D2O revealed a strong correlation ($R^2=0.79$, 0.71) ($p < 0.0001$), respectively; these correlations are shown in figure 1.

The relationship between BMI and BF%, measured by BIA, DEXA and D2O, are shown in figures 2. These figures show a statistically significant correlation between BF% and BMI in the Syrian women. The correlation between BMI and BF% measured by BIA, DEXA and D2O were also studied in all different age groups separately. These results

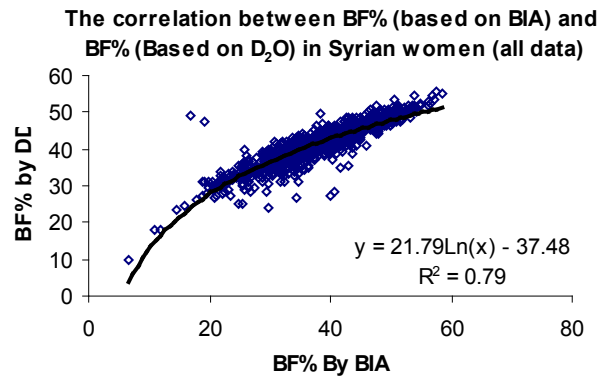
also, reveal close statistically significant correlations in all age groups. The results are shown in table 2.

Using the WHO's BMI cut-off values of overweight (BMI 25–29.9) and obese (BMI ≥ 30) as cut-off points, 31% and 43% of women were classified as overweight and obese, respectively. The results showed that 74% of women were either overweight or obese.

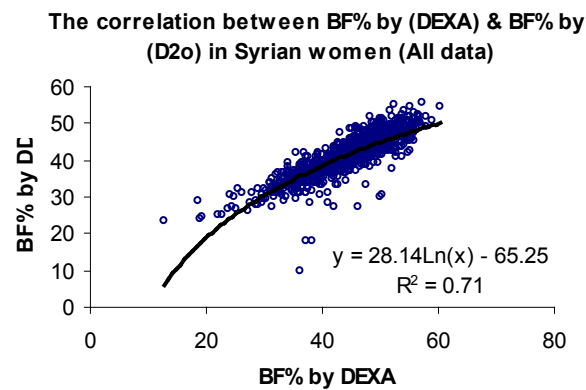
ROCs were drawn to define BMI cut-off points for defining overweight and obesity using BIA, DEXA and D2O methods. Cut-off points of BF% as recommended by WHO were used. The results are presented in table 3. Cut-off points of 25.55, 21.55 and 20.59 for overweight and 28.35, 24.75 and 24.06 for obesity in Syrian women were derived, respectively. Sensitivity, specificity and area under the curve for each cut-off point are also

FIGURE 1. The relationship between BF% measured by D2O, and BIA, DEXA. (A) BIA, (B) DEXA

(A):



(B):



shown. When these values (resulting for using BIA, DEXA and D2O) were used to define overweight and obesity ratios among Syrian women, 18.7%, 15% and 18.2% of the studied group were overweight, and 52.5%, 75.9% and 72.7% were obese (results are presented in table 4).

