IJMS
Vol 41, No 4, July 2016

Original Article

The Accuracy of Body Mass Index and Gallagher's Classification in Detecting Obesity among Iranians

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Received: 06 December 2014
Revised: 11 March 2015
Accepted: 19 April 2015

Abstract

Background: The study was conducted to examine the comparability of the BMI and Gallagher's classification in diagnosing obesity based on the cutoff points of the gold standards and to estimate suitable cutoff points for detecting obesity among Iranians.

Methods: The cross-sectional study was comparative in nature. The sample consisted of 20,163 adults. The bioelectrical impedance analysis (BIA) was used to measure the variables of interest. Sensitivity, specificity, positive predictive power (PPV), and negative predictive power (NPV) were used to evaluate the comparability of the two classification methods in detecting obesity.

Results: The BMI wrongly classified 29% of the obese persons as overweight. In both classifications, as age increased, the accuracy of detecting obesity decreased. The Gallagher's classification is better than MBI in detecting obesity in men with the exception of those older than 59 years. In females, the BMI was better in determining sensitivity. In both classifications, either female or male, an increase in age was associated with a decrease in sensitivity and NPV with the exception of the BMI for the 18 year olds. Gallagher can correctly classify males and females who are less than 40 and 19 years old, respectively.

Conclusion: Gallagher's classification is recommended for non-obese in both sexes and in obese males younger than 40 years old. The BMI is recommended for obese females. The suitable cutoff points for the BMI to detect obesity are 27.70 kg/m^2 for females and males, 27.70 kg/m^2 for females, and 27.30 kg/m^2 for males.

Please cite this article as: Shahab Jahanlou A, Kouzekanani K. The Accuracy of Body Mass Index and Gallagher's Classification in Detecting Obesity among Iranians. Iran J Med Sci. 2016;41(4):288-295.

Keywords ● Fat body ● Body mass index ● Obesity ● Overweight

What's Known

- Body mass index (BMI) and Gallagher's classification can be used for detecting obesity

What's New

- Gallagher's classification is more appropriate in detecting obesity in men, whereas BMI is more suitable in women.

Introduction

Obesity is a serious health problem, which may range from a simple complaint of disability to premature death.[1] In many epidemiological studies, the body mass index(BMI ≥30 kg/m^2)[2,3] or percentage of body fat (PBF >25% in men and >35% in women)[4] were used as an indicator of obesity in adolescents. The PBF is measured by several methods, such as magnetic resonance imaging (MRI), bioelectrical impedance analysis (BIA), and X-ray.[5] The BIA is affordable and accurate in assessing body composition.[6-9]

The World Health Organization (WHO), based on a 2004 study of 3,378 adults in southern Iran, reported 21 to 25 kg/m^2 as the range of the BMI and that 8% of women and 2.5% of men were obese without reporting the suitable cutoff points.[10] Mirzazadeh et al.[11] conducted a meta-analysis of published reports in Iran, including proceedings of professional meetings, books, journal articles, and estimated the prevalence of obesity in men and women to be 12.9% and 26.2%, respectively. In some Iranian articles, suitable BMI cutoff points for detecting obesity are reported. For example, in one,[12] it is reported to be 26.6 kg/m^2 based on data from 206 elderly. In another study,[13] data from 4,756 diabetic people were used to estimate the cutoff points as 24.8 kg/m^2 and 26.3 kg/m^2 for males and females, respectively.

In the review of the literature, we identified Iranian studies in which the BIA had been used to measure body composition in samples ranging from 25 to 300 people. Some reported that the BMI was accurate in detecting obesity while others concluded that it was not an accurate indicator of obesity.[14-19] We also found non-Iranian studies which supported the pros and cons of employing the BMI to detect obesity.[20-23]

Gallagher classified individuals based on the PBF for males and females in various age groups, namely, 18, 19, 20-39, 40-59, and >59 years old.[24] A systematic review of the literature showed no published Iranian studies using these age groups and no international studies focusing on either the accuracy of Gallagher's classification or its comparison with the BMI. The purpose of this study was twofold, (i) to examine the comparability of the BMI and Gallagher's classification in diagnosing obesity, and (ii) to determine the suitable BMI cutoff points for detecting obesity in a large sample of Iranians, using the BIA method. The significance of the study was that it compared two popular methods in detecting obesity, which had not already been done.

