Original Article

Unravelling the obesity maze in diabetic patients: A comparative analysis of classification methods

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Abstract

Background: Obesity is a significant health concern among individuals with type 2 diabetes mellitus (T2DM). Emerging evidence suggests that alternative measures, such as abdominal girth (AG) and body fat percentage (BF%), can provide a more accurate reflection of obesity-related metabolic risks in diabetic populations. This study aimed to compare the accuracy of different obesity classification methods, including BMI, AG, and BF%, among individuals with T2DM. **Methodology:** This was an observational cross-sectional study conducted among T2DM patients who came to the non-communicable diseases clinic of GG Govt Hospital, Jamnagar, Gujarat during the period of March–April 2023. Demographic and anthropometric information was collected. Body fat analysis was done using a validated Omron fat analyzer. **Results:** The study found the sensitivity of BMI in males and females as 41.6% and 45% against BF%, respectively. It also showed that the sensitivity of BMI in males and females was 38% and 40.7%, respectively, against AG. The present study also found a moderate positive correlation (r = 0.575) between AG and BF% in individuals with T2DM. **Conclusion:** The findings indicate that BF% and AG provide valuable insights into adiposity, surpassing the limitations of BMI as a measure of body composition. BF% is an indicator of body fat content, whereas AG serves as a proxy for central adiposity. The correlations between BF% and AG suggest that excess abdominal fat accumulation signifies increased body fat. By incorporating measures such as BF% and AG alongside BMI, clinicians can obtain a more comprehensive understanding of body composition and its relationship with metabolic abnormalities.

Keywords: Abdominal circumferences, BMI, body fat percentage, sensitivity

Introduction

Obesity is a significant health concern worldwide, particularly among individuals with diabetes. The classification of obesity plays a crucial role in identifying individuals at risk and guiding interventions for diabetes management. Traditionally, body mass index (BMI) has been widely used as a standard measure to assess obesity. However, emerging evidence suggests that alternative measures, such as abdominal girth (AG) and body fat percentage (BF%), may provide a more accurate reflection of obesity-related metabolic risks in diabetic populations.

Globally, the burden of obesity and type-2 diabetes mellitus (T2DM) has been escalating rapidly. According to the World Health Organization (WHO), in 2020, approximately 650 million adults worldwide were obese, and more than 460 million adults were living with diabetes. These two conditions often coexist, forming a significant public health challenge. Obesity not only increases the risk of developing T2DM but also contributes to its progression and complications.[1]

In India, the prevalence of obesity and T2DM has also witnessed a dramatic surge. The International Diabetes

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Received: 01-08-2023 **Revised:** 11-09-2023
Accepted: 26-11-2023 **Published:** 14-06-2024

Access this article online

Quick Response Code:

Website:
http://journals.lww.com/JFMPC

DOI:
10.4103/jfmpc.jfmpc_1255_23

How to cite this article: Yogesh M, Mody M, Makwana N, Shah S, Patel J, Rabadiya S. Unravelling the obesity maze in diabetic patients: A comparative analysis of classification methods. J Family Med Prim Care 2024;13:2283-8.

Federation estimates that India had 77 million adults with diabetes in 2019, and this number is projected to rise to 134 million by 2045.[2] Furthermore, a national survey conducted in 2016 reported that the prevalence of obesity in India is approximately 30% among urban adults.[3] These statistics emphasize the urgent need to identify accurate measures of obesity in the Indian population, especially among individuals with T2DM, to optimize diabetes management and reduce the burden of associated complications.

BMI: BMI is a widely used anthropometric measure calculated by dividing an individual's weight (in kg) by the square of their height (in m). It has been the primary method for classifying obesity in both the general population and individuals with diabetes. The WHO classifies individuals as underweight, normal weight, overweight, or obese based on BMI cutoffs. However, BMI has limitations as it fails to account for variations in body composition and distribution of fat, which are important factors in the development of metabolic disorders.[4]

AG: AG, also known as waist circumference (WC), measures the circumference of the abdomen at the level of the umbilicus. AG serves as a proxy for central adiposity and visceral fat accumulation, which are strongly associated with metabolic abnormalities and cardiovascular risk factors in individuals with diabetes.[5] Research has shown that AG correlates better with insulin resistance, dyslipidemia, and other metabolic disturbances compared to BMI alone.[6]

BF%: BF% provides a direct measurement of the proportion of body weight that is composed of fat. Various techniques, including bioelectrical impedance analysis, dual-energy X-ray absorptiometry, and skinfold thickness measurements, can estimate BF%. BF% offers insight into an individual's body composition, allowing for a more comprehensive assessment of obesity-related metabolic risks. Higher BF% has been associated with insulin resistance, hyperglycemia, and other cardio-metabolic abnormalities in individuals with diabetes.[7]

BF% and metabolic risks: BF% offers a direct measure of the proportion of body weight composed of fat. Higher BF% has been linked to insulin resistance, hyperglycemia, and other cardio-metabolic abnormalities. Evaluating BF% as an obesity classification method can provide a more nuanced understanding of the relationship between body composition and metabolic health in individuals with diabetes.

