Magnitude and Performance of Percentage Body Fat and Fat Mass Index in Determining Overweight/Obesity among University Undergraduate Students in the Kumasi Metropolis, Ghana.

Christian Obirikorang
Department of Molecular Medicine, School of Medicine and Dentistry, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

Emmanuel Acheampong
Department of Molecular Medicine, School of Medicine and Dentistry, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

Enoch Odame Anto
Department of Molecular Medicine, School of Medicine and Dentistry, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

Yaa Obirikorang
Garden City University College, Department of Nursing, Kumasi, Ghana

Angela Nana Bosowah Fynn
Department of Medical Diagnostics, Faculty of Allied Health Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

George Osei-Somuah
Department of Medical Diagnostics, Faculty of Allied Health Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Brodrick Yeboah Amoah
Chemical Pathology Unit, Department of Medical Laboratory Sciences, School of Biomedical and Allied Health Sciences, University of Ghana

Eunice Adwubi Busumbru
Garden City University College, Department of Nursing, Kumasi, Ghana

Michael Appiah
Department of Molecular Medicine, School of Medicine and Dentistry, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

Evans Asamoah Adu (evansasamoahadu@gmail.com)
Department of Molecular Medicine, School of Medicine and Dentistry, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana https://orcid.org/0000-0001-6374-0979

Emmanuella Nsenbah Acheampng
Department of Molecular Medicine, School of Medicine and Dentistry, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
Daniel Gyamfi
Department of Medical Diagnostics, Faculty of Allied Health Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Research Article

Keywords: Fat mass index, Percentage body fat, Body mass index, Kumasi Metropolis, Overweight/Obesity

Posted Date: May 22nd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-30910/v1

Abstract

Background: Anthropometric indices such as body mass index (BMI) is a widely used index of adiposity across clinical settings, yet there are limitations regarding their estimates of body fat. We determined the magnitude and the performance of fat mass index (FMI), and percentage body fat (PBF) for determining obesity among undergraduate students in the Kumasi Metropolis, Ghana.

Methods: This University community-based cross-sectional study included 1,552 undergraduate students (700 males and 852 females) aged 15–29 years from the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Anthropometric measurements and bioelectrical impedance analyses were performed. Data on sociodemographic and lifestyle-related characteristics were obtained using a structured questionnaire.

Results: Comparing male to female students, the age-standardised prevalence of overweight/obesity was 10.8%/3.5% vs. 19.3%/7.6% (p<0.0001) for BMI criterion, 16.4%/8.5% vs. 21.9%/19.9% (p<0.0001) for PBF criterion and 16.0%/9.2 vs. 21.2%/22.0% for FMI criterion (p<0.0001), respectively. There was a stronger agreement between PBF and FMI in the classification of overweight and obesity in terms of males (kappa=0.855) and females (kappa=0.865) but a weak agreement between BMI and PBF and between BMI and FMI. About 29.3% of males and 61.4% of the females categorized as normal weight by BMI were identified as overweight by PBF. Similarly, 3.0% of male and 1.3% of females defined as normal weight by BMI were obese when examined by PBF. FMI can be predicted from BMI and BMI^2 with much accuracy (mean bias = -0.1).

Conclusion: The inconsistency observed between BMI and PBF reflects a limitation of BMI. FMI accurately assessed obesity with many conveniences as BMI to the same extent.

Introduction

Over the past three decades, chronic conditions such as diabetes, cardiovascular conditions, and obesity accounted for <45% of the global disease burden [1]. Today, obesity, which represents an abnormal or excessive fat accumulation, is one of the major public health problems leading the toll on death and disability worldwide [1]. Prevalence of obesity across the world has tripled (>100% increase) since 1975 with nearly 1.9 billion adults estimated to be overweight in 2016, including 650 million adults with obesity [2]. Especially in developing countries, the possible implications of obesity on current and future population health and health care spending is likely to be blatantly enormous [3]. The implication of this is that health benefits encouraged by modern medicine are being eroded by the current obesity epidemic. In Ghana, overweight and obesity prevalence is estimated to be 25.4% and 17.1%, respectively which are significantly higher in women than men and the patterns generally mimic the levels of urbanization [4].