Materials and Methods

This cross-sectional study was comparative in nature. The permission to conduct the study and the ethics approval were obtained from the office of Vice-chancellor for Research and Technology at Hormozgan University of Medical Sciences (#6-HEC-88-2-16, 6 May 2009).

The prevalence of obesity in the Iranian adult population[25] is reported as 21.50%, which we used to estimate the initial sample size at the 0.05 level of significance for testing non-directional hypotheses. The power analysis showed that 6,483 would be the required sample size. However, due to the duration of the investigation (2009-2014), 23,300 individuals who visited a health and diet therapy center in Bandar Abbas, Iran, and agreed to participate in the study were recruited. Those who were not at least 18 years old, had pacemakers, were pregnant, and were hospitalized at least 3 months prior to entering the study were excluded. In total, 20,163 adults met the inclusion criteria and their data were used in the study.

The BIA was performed using Plusavis 333 body composition analyzer. This device uses the frequency range between 50 kHz and 250 kHz, and utilizes the method of direct segmental multi-frequency BIA. With a high level of accuracy, this method enabled us to measure various body composition indices (i.e., the BMI, waist to hip ratio, percentage of body fat, total body fat, proteins, minerals, soft lean mass, fat free mass, muscle quantity, lean body mass, total body water, total energy expenditure, basal metabolic rate, fat-trunk, and muscle-trunk). The standard positions of outer and inner electrodes on the right hand and foot were employed for measuring the whole body impedance.[26] The device was explained to all research participants and trained technicians were in charge of all measurements. The height (cm) was measured to the nearest 0.50 cm by a stadiometer. Weight (kg) was divided by the squared height (cm^2) to measure the BMI, which was used to classify participants into four groups, (i) underweight (under 18.50), (ii) normal weight (18.50 to 24.99), (iii) overweight (25.00 to 29.99), and (iv) obese (30.00 and higher). The participants were also classified into four groups (underweight, normal weight, overweight, and obese) using Gallagher's classification and subdivided the sample by sex and age. Table 1 shows the classification of the participants based on the PBF using the Gallagher's classification.

The WHO Gold standards were used to determine the accuracy of the BMI and Gallagher's classification in detecting obesity. As noted earlier, PBF >25% in men and >35% in women indicate obesity. In the BMI and Gallagher's classifications, all individuals in the subgroups of underweight, normal weight, and overweight were classified as non-obese and the rest were considered obese.

For the purpose of the study, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were computed using contingency tables. Receiver-operating characteristic (ROC) curves were used to describe the diagnostic performance of screening test in terms of diagnostic accuracy

Table 1: Distribution of participants based on Gallagher's classification

Age (years)	Percentage of body fat by age and sex						
	Category	Gender					
		Male			Female		
		PBF (%)	N	%	PBF (%)	N	%
18	Underweight	<10	27	28.7	<17.0	55	21.7
	Normal	10.0–20	24	25.5	17.0–31	63	24.9
	Overweight	20.0–24	6	6.4	31.0–36	69	27.3
	Obese	≥24.0	37	39.4	≥36	66	26.1
19	Underweight	<9	27	21.8	<19.0	102	31.3
	Normal	9.0–20	46	37.1	19.0–32	84	25.8
	Overweight	20.0–24	21	16.9	32.0–37	81	24.8
	Obese	≥24.0	30	24.2	≥37	59	18.1
20–39	Underweight	<8.0	342	8.4	<21.0	1,216	12.1
	Normal	8.0–20.9	929	22.9	21.0–32.9	3,054	30.5
	Overweight	21.0–25.9	829	20.4	33.0–38.9	3,815	38
	Obese	≥26.0	1,963	48.3	≥39.0	1,942	19.4
40–59	Underweight	<11.0	27	1.9	<23.0	45	1.3
	Normal	11.0–22.9	360	25	23.0–34.9	823	24.3
	Overweight	23.0–28.9	577	40.1	35.0–40.9	1,652	48.7
	Obese	≥29.0	475	33	≥41.0	870	25.7
≥60	Underweight	<13.0	2	1.2	<25.0	5	1.8
	Normal	13.0–24.9	64	37	25.0–37.9	84	30.7
	Overweight	25.0–30.9	63	36.4	38.0–42.9	130	47.4
	Obese	≥31.0	44	25.4	≥43.0	55	20.1
Total			5,893			14,270	