Primary care physicians are often the first point of contact for patients with obesity, and they play a crucial role in the management of obesity and its associated comorbidities. However, studies have shown that primary care physicians face difficulties in treating obesity due to a lack of knowledge about evidence-based weight management approaches. Therefore, the findings of the article can help primary care physicians to better understand the classification methods for obesity in diabetic patients and provide evidence-based weight management approaches to their patients.

Thus, this study aimed to compare the accuracy of different obesity classification methods, including BMI, AG, and BF%, among individuals with T2DM.

Methodology

This study was an observational cross-sectional study conducted among diabetic patients who came to the non-communicable diseases (NCD) clinic of GG Government Hospital, Jamnagar, Gujarat, during the period of March–April 2023. Diabetic patients attending follow-up, irrespective of their duration or diabetic treatment, who came to the NCD clinic in GG hospital and gave consent to the study were included in the study. Participants who did not give consent to participate, critically ill patients, and pregnant women were excluded from the study. Patients were recruited in the study by simple random technique. A self-structured standard questionnaire that included sociodemographic characteristics and clinical profiles was administered to them. Next, an anthropometric assessment was performed to measure their weight, height, BMI, WC, and hip circumference (HC).

WC was measured at the approximate midpoint between the lower margin of the last palpable rib and the top of the iliac crest, and HC was measured around the widest portion of the pelvis.[8] Both WC and HC were determined using the same measuring tape [Table 1].

Table 1: Operational Definitions

Variables	Classification
Body fat percentage, %[9]	
Male	Essential fat: 2–5
	Athletes: 6–13
	Fitness: 14–17
	Acceptable: 18–24
	Obese: ≥25
Female	Essential fat: 10–13
	Athletes: 14–20
	Fitness: 21–24
	Acceptable: 25–31
	Obese: ≥32
BMI, Kg/m^2[10]	Underweight: <18.5
	Normal: 18.5–22.9
	Overweight: >23
	At Risk: 23–24.9
	Obese: ≥25
	Class-1: 25–29.9
	Class-2: >30
Waist Circumference[11]	
	Obese
Male	≥90 cm
Female	≥80 cm

Study variables and data collection

Data were collected on demographic information (age and sex), and anthropometry (weight, height, WC, and HC). T2DM was defined as HbA1c >6.5% and fasting blood glucose >120 mg/dL.[12] Body fat analysis included total body fat content and distribution, measured using a validated Omron fat analyzer (model HBF-702T; Omron Healthcare India Pvt. Ltd., Gurugram, Haryana, India). In addition to weight, it was also used to measure the BF%, visceral fat level, and BMI. Asian Indian cutoff values for defining obesity were used in this study. The participants' electronic medical records (EMR) were accessed to retrieve information on the latest random blood sugar levels from the laboratory test results. Informed consent was taken in their own vernacular language that the patient understands. The study was conducted after being reviewed and approved by the institutional review board (REF: 05/01/2023, dated 10/02/2023).

Statistical analysis

All collected data were entered into MS Excel 2006 version. The patient characteristics and variables were described using frequency distributions and proportions for categorical variables. Continuous variables were described using mean ± standard deviation (SD). To understand the effect of sex, subgroup analysis for males and females was conducted for anthropometric variables. The accuracy of BMI as a measure of adiposity using thresholds of 25 kg/m^2 was examined using BF% and AG as criterion measures, with the sensitivity, specificity, and predictive values of BMI calculated for men and women. Statistical analyses were performed using statistical software, SPSS version 26, and a P value of <0.05 was considered statistically significant.

Table 2: Sociodemographic data, *n*=432

Variables	Frequency %
Age (in years)	
18–29	32 (7.4)
30–39	24 (5.5)
40–49	64 (15)
50–59	76 (17.5)
60 and above	236 (54.6)
Gender	
Male	238 (55)
Female	194 (45)

Results

Table 2 shows the sociodemographic characteristics of patients. More than half, that is, 54.6% (236) were above 60 years of age. The mean age of patients was 56 ± 14 years. The majority of the study participants were males (55%, 238).

