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Assessment of Body Mass Index versus Body Fat Percentage in Detecting Obesity and Related Comorbidity

Waleed I. Albaker, MBBS, FRCP, ABIM*

Background: Obesity is an increasingly metabolic disorder worldwide. Therefore, obesity comorbidities and risk factors are increasing.

Objective: To assess the relationship between body mass index (BMI) and body fat percentage (BF%) in relation to metabolic risk factors (hypertension, type 2 diabetes-mellitus [DM-II] and dyslipidemia).

Design: A Cross-Sectional Study.

Setting: King Fahd University Hospital, Eastern Province, Saudi Arabia.

Method: Seven hundred eleven individuals were assessed during 2-day campaign; age ranged from 18 to 60 years; 355 (49.9%) were males. The following data were documented: history of DM-II, hypertension and/or dyslipidemia. Measurements included body mass index (BMI), brachial blood pressure, blood glucose and BF%.

Result: The overall prevalence of obesity according to BMI (>30 kg/m2) was 344 (48%) compared to 466 (66.5%) according to BF% (>32% in females and >25% in males). The rate of missed diagnosis of BMI for obesity is higher than BF%. When the BMI cut-off point was lowered to 27.5, the overall prevalence of obesity became 459 (64.6%), which is close to BF% result. The sensitivity and specificity of BMI 30 and BMI 27.5 in detecting the risk of DM-II, hypertension and dyslipidemia were measured.

Conclusion: The sensitivity of BMI 27.5 was higher than that of BMI 30 which gives us a better screening tool for the co-morbidities. The choice of BF% reference is good for assessment of obesity prevalence compared to the BMI.

* Department of Internal Medicine
King Fahd Hospital of the University
University of Dammam
Kingdom of Saudi Arabia
Email: wialbakr@ud.edu.sa

Excess body fat or obesity is an increasing metabolic disorder worldwide[1]. Being overweight or obese is associated with an increased risk of coronary heart disease[2]. High BMI is associated with three metabolic risk factors: high blood pressure, cholesterol, and glucose[3]. The prevalence of obesity in Saudi Arabia was 22.1% in 1993 and it has increased to 35.6% in 2000[4]. Overweight and obesity are leading causes for global deaths[5]. Approximately 2.8 million adults die each year as a result of being overweight or obese[5]. In addition, 44% of the diabetics, 23% of those with ischemic heart disease and 7%-41% with certain cancer are attributable to overweight and obesity[5].

Both body mass index (BMI) and body fat percentage (BF%) have been used to define whole-body obesity[6]. Body mass index (BMI) is commonly used for the prediction of health risks[6]. According to the criteria of World Health Organization (WHO), subject with BMI of 30 or 25 kg/m^2 is considered obese or overweight[6]. Body fat percentage is the amount of body fat mass expressed as a percentage of total body weight[6]. The range of BMI is as follows: underweight below 18.5 BMI, normal 18.5-24.9 BMI, overweight 25.0-29.9 BMI and obese 30 and above BMI.

According to WHO, the prevalence of overweight and obesity in Saudi Arabia is 69%, and 33% respectively; in males 69.1%, 28.6% in and females 68.8%, 39.1%[7].

The prevalence of diabetes and hypertension in Saudi Arabia are very high compared to other countries[1]. Screening for high BF% and/or high BMI is essential to detect and prevent cardio-metabolic diseases. BMI cut-off for overweight as defined by the WHO for Asians may not be adequate to reflect the actual overweight. Studies in other countries showed that the risk for cardiovascular disease or diabetes is high at lower BMI[6]. Therefore, a personalized cut-off point for the population of Saudi Arabia is called for.

The aim of this study is to evaluate BMI and BF% in relation to hypertension, type 2 diabetes mellitus (DM-II), and dyslipidemia.

METHOD

A study in both genders aged 18 years and above was conducted from 24 to 26 February 2013. A total of 711 subjects, 355 (49.9%) males and 356 (50.1%) females responded and agreed to participate. Newly discovered diabetes and hypertension cases were referred to primary health care center for further evaluation and follow-up. Data were collected by a personal face-to-face inquiry.

Body height and weight measurements (using a Stadiometer and digital weight scale) were recorded for each participant. BMI was calculated as body weight (kilograms) divided by height (meters square)[8]. WHO classification of BMI and the American Council of Exercise (ACE) classification for BF (>25 for males and >32 for females) were adopted.

Brachial blood pressures were measured in the left arm. Three readings were taken; the mean was used for analysis. Peripheral pulse pressure was calculated as the difference between brachial systolic and diastolic BP[9]. Capillary blood capillary glucose test was performed[10].

Two consecutive MF-BIA measurements were taken within 20 minutes of the blood sampling with the subject in supine position, before serum osmolality results were available (the assessor was blinded to hydration status). MF-BIA measurements were taken using the manufacturers recommended method[11].

Adults 18 years and above were included in the study. Exclusion criteria included visitors below 18 years or having type-I DM, hypothyroidism, thyrotoxicosis, tuberculosis, end stage liver or renal failure or known cancer. Informed consent was obtained.