PBF: Percentage of body fat

or the ability to classify participants correctly into clinically relevant subgroups, as defined by a reference test.[27] Version 22 of the statistical package for the social sciences (SPSS) was used for the purpose of data manipulation and analysis, which included contingency tables, linear regression, and Hanely formula to compare the two ROC curves.[28]

Results

The participants were selected from 14,270 (70.80%) women and 5,893 (29.20%) men aged between 18 and 85 years. Prevalence of obesity was estimated at 51% based on the Gold standard 38.5% based on BMI and 27.4% by Gallagher's classification. Based on the Gold standard 49.9% and 54.4% of women and men respectively, were classified as obese.

BMI in All Participants

There were 7,768 (38.5%) individuals identified as obese by the BMI sensitivity. NPV values were 70.8% and 75.7%, respectively. The BMI wrongly classified 29% of the obese persons as non-obese. Thus, the BMI was moderately effective in detecting obesity in all participants.

BMI in Men

The BMI showed that 2,224 men were obese. Sensitivity and NPV values were 63% and 67.6%, respectively. The BMI wrongly classified 37% of the obese males as non-obese. Results showed that the BMI was not suitable for detecting obesity among males.

BMI in Men by Age Group

In this category, the following ranges were calculated: sensitivity (51.4% to 80%), specificity (89.4% to 100%), PPV (88.7% to 100%), and NPV (53.2% to 93.9%). In the 20-39, 40-59, and 60-81 age groups, the BMI classified 34%, 45%, and 49% of male obese individuals as non-obese, respectively. The BMI was not effective in detecting obesity in men older than 39 years.

Gallagher in Men by Age Group

Gallagher's classification showed that 43.2% of the men were obese. The following ranges were obtained: sensitivity (41.1% to 100%), specificity (99.8% to 100%), PPV (99.8% to 100%), and NPV (51.2% to 100%). In the 18 and 19 age groups, sensitivity, specificity, NPV, and PPV were 100%. In the 20-40 age group all ranges were between 90.8% and 100%. Beyond 39 years of age, sensitivity and NPV decreased as age increased. Specificity and PPV were similar in all age groups. In the 20-39 years age group, 9%, in 40-59 years age group, 46%, and in greater than 60 age groups, 59% of obese individuals were wrongly classified as non-obese. Thus, it was concluded that the Gallagher's classification is better than the BMI for detecting obesity in men with the exception of those who are older than 59 years (table 2).

BMI in Women

The number of women who were classified as obese by the BMI was 5,544 (38.9%). Sensitivity and NPV values were 74.3% and 79%, respectively. The BMI classified 25.7% of the obese women as non-obese, which led to a conclusion that it is suitable for detecting obesity in females.

BMI in Women by Age Group

In this category, the following ranges were obtained: sensitivity (70.6% to 84.2%), specificity (92.8% to 98.3%), PPV (94.1% to 97.9%), and NPV (56.1% to 93.5%). Sensitivity and NPV decreased as age increased. In the five age groups, the BMI classified 16%, 23%, 23%, 27% and 29% of obese womens as non-obese, respectively.

Gallagher in Women

Based on this indicator, 20.9% of women were wrongly classified as obese. The sensitivity ranged from 27.9% to 86.8%, and the NPV's range was 35.2% to 94.7%. Specificity and PPV were 100% in all age groups. Sensitivity and NPV decreased as age increased, which was consistent with the BMI's findings. The range of decreases in sensitivity, based on the BMI and Gallagher, were 13.6% and 58.9%, respectively. Beyond 19 years of age, based on the Gallagher's and the BMI, 55-72% and 29-33% of the obese individuals were wrongly classified as overweight, respectively. Results showed that the BMI is better than Gallagher in classifying the women (table 3).

Gallagher's classification can correctly classify men and women who are less than 40 and 20 years old, respectively. In both classifications, an increase in age was associated with a decrease in sensitivity and the NPV.