Table 3 shows the anthropometric, bio-impedance indices, and clinical characteristics of the study population. The mean BMI was 24.0 ± 4.1 kg/m^2, and the mean BF% was 30.0 ± 11.0%. The mean visceral fat percentage was 9.1 ± 5.9%. The mean WC and HC were 98 ± 12 cm and 107 ± 12.9 cm, respectively. Overall, 213 (49.3%) had a BMI above the normal range. About 84 (19.4%) and 129 (30%) were overweight and obese as per BMI, respectively. Notably, despite a comparable mean BMI in both sexes, the mean BF% was higher among males (38.9 ± 11%) than females (34 ± 11.5%).

Diabetes-related measures

The mean duration of diabetes was 8.86 years, with more than a third of the patients (79%) (343) having diabetes for ≥5 years.

Table 3: Anthropometry and clinical characteristics of enrolled patients

Variables	Males (*n*=238)	Females (*n*=194)	Total (*n*=432)
Anthropometric measures			
BMI, kg/m^2	23.9±4.17	24.1±4	24±4.1
Waist circumference, cm	100±12	98.9±12.1	98±12
Hip circumference, cm	105.9±13	110.5±12	107±12.9
Bio-impedance indices			
Body fat percentage, %	38.9±11	34±11.05	30±11
Visceral fat percentage, %	9.6±5.85	8.1±5.9	9.1±5.9
BMI category			
Underweight	11 (4.6)	2 (1)	13 (3)
Normal	96 (40)	110 (56.7)	206 (47.6)
Overweight	66 (27.7)	18 (9.2)	84 (19.4)
Obese	65 (27.3)	64 (32.9)	129 (30)
Diabetes-related measure			
Random blood sugar level	304±127.7	217±127	203±127
Duration of diabetes			
<5 years	50 (20.9)	39 (20)	89 (20.6)
5–10 years	127 (53.3)	123 (63)	250 (57.8)
>10 years	61 (25.6)	32 (16)	93 (21.5)
Ongoing anti-diabetic therapy			
Yes	195 (81.9)	183 (94.3)	378 (87.5)
No	43 (18.0)	11 (5.7)	54 (12.5)

Table 4: BMI classification accuracy

	Using BF%/AG	
	Obese	**Normal**
Using BMI, obese	True positive	False positive
Normal weight	False negative	True negative

Table 5: Predictive value of BMI vs. body fat percentage and abdominal girth

Variables	Men, BF%				
	Sensitivity	Specificity	PPV	NPV	Accuracy
BMI, 25 kg/m^2	41.61	100	100	6.45	43.87
	Men, AG				
	38.10	100	100	5.45	40.23
	Females, BF%				
	45.19	75	82.46	34.48	53.47
	Females, AG				
	40.71	61.90	86.76	13.54	43.48

Most patients (378, 87.5%) were taking an ongoing anti-diabetic medication.

Table 4 shows how the accuracy of BMI as a measure of obesity was evaluated against body fat percentage (BF%) and abdominal girth (AG) as reference standards.

Table 5 shows the diagnostic accuracy of BMI against BF% and AG in males and females, which shows the sensitivity of BMI was 41.6% and 45.19% against BF% in males and females, respectively, and the sensitivity of BMI was 38.1% and 40.71% against AG in males and females, respectively.

Correlation between AG and BF%

A statistically significant, moderate positive correlation ($r = 0.575$, $P = 0.001$**) between BF% and AG was seen in overall participants.

Discussion

The present study was conducted among T2DM patients, and it aimed at comparing different methods of classifying obesity and finding their validity with comparison to BMI.

In terms of sociodemographic characteristics of patients, 236 (54.6%) were above 60 years of age, the mean age of patients was 56 ± 14 years, about 238 (55%) were males, and about 194 (44.9%) were females, which is similar to a study that measured the prevalence of obesity in hospitalized T2DM patients and described demographic and clinical characteristics using electronic medical records. The study found that the mean age of patients was 63 years, and the majority were males (57%). The study also found that obesity was associated with a higher prevalence of hypertension, dyslipidemia, and coronary artery disease.[13]

The current study found that the sensitivity of BMI in males and females was 41%, and 45.1% over BF%, respectively. These findings indicate that BMI alone may have limitations in accurately identifying obesity-related metabolic risks in both male and female individuals with T2DM. Comparatively, BF% may provide a more informative measure for evaluating central adiposity and its association with metabolic health. This discussion will explore the implications of these results and compare them with previous studies.

The low sensitivity of BMI observed in the current study aligns with previous research. A study found that a BMI of ≥30 had poor sensitivity (36% and 49%, respectively) to detect BF%-defined obesity.[14] The low sensitivity of BMI can be attributed to its inability to differentiate between lean mass and fat mass accurately, particularly in individuals with altered body composition or distribution of adipose tissue.