Data were analyzed using JMP version 5.0 and SPSS version 15.0, $P<0.05$ was considered significant.

RESULT

The study consisted of 711 participants, the mean age was 18 to 60 years (40±12.9 years), 355 (50.6%) were males. The overall prevalence of obesity using BMI (>30 kg/m2) was 334 (47%) (Mean 30.6, CI: 30.08-31.23), compared to 466 (65.5%) (Mean 33.9, CI: 32.4-35.4) using BF% (>32% in females and >25% in males), see tables 1, 2 and 3.

Table 1: Clinical and Personal Characteristics

Variables	Mean ± SD
Age (Years)	40 ± 12.9
Gender (M:F)	50:50 (%)
Height (cm)	161.4± 10.9
Weight (kg)	79.4±18.9
Body Mass Index (kg/m^2)	30.67±7.84
Total Body Fat (%)	32.81±10.71
Systolic Blood Pressure (mmHg)	129.6.6±18
Diastolic Blood Pressure (mmHg)	73.5±8.3
Pulse Pressure (mmHg)	56±13.8
Blood Glucose (mg/dL)	115.2±48.9
History of Diabetes Type 2 (%)	16
History of Hypertension (%)	16
History of Dyslipidemia (%)	21

Table 2: Clinical and Personal Characteristics According to Gender

Variables	Males (n=355) Mean ± SD	Females (n=356) Mean ± SD	P Value
Age (Years)	40.7±13.1	38.6±12.6	=0.0366
Height (cm)	168.3±7.92	154.5±9	<0.0001
Weight (kg)	83.4±0.17.9	75.5±19	<0.0001
Body Mass Index (kg/m^2)	29.38±5.84	31.93±0.4	<0.0001
<25 Body Mass Index	22.58±1.7	21.68±2.32	=0.0108
25-<30 Body Mass Index	27.59±1.41	27.46±1.39	NS
30-35 Body Mass Index	32.01±1.47	32.19±1.46	=0.416
>35 Body Mass Index	39.06±4.86	42.65±9.28	=0.0092
Total Body Fat (%)	28.59±8.76	37.03±10.84	<0.0001
Systolic Blood Pressure (mmHg)	133±18.6	126.2±16.8	<0.0001
Diastolic Blood Pressure (mmHg)	75.8±0.4	71.3±0.4	<0.0001
Pulse Pressure (mmHg)	57.2±15.13	54.9±12.13	=0.0245
Blood Glucose (mg/dL)	117.6±50.9	112.8±46.1	NS

Table 3: Clinical and Personal Characteristics According to Body Mass Index

Variables		BMI <25 138 (19.41%)	BMI 25-30 239 (33.61%)	BMI 30-35 176 (24.75%)	BMI >35 158 (22.22%)	P Value
BMI		22.13±2.08	27.53±1.4	32.09±1.46	41.44±8.23	<0.0001
Age (Years)		33.15±11.36	38.92±13.2	42.69±12.14	43.13±12.12	<0.0001
Gender (M:F)		52.2:47.8	56.1:43.9	54.6:45.4	33.5:66.5	<0.0001
Body Fat Percent	Male	19.76±4.79	32.08±4.77	32.02±2.94	41.52±11.32	<0.0001
	Female	25.12±3.61	25.7±3.14	38.9±4.23	48.05±10.79	<0.0001
	Total	**22.34±5.03**	**28.47±5.04**	**35.15±4.96**	**45.85±11.37**	**<0.0001**
Diabetes-II	Male	10 (2.82%)	21 (5.92%)	16 (4.51%)	12 (3.38%)	=NS
	Female	3 (0.84%)	16 (4.49%)	14 (3.93%)	22 (6.18%)	=0.0322

	Total	**13 (1.83%)**	**37 (5.20%)**	**30 (4.22%)**	**34 (4.8%)**	**=0.0427**
Hypertension	Male	6 (1.69%)	21 (5.92%)	23 (6.48%)	11 (3.1%)	=0.0457
	Female	2 (0.56%)	6 (1.66%)	19 (5.34%)	23 (6.46%)	<0.0001
	Total	**8 (1.13%)**	**27 (3.8%)**	**42 (5.91%)**	**34 (4.78%)**	**<0.0001**
Dyslipidemia	Male	13 (3.67%)	21 (5.92%)	25 (7.04%)	11 (3.1%)	=NS
	Female	4 (1.12%)	23 (6.46%)	21 (5.9%)	28 (7.87%)	=0.0066
	Total	**17 (2.4%)**	**44 (6.19%)**	**46 (6.47%)**	**39 (5.49%)**	**=0.0106**

Gender specific prevalence according to BF% was 220 (62%) for males (mean 28.9 CI: 27.7-30.06) and 264 (74%) for females (mean 39.1 CI: 36.5-41.7). However, gender specific prevalence according to BMI above 30 was 147 (41.4%) for males (mean 29.3 CI: 28.7-29.9) and 187 (52.5%) for females (mean 32.008 CI: 31.02-32.9). The prevalence was significantly higher in females than in males according to BF% than according to BMI.