Suitable Cutoff Points for BMI

In all participants, a suitable cutoff point for BMI in detecting obesity was 27.70 kg/m^2 (sensitivity=88%, specificity=88.6%). Among females, the suitable cutoff point was also found to be 27.7 kg/m^2 (sensitivity=92%, specificity=90%) and among males, it was 27.3 kg/m^2 (sensitivity=84%, specificity=84%). The comparison of the two ROC curves, using the Hanely formula, showed no statistically significant differences between these cutoff points (figure 1).

Discussion

The aim of the study was to examine the comparability of the BMI and Gallagher's classifications in detecting obesity in a large sample of Iranian adults. A systematic review of the literature showed that the accuracy of Gallagher's classification and its comparison with the BMI classification had not been adequately investigated. Results showed that Gallagher's classification is better than the BMI in detecting obesity in men younger than 40 years old; beyond this age, both methods wrongly classified nearly half of the obese males as non-obese. The BMI was better than Gallagher's

Table 2: Sensitivity, specificity, PPV, and NPV based on the BMI and Gallagher's criteria for overweight and obese men

	N		%			
	Overweight	Obese	Sensitivity	Specificity	PPV	NPV
BMI: All males	3,669	2,224	63	92.4	90.9	67.6
BMI: 18 years	68	26	70.3	100	100	83.8
BMI: 19 years	99	25	80	98.9	96	93.9
BMI: 20-39 years	2,492	1,571	66.4	92.7	91.1	70.9
BMI: 40-59 years	899	540	55.2	90.2	89.8	56.2
BMI: 60-81 years	111	62	51.4	89.4	88.7	53.2
Gallagher: All males	3,344	2,549	79.4	99.9	99.9	80.2
Gallagher: 18 years	57	37	100	100	100	100
Gallagher: 19 years	94	30	100	100	100	100
Gallagher: 20-39 years	2,100	1,963	91	99.9	99.9	90.8
Gallagher: 40-59 years	954	475	53.9	99.8	99.8	58
Gallagher: 60-80 years	129	44	41.1	100	100	51.2

BMI: Body mass index; PPV: Positive predict value; NPV: Negative predictive value

Table 3: Sensitivity, specificity, PPV, and NPV based on the BMI and Gallagher's criteria for overweight and obese women

	N		%			
	Overweight	**Obese**	**Sensitivity**	**Specificity**	**PPV**	**NPV**
BMI: All females	8,726	5,544	75.2	96.3	95.2	80.1
BMI: 18 years	185	68	84.2	97.7	94.1	93.5
BMI: 19 years	250	76	76.6	98.3	94.7	91.2
BMI: 20-39 years	6,511	3,516	76.2	96.9	95.1	84
BMI: 40-59 years	1,648	1,742	73.3	92.8	95.4	63.3
BMI: 60-81 years	132	142	70.6	96.1	97.9	56.1
Gallagher: All females	1,1278	2,992	42.6	100	100	64.3
Gallagher: 18 years	187	66	86.8	100	100	94.7
Gallagher: 19 years	267	59	62.8	100	100	86.9
Gallagher: 20-39 years	8,085	1,942	44.3	100	100	69.8
Gallagher: 40-59 years	2,520	870	38.4	100	100	44.6
Gallagher: 60-80 years	219	55	27.9	100	100	35.2

BMI: Body mass index; PPV: Positive predict value; NPV: Negative predictive value

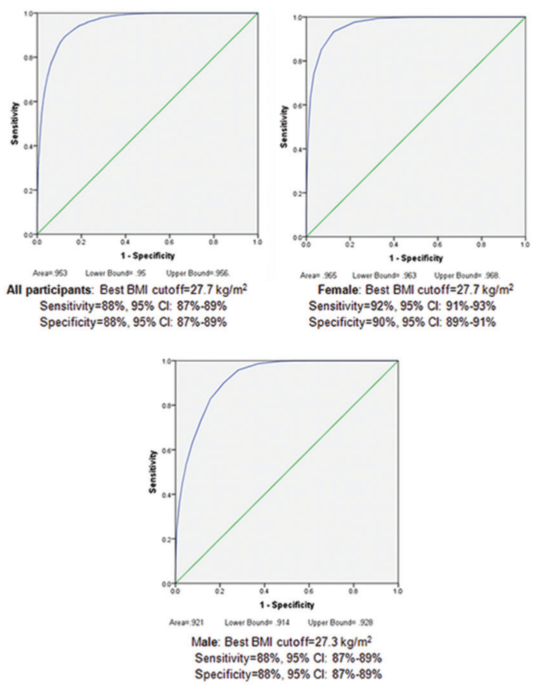

Figure 1: Receiver operating characteristic for body mass index to detect obesity in all participants, women and men.

classification in detecting obesity in females and an increase in age was associated with a decrease in the accuracy of both techniques, especially in Gallagher's.