DISCUSSION

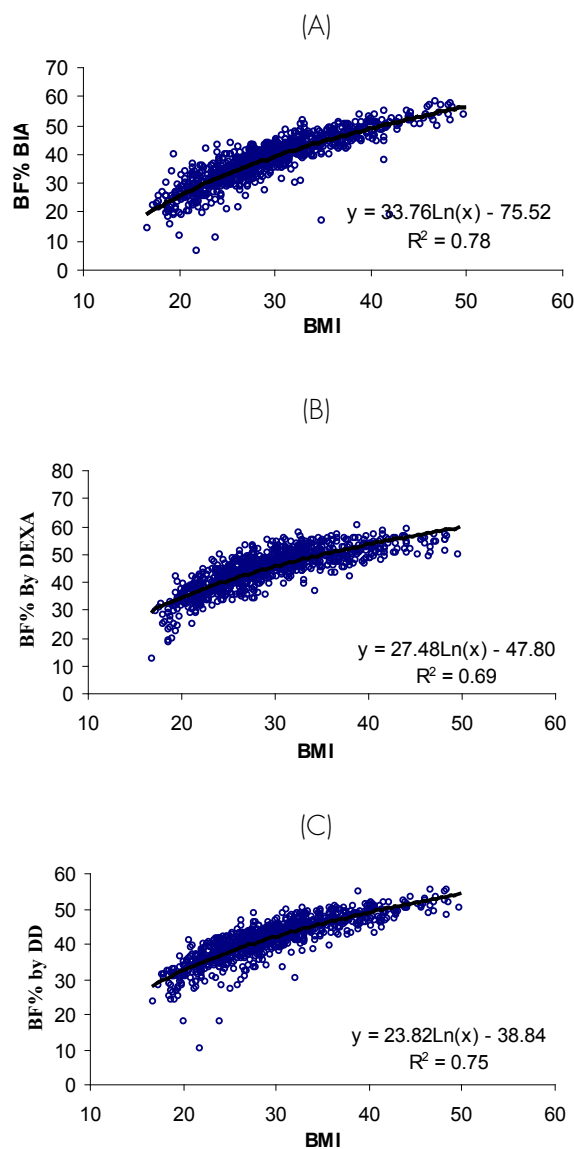
The current study is the first, in Syria, to evaluate the correlation between the currently used obesity BMI cut-off points and the criterion standard definition (proposed by WHO) of obesity in women using BF%. However, there are different methods to estimate BF%; their validity and reliability have been discussed in various studies [25-27]. BIA and DEXA methods were used to estimate the BF% in Syrian women. The use of BIA as a safe, inexpensive and valid tool has been accepted in nutritional epidemiologic studies in clinical practice for body composition. DEXA is an increasingly important method for the evaluation of body composition [28-29]. DEXA is available in many clinical

and research centres and provides a useful technique for the measurement of BF in epidemiological studies [29, 30-31]. However, in this study, the results of these methods were further calibrated through randomly selected 66 women of the participating group and subjected to BF measurement by D2O. The BF% results obtained by BIA, DEXA and D2O revealed a strong correlation ($R^2=0.79$, 0.71) ($p<0.0001$), respectively.

Many published studies have indicated that the relationship between BMI and BF% differs across various ethnicities [11-12]. The use of reliable data on accurate BMI cut-off points based on BF% to define obesity of different ethnicities is needed for precise assessment of individuals at risk of obesity related morbidity and mortality and consequently planning national treatment and prevention programme.

The results of the current study have shown a strong positive correlation between BMI and each of BF% measured by BIA, DEXA and D2O ($R^2=0.78$, 0.69 , 0.78 , $P<0.0001$, respectively). This was observed in total studied group and in each age group. These results are

FIGURE 2. The relationship between BMI and BF% measured by BIA, DEXA, and D2O. A (BIA), B (DEXA), C (D2O)



in agreement with previous studies, suggesting that BMI is highly related to adiposity and may be useful in identifying excess BF. In the current study, we have demonstrated these findings in a different ethnic sample of women from Syria (in the Eastern Mediterranean Region). In earlier studies by P.Deurenberg [32] and Jackson et al. [33] done in Caucasians, this interaction was significant. Rush et al. [34] also confirmed the significant positive relationship in BMI-BF% in European, Maori, and Pacific Islanders and Asian Indian adults. However, Meeuwssen [35] has recently shown that the association is not particularly good in UK adults, especially when BMI is less than 25 kg/m².

One major aim of the current study was identifying BMI cut-off points for defining overweight and obesity in Syrian women using BF%, as measured by BIA, DEXA, and D2O. The results of our study demonstrate that the

WHO BMI cut-off points for overweight and obesity are too high and do not reflect the actual amount of BF. Cut-off points of 25.55, 21.55 and 20.59 for overweight and 28.35, 24.75 and 24.06 for obesity in Syrian women were derived by ROCs. Using these criteria resulted in the misclassification of many obese Syrian women when compared with WHO BF%. When the new cut off points were used to define overweight and obesity ratios among Syrian women, 18.7%, 15% and 18.2% of the studied group were overweight, and 52.5%, 75.9% and 72.7% were obese as measured by BIA, DEXA, and D2O. The means of cut-off points for overweight and obesity obtained by the methods used in our study are 22.6 and 25.7, respectively. However, our results showed that the WHO's BMI cut-off points underestimate the ratio of obesity in the Syrian women by, approximately, 24% and

TABLE 3. Receiver operating characteristic ROC Data of BMI cut -off values in prediction of BF% in Syrian women.