Although there are simple and easily estimated measures of adiposity, BMI has been widely used as a marker of adiposity in both epidemiological and clinical practices [5, 6]. The usefulness of BMI, however, is limited in identifying differences in body composition and body fat distribution. The categorization of

overweight/obesity is broad and imprecise, especially when using BMI classification [5, 7]. Regarding the effects of visceral fat accumulation on an increased risk of metabolic diseases, waist circumference (WC) [8], waist-to-height ratio (WHtR) [9], and body adiposity index [10] has been promising alternatives for estimating obesity. Also, bioelectrical impedance analysis (BIA) has been reliably established as a measure of body adiposity with equivalent sensitivity as underwater weighing (UWW) and dual-energy X-ray absorptiometry (DEXA) [11, 12]. Although BIA is widely used in clinical and epidemiologic field [11, 12], it requires predictive equations for the determination of fat-free mass that are specifically developed for different populations, ethnicities, age groups, and sex [13]. Thus, there is still a need for an even more simplified approach to assessing body fat content in large epidemiological studies and the clinical setting.

A potential indicator of body adiposity is fat mass index (FMI). This index since its introduction in 1990 [14], has been reliably applied in several populations [15, 16]. It is defined by taking the body fat mass component from BIA and dividing by height squared. Although FMI, BMI and PBFmaybe composed of the same variables and similar, each one of them, has been shown to categorize overweight and obesity differently [12, 16]. BMI takes into account body weight and body height while FMI requires information on body weight, body height, and fat mass content. Comparing FMI to other indices, this index is highly influenced by fat mass content, which is the desired variable to be measured in obesity studies [17]. Also, the superiority of FMI over PBF has been shown in some studies [14, 15].

This study focused on describing the prevalence of overweight/obesity among tertiary education students in the Kumasi metropolis and proposed FMI cut-off points for this population. Additionally, we examined the performance of BMI, WC, WHtR, AVI, and BAI, and developed a predictive model of FMI that can be used in field studies requiring body composition assessment in Ghanaian young adults without the need for sophisticated equipment or techniques subject to operator error. This approach is useful for weight management programs especially among the youths that are actively involved in bodybuilding activities to identify appropriate indices defining weight-related behaviours.

Methodology

Study design/setting

This cross-sectional study was undertaken at the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, from August 2018 to July 2019.

Subject selection

A multi-stage random sampling stratified was used to select 1552 first to fourth-year undergraduate students aged 15–29 years. These students were selected to cover the six Faculties in KNUST including the College of Art and Built, Social Sciences, Health Sciences, Engineering, Applied Sciences, Architecture, and Agricultural sciences. Students with any underlying conditions which are associated with abnormal

weight were excluded. A structured questionnaire was used to collect data on socio-demographic characteristics, lifestyle risk factors (drinking of alcohol and smoking), and family history of obesity.

Sample size determination

To obtain a representative sample size for the entire student's population at all college level, at a confidence level of 97% and a margin of error of 0.05, the minimum sample size required for the study was 1090 using the formula below:

$$n = \frac{N}{1 + N(e)^2}$$

Where N = total undergraduate student population (56,000), n = estimated sample size, e = margin of error. However, to ensure a fair distribution of the samples at the college level and stronger statistical power and effect size, the samples were projected to 1552 students.

Anthropometric measurement

Each participant stood up-straight on the main unit, looking straight, barefooted and with arms horizontally raised holding the display unit, extended at a 90° angle, and weight in kilograms (kg) was estimated using the Omron B511. All students stood straight, with feet placed together and flat on the ground and a portable height rod Stadiometer was used to measure the body height. Waist circumference (WC) and Hip circumference (HC) were measured using a tape measure at the point of the umbilicus and maximum gluteal protrusion, respectively.

PBF was estimated using the Omron B511. Omron B511 is a clinically validated full body composition monitor with 8 high-precision sensors for hand-to-foot measurement (OMRON HEALTHCARE Co., Ltd.). The machine conforms to EN60601–1–2:2015 Electro Magnetic Compatibility (EMC) standard and uses the bioelectrical impedance, along with height, weight, age and gender information to generate results based on OMRON's data of body composition [18]. PBF was expressed as the ratio of body fat mass (kg) to body weight (kg) expressed as a percentage. FMI was also estimated as