The BMI correctly classified 70.8% of the obese persons, suggesting that it is a moderate indicator of obesity, which is supported by other studies.[29-32] Neovius et al.[33] reported that the BMI accurately diagnosed excess adiposity in 84% of those participated in their study. In our study, the BMI and Gallagher's criteria correctly identified 92.4% and 99% of males, and 96.5% and 100% of females as being non-obese, respectively. Although the BMI is a good indicator for detecting non-obese individuals, but Gallagher's classification is better than the BMI in classifying non-obese males and females.

Nearly 74.3% and 42% of females, and 63% and 79.4% of males were correctly classified as being obese by the Gallagher's classification and the BMI, respectively. The BMI is better than Gallagher among obese females. Neovius[33] reported low sensitivity and high specificity for the BMI in both sexes with the average age of 15 years. In spite of age differences, the results of this study are similar to those reported by Neovius.

Based on the BMI, among females and males 16%-29% and 20%-49% of obese individuals were wrongly classified as non-obese, respectively. These findings suggest that the BMI is a good indicator of obesity in females but not males. Accuracy of the BMI in both females and males increased after the age of 19 years. Coe et al.[34] reported that the accuracy of the BMI decreased in females and no apparent trend was noted in males. It contradicts the results of this study, which could be due to age, ethnicity, and sample size differences.

The correlations between the BMI and PBF were 0.86 and 0.91 in men and women, respectively; similar to those reported by Heyadari, et al.[17] Thus, it was concluded that the BMI is a good predictor of the PBF but not adequate in diagnosing excess adiposity, especially in males as supported by Romero et al.[23] and contradicted in other studies.[17,18] The contradiction could be due to the selection of individuals, race, and sample size.

The BMI among males had 9.1% false positive and 32.4% false negative, which were similar to a study by Jitnarin et al.,[35] who studied firefighters between the ages of 20 and 62 years. In short, there are errors in the identification of obese males with the BMI; however, it is more suitable for females.

In males under the age of 40 and females who are less than 20 years old, Gallagher's classification is a better determinant of obesity than the BMI. Schutter et al.[36] reported a paradox in the findings of elderly patients with coronary heart disease with Gallagher's classification by reporting the highest mortality in the underweight and normal groups and the lowest mortality in the overweight group. In our study, more than 46% of the male obese and 62% obese females older than 39 years were wrongly classified as overweight by this indicator; thus, we concluded that it is not a good indicator to distinguish between older overweight and obese individulas, which made Schutter's paradox questionable.

A systematic comparison of all results showed that Gallagher's classification is better in detecting obesity in men, especially among those who are less than 40 years old. On the other hand, the BMI is more suitable for females. In short, the statement by Rothman, "the use of BMI as an indicator of obesity can introduce misclassification problems that may result in important bias in estimating the effects related to obesity" is confirmed.[37]

In spite of the large sample, it should be noted that the participants were recruited from southern Iran and they do not represent the whole population of the country. We recommend replication of the study in other regions of Iran, which could enhance the generalizability of the results.

Conclusion

Gallagher's classification is recommended for non-obese males and females and obese males. The BMI is recommended for obese females. Additionally, for the Iranian population, it is recommended to employ 27.7 kg/m^2 as the cutoff point for detecting obesity among women and men, 27.7 kg/m^2 for women, and 27.3 kg/m^2 for men. The results of the study would enlighten scientists to consider other methods in examining body conditions rather than the status quo.

Acknowledgement

This study represents a collaborative effort between Hormozgan University of Medical Sciences and Texas A&M University-Corpus Christi. The authors would like to thank the study participants and the Deans of the Medical School at Hormozgan University and the College of Education at Texas A&M University-Corpus Christi for their support.

Conflict of Interest: None declared.

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