The difference between the two prevalence values (BMI 30 and BF%) measured with a McNemar test was significant (P-value 0.001 for both females and males). These results suggest that the rate of missed diagnosis of BMI for obesity is higher than that of BF%. Hence, a lower BMI cut-off point is called for to raise the BMI sensitivity in detecting obesity.

When the BMI cut-off point was lowered to 27.5, the overall prevalence of obesity became 459 (64.6%) and the gender-specific prevalence of obesity went up to 216 (60.8%) for males and 244 (68.7%) for females, which is closer to that of BF% results. McNemar test revealed no statistically significant difference between the two prevalence values at that point (P-value 0.143 for males and 0.608 for females).

Sensitivity, specificity and likelihood ratio (LR) of BMI according to BF% cut-offs points (25 in males and 32 in females) were calculated by ROC curve analysis. This revealed that BMI of 27.5 had much higher sensitivity than BMI of 30 in females (P-value 0.001). However, in males there was a decrease in specificity by 26% and increased in sensitivity by 4% P=0.001, see table 4.

Table 4: Sensitivity and Specificity According to Body Mass Index

Items	**BMI 30**		**BMI 27.5**	
	Male	**Female**	**Male**	**Female**
Sensitivity	94%	73%	96%	91%
Specificity	80%	96%	54%	86%
Likelihood ratio	+4.66	+19.9	+2.00	+6.55

In addition, sensitivity, specificity and LR of BF% cut-off points were also calculated by ROC curve analysis using BMI at 30 and BMI at 27.5 which revealed that lowering the BMI cut-off point from 30 to 27.5 doubled the likelihood ratio (2.7 to 6.1 for females, 2.6 to 6.3 for males), and increased the specificity (64% to 85% for females and 63% to 86% for males) with a minor decrease in sensitivity (97% to 93% for females and 98% to 93% for males).

Due to the small sample size, both male and female BMI groups (underweight <18.5, normal <25, obese class II 35-40 and obese class III >40) were merged in one group.

Overweight and obese individuals showed a higher percentage of diabetes, hypertension and dyslipidemia. This was found to be significant in female patients ($P \leq 0.05$). However, only male patients showed significant results with hypertension (P=0.0457).

The sensitivity and specificity of BF, BMI 30 and BMI 27.5 in detecting the risk of DM-II, hypertension and dyslipidemia are listed in table 4. The sensitivity of BMI 27.5 was higher than that of BMI 30 for diabetes, hypertension and dyslipidemia. However, the specificity was lower for BMI-27.5 compared to BMI-30. Therefore, a lowered cut-off point of BMI gives us a better screening tool for the previously mentioned co-morbidities. The sensitivity of BMI 27.5 and BF% was higher in females and the specificity was higher in males.

DISCUSSION

Obesity has been proposed as the most important determinant for metabolic syndrome. Therefore, it is important to develop simple and reliable anthropometric measurement tools for obesity, to facilitate the prevention of metabolic syndrome and consequent morbidity and mortality[12].

BMI is directly related to health risks and death rates in many populations. It should be kept in mind that BMI is associated with fat free mass and to a lesser extent to body build[13]. In addition, the associations between BMI, percentage of body fat, and body fat distribution differ across populations. Hence, a population specific BMI cut-off point is called for.

The associations of BMI and comorbidities are probably not stable within populations over time. Similarly, there are environmentally determined differences in these associations across different population groups and these associations also vary within populations according to environmental changes and nutritional transitions.

Our study showed that the prevalence of obesity according to BMI (>30 kg/m2) was 47% (mean 30.6, CI 30.08-31.23), compared to 66.5% (mean 33.9, CI 32.4-35.4) according to BF%. A McNemar test was done to compare the significance between BMI-30 and BF% which revealed significant values. After lowering BMI to 27.5, the prevalence increased up to 64.5%, which is closer to the BF% prevalence. In addition, McNemer test was done to compare the prevalence between BMI 27.5 and BF%, which indicated no significant value for both males and females. Habib found that the lower cut-off points for males and females were 26.6 and 26.75 respectively[14].

Previous studies showed that the risk of cardiovascular disease or diabetes is high at a lower BMI level[6]. The prevalence of hypertension, diabetes, dyslipidemia, and risk factors increases with an increasing BMIs[15]. Therefore, we developed crosstabs sensitivity and specificity models for hypertension, DM-II, dyslipidemia and average BF% based on the use of international BMI cut-off point 30 and the suggested BMI 27.5. Data suggests that a BMI of 27.5 kg^2 in either sex may be more ‘appropriate’ to be considered as a cut-off point in Saudi nationals. For females, the BF% and 27.5 BMI showed significantly higher sensitivity values than BMI 30 in predicating DM, hypertension and dyslipidemia, although significant values were only seen with hypertension in males.

CONCLUSION

The sensitivity of BMI 27.5 was higher than that of BMI 30 which gives us a better screening tool for the co-morbidities. The choice of BF% reference is of great influence for the assessment of obesity prevalence compared to the BMI.

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