CHARACTERISTICS	BODY FAT%	BMI CUT-OFF VALUE	SENSITIVITY %	SPECIFICITY %	AREA UNDER THE CURVE (AUC)	P VALUE
BF% (D2O) (n=66)	BF>30% BF>35%	20.59 24.06	95.2 91.8	100.0 82.4	0.968 0.900	0.006 0.001
BF% (DEXA) (n=908)	BF>30% BF>35%	21.55 24.75	93.8 84.7	96.7 89.0	0.983 0.940	0.001 0.001
BF% (BIA) (n=908)	BF>30% BF>35%	25.55 28.35	87.0 82.0	90.3 89.3	0.949 0.937	0.001 0.001

TABLE 4. Overweight and obesity rates in the current study based on BMI (WHO Criterion), and BF% as measured by BIA, DEXA, and D2O analysed according to ROC test.

METHODS (n)	NORMAL (n,%)	OVERWEIGHT (n,%)	OBESITY (n,%)
BMI(908)*	218(24)	281(31)	390(43)
BIA(908)	262(28.8)	170(18.7)	477(52.5)
DEXA(908)	83(9.1)	136(15)	689(75.9)
D2O(66)	6(9.1)	12(18.2)	48(72.7)

BMI (normal): 18.5-24.9 Kg/m², (Overweight): 25-29.9 Kg/m², (Obesity): ≥ 30 Kg/m²

BF%, BIA, DEXA, D2O: (normal): <30%, (overweight): ≥ 30-35%, (Obesity): >35%

Underweights are not included*

misclassify the ratio of overweight (taking the average of increased obesity using the three methods studied in current work). These results indicate that the group in the current study has lower BMI values for the same amount of BF% when compared to Caucasians. Similar findings were observed by Romero-Corral et al. [36], who reported that the current BMI cut-off point to define obesity had low sensitivity in USA women aged between 20-80 years old. They reported that the cut-off point should be 25.5 kg/m² among multi-ethnic women. Evans et al. [37] identified obesity as those with BMI values 26.9 kg/m² or greater among white women and 28.4 kg/m² or greater among black women. However, similar to our results, Blew et al. [38] proposed that the current WHO's BMI cut-off point to define obesity is too high. Based on ROC analysis, Blew et al. determined that a BMI cut-off point of 24.9 kg/m² was more accurate than the conventional 30 kg/m² for defining the obesity in mostly white post-menopausal women. Bozkirili et al [39] calculated a cut-off point in a group of Turkish women as 28.0 kg/m² (when obesity was defined as BF% > 35%) and concluded in their study

that the WHO cut-off point underestimates the obesity rate in the Turkish women and detected a 33.9% increase in their study. Similarly, Fernandez-Real [40], concluded that a BMI > 27.5 kg/m² could be indicative of obesity in Spanish population. This ethnicities difference is more likely to be a reflection of the racial differences in body composition. However, our results provide additional evidence that the currently used WHO's BMI points for defining overweight and obesity may be too high and associated with low overall sensitivity and specificity.

These research results, which represent some evidence that BMI differs according to ethnicity, were subject to an on going debate during the last two decades on using same BMI cut-offs in different ethnic groups [41]. A WHO expert consultation committee addressed this debate about the controversy of anthropometric cut-offs and urged for a review of scientific evidence on this issue. They reviewed scientific evidence that suggests that Asian populations have different associations between BMI, percentage of body fat and health risks than White Caucasian counterparts. After extensive literature review,

the consultation concluded that Asian populations have different associations between BMI, percentage of body fat and health risks than their white Caucasian counterparts [42]. The consultation concluded that Asians are at high risk of type 2 diabetes and cardiovascular disease at substantially lower BMI compared to the existing WHO cut-off level for overweight (>25 kg/m²). However, since they considered data from different Asian groups including South Asians and Chinese, they were unable to set a clear BMI cut-off value for all Asians overweight or obesity. Therefore, no attempt was made to redefine cut-off points for each population separately. The WHO expert consultation committee also agreed that the WHO BMI cut-off points should be retained as international classifications. The consultation identified further potential public health action points (23.0, 27.5, 32.5 and 37.5 kg/m²) along the continuum of BMI and proposed methods by which countries could make decisions about the definitions of increased risk for their population.