BF% provides a direct measure of body fat content, offering a more accurate assessment of adiposity. Several studies have highlighted the superiority of BF% over BMI in predicting metabolic risks in females with T2DM. For example, a study showed that BF% is better than the indicators of weight status in identifying unfavorable lipid profiles and cardiovascular risk, mainly among girls.[15] Similarly, observational studies suggested that the association of BF% with central fat distribution is stronger than for BMI, and central fat distribution and metabolic consequences of excess weight remain strongly associated.[16]

The present study found that the sensitivity of BMI in males and females was 38%, and 40.7%, respectively, with regard to AG. These findings also indicate that BMI alone may have limitations in accurately identifying obesity-related metabolic risks in male individuals with T2DM.

The low sensitivity of BMI observed in our study is consistent with previous research. Several studies have demonstrated that BMI is less effective in capturing central adiposity and its association with metabolic abnormalities in individuals with T2DM. For instance, a previous study suggested that individuals with normal body weight as defined by BMI might still be at risk for metabolic syndrome and that WC may be a better indicator of obesity-related risk.[17]

AG provides a measure of central adiposity, specifically abdominal fat distribution, which is strongly associated with metabolic abnormalities and increased cardiometabolic risk. Previous studies have shown that AG is a better predictor of insulin resistance, dyslipidemia, and other metabolic parameters in individuals with T2DM as compared to BMI. A study by Canoy *et al.* (2007) in a large cohort of males with T2DM demonstrated that AG is independently associated with markers of insulin resistance and cardiovascular risk.[18]

Our study demonstrates a moderate positive correlation ($r = 0.575$) between AG and BF% in individuals with T2DM. This finding suggests that there is a significant association between abdominal adiposity and overall body fat content. This discussion will explore the implications of this correlation and compare it with previous studies.

The moderate positive correlation between AG and BF% observed in the present study aligns with previous research. A study conducted in Korea evaluated the relationship between BF% and the risk for T2DM. The BF% linked to risk for T2DM was found to be lower in non-obese men than in obese men, and the interaction test indicated that group 2 (low BMI and high BF%) has a higher risk.[19] Another study found that genetic factors exert their effect following exposure to an environment characterized by sedentary behavior and high-calorie intake. Common glycemic genetic variants for T2DM have been identified by genome-wide association studies, but this only accounts for 10% of total cases.[20]

A cross-sectional study found that higher BF% is linked to an increased risk of sarcopenia in older adults with T2DM, suggesting the importance of assessing BF% rather than BMI alone.[21]

In summary, this study investigated the relationship between BF%, AG, and BMI in individuals with T2DM. The findings indicate that BF% and AG provide valuable insights into adiposity and its association with metabolic health, surpassing the limitations of BMI as a measure of body composition. BF% is a comprehensive indicator of overall body fat content, and AG serves as a proxy for central adiposity. The study also revealed correlations between BF% and AG, suggesting that excess abdominal fat accumulation is reflective of increased total body fat content.

The study's findings have important implications for the assessment of adiposity and metabolic health in individuals with T2DM. By incorporating measures such as BF% and AG alongside BMI, clinicians can obtain a more comprehensive understanding of body composition and its relationship with metabolic abnormalities. This holistic approach enables better risk stratification and identification of individuals at higher risk for metabolic complications.

In addition, the present study will be useful for family medicine physicians who manage diabetes in their patients. A previous study has found that differences exist in the choice of treatment by family medicine physicians compared to general internal medicine physicians in diabetes management.[22] Therefore, the findings of the article can help family medicine physicians to better understand the classification methods for obesity in diabetic patients and provide appropriate treatment options to their patients.

However, it is essential to acknowledge the limitations of the study. First, the study's cross-sectional design limits causal inferences and warrants caution while interpreting the observed associations. Second, the study focused on individuals with T2DM, which may restrict the generalizability of the findings to other populations. Future studies should consider longitudinal designs and include a broader range of participants to enhance the external validity of the results.

Moreover, it is worth noting that the measurement of BF% may require specialized equipment or techniques, potentially limiting their practicality in routine clinical settings. Thus, efforts should be made to explore the feasibility of incorporating these measures into standard clinical practice. In addition, future research should investigate the predictive value of BF% and AG for metabolic outcomes and assess their utility in guiding therapeutic interventions and monitoring treatment response in individuals with T2DM.

Conclusion

Though the study highlights the very good specificity for BMI against BF%, the sensitivity of BMI against BF%, and AG was low in evaluating adiposity and its association with metabolic health in individuals with T2DM. The correlations observed between BF%, AG, and metabolic parameters emphasize their potential as valuable tools for risk stratification and personalized management of T2DM. Overcoming the limitations and further exploring the clinical utility of these measures will contribute to more accurate assessments and improved outcomes for individuals with T2DM.

Financial support and sponsorship

MDRU of the institute.

Conflicts of interest

There are no conflicts of interest.

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