CONCLUSIONS

This is the first study in Syria to assess the accuracy of currently used WHO's BMI cut-off points to identify overweight and obesity among Syrian women and the relationship between BMI and BF%. Our results demonstrate that BMI strongly correlates with BF% as estimated by BIA, DEXA and D2O. The current BMI cut-off points recommended by the WHO are too high and do not reflect the actual amount of BF. Our results indicate that it is important to readjust the BMI cut-off points for our population; this suggests that women with currently accepted WHO's BMI cut-off points for overweight and obesity may require additional counselling on how to reduce their BF in order to avoid obesity related morbidity and mortality. Furthermore, our data suggests that using race or ethnic-specific BMI cut-off points or adopting new potential public health action points would be more appropriate in identifying overweight and obesity in various ethnicities.

Conflict of interest

The Authors declare that they have no competing interests to the present article.

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REFERENCES

1. World Health Organization. Obesity and overweight: fact sheet 2012; 311.
2. Popkin BM. The shift in stages of the nutrition transition in the developing world differs from past experiences. *Public Health Nutrition* 2002; 5(1): 205–14.
3. McLaren L. Socioeconomic status and obesity. *Epidemiologic Reviews* 2007; 29(1): 29–48.
4. Wagner DR, Heyward VH. Techniques of body composition assessment: a review of laboratory and field methods. *Res Q Exerc Sport* 1999; 70: 135–49.
5. Musaiger AO. Overweight and obesity in the Eastern Mediterranean region: can we control it? *Eastern Mediterranean Health Journal* 2004; 10(6): 789–93.
6. World Health Organisation. Physical Status: the use and interpretation of anthropometry. Technical Report Series, Geneva, 1995; 854.
7. Alsaif MA, Hakim IA, Harris RB, et al. Prevalence and risk factors of obesity and overweight in adult Saudi population. *Nutrition Research* 2002; 22(11): 1243–52.
8. Schoeller DA. Hydration. In: *Human Body Composition*, edited by Roche AF, Heymsfield Sb, and Lohman TG, IL: Human Kinetics 1996 chap. 1996; 2: 25–44.
9. Halliday D, Miler AG. Precise measurement of total body water using trace quantities of deuterium oxide. *Bio Mass Spec* 1977; 4: 82–9.
10. Forbes GB. Human body composition. In: *Growth, aging, nutrition, and activity*. Springer-Verlag 1987; 171: 279–96.
11. Gurrici S, Hartriyanti Y, Hautvast JGAJ, Deurenberg P. Relationship between body fat and body mass index: differences between Indonesians and Dutch Caucasians. *Eur J Clin Nutr* 1998; 52: 779–83.
12. Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat percent relationship. *Obes Rev* 2002; 3: 141–46.
13. Deurenberg P, Yap M, van Staveren WA. Body mass index and percent body fat: a meta analysis among different ethnic groups. *Int J Obes Relat Metab Disord* 1998; 22: 1164–71.
14. Stevens J, Nowicki EM. Body mass index and mortality in Asian populations: implications for obesity cut-points. *Nutr Rev* 2003; 61: 104–107.
15. He M, Tan KC, Li ET, Kung AW. Body fat determination by dual energy X-ray absorptiometry and its relation to body mass index and waist circumference in Hong Kong Chinese. *Int J Obes Relat Metab Disord* 2001; 25: 748–52.
16. Chang CJ, Wu CH, Chang CS, et al. Low body mass index but high percent body fat in Taiwanese subjects: implications of obesity cutoffs. *Int J Obes Relat Metab Disord* 2003; 27: 253–59.
17. World Health Organization. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *The Lancet* 2004; 363(9403): 157–63.
18. Oh SW, Shin SA, Yun YH, Yoo T, Huh BY. Cut-off point of BMI and obesity-related comorbidities and mortality in middle-aged Koreans. *Obes Res* 2004; 12: 2031–40.
19. Razak F, Anand SS, Shannon H, et al. Defining obesity cut points in a multiethnic population. *Circulation* 2007; 115: 2111–8.
20. Jee SH, Sull JW, Park J, et al. Body-mass index and mortality in Korean men and women. *N Engl J Med* 2006; 355: 779–87.

21. Gu D, He J, Duan X, et al. Body mass index and mortality among men and women in China. *JAMA* 2006; 295: 776-83.
22. Coward WA. The doubly-labelled water method for measuring energy expenditure. Technical recommendation for use in humans. International Dietary Energy Consultancy Group, International Atomic Energy Agency (IAEA) 1990; 48-68.
23. Pace N, Rathburn EN. Study on body composition. III: the body water and chemically combined nitrogen content in relation to fat content. *J Biol Chem* 1945; 158: 685-91.
24. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986; 1(8476): 307-10.
25. Berker D, Koparal S, Isik S, et al. Compatibility of different methods for the measurement of visceral fat in different body mass index strata. *Diagn Interv Radiol* 2010; 16(2): 99-105.
26. Minderico CS, Silva AM, Keller K, et al. Usefulness of different techniques for measuring body composition changes during weight loss in overweight and obese women. *Br J Nutr* 2008; 99(2): 432-41.
27. Fakhrawi DH, Beeson L, Libanati C, et al. Comparison of body composition by bioelectrical impedance and dual-energy x-ray absorptiometry in overweight/obese postmenopausal women. *J Clin Densitom* 2009; 12(2): 238-44.
28. Pietrobelli A, Formica C, Wang Z, Heymsfield SB. Dual-energy X-ray absorptio-metry body composition model: review of physical concepts. *Am J Physiol* 1996; 271: 941-51.
29. Lee SY, Lee SY, Gallagher D. Assessment methods in human body composition. *Clin Nutr Metab Care* 2008; 11: 566-72.
30. Kelly TL, Wilson KE, Heymsfield SB. Dual energy X-ray absorptiometry body composition reference values from NHANES. *PLoS One* 2009; 4: e7038.
31. Cornier MA, Despre's JP, Davis N, et al. Assessing adiposity: a scientific statement from the American Heart Association. *Circulation* 2011; 124: 1996-2019.
32. Deurenberg P, van der Kooy K, Hulshof T, Evers P. Body mass index as a measure of body fatness in the elderly. *Eur J Clin Nutr* 1989; 43: 231-36.
33. Jackson AS, Pollock ML, Ward A. Generalized equations for predicting body density of women. *Med Sci Sports Exerc* 1980; 12(3): 175-81.
34. Rush EC, Freitas I, Plank LD. Body size, body composition and fat distribution: comparative analysis of European, Maori, Pacific Island and Asian Indian adults. *Br J Nutr* 2009; 102(4): 632-41.
35. Meeuwssen S, Horgan GW, Elia M. The relationship between BMI and percent body fat, measured by bioelectrical impedance, in a large adult sample is curvilinear and influenced by age and sex. *Clin Nutr* 2010; 29(5): 560-66.
36. Romero-Corral A, Somers VK, Sierra-Johnson J, et al. Accuracy of body mass index in diagnosing obesity in the adult general population. *Int J Obes* 2008; 32: 959-66.
37. Evans EM, Rowe DA, Racette SB, Ross KM, McAuley E. Is the current BMI obesity classification appropriate for black and white postmenopausal women? *Int J Obes* 2006; 30: 837-43.
38. Blew RM, Sardinha LB, Milliken LA, et al. Assessing the validity of body mass index standards in early postmenopausal women. *Obes Res* 2002; 10: 799-808.
39. Bozkirili E, Ertoer ME, Bakiner O, Bascil N, Demirag NG. The validity of the World Health Organisation's obesity body mass index criteria in a Turkish population: a hospital-based study. *Asia Pac J Clin Nutr* 2007; 16(3): 443-47.
40. Fernandez-Real JM, Vayreda M, Casamitjana M, Saez M, Ricart W. Body mass index (BMI) and percent fat mass. A BMI >27.5 kg/m² could be indicative of obesity in the Spanish population. *Med Clin (Barc)* 2001; 117: 681-84.
41. Kagawa M, Kerr D, Binns CW. Ethnic differences in the BMI-%BF relationships between young Japanese and Australian-Caucasian males living in Australia using dual-energy X-ray absorptiometry. *Asia-Pacific Journal of Public Health* 2003; 15(1): 27-32.
42. Zwierzchowska A, Grabara M, Palica D. BMI and BAI as Markers of Obesity in a Caucasian Population. *Obes Facts* 2013; 6: 507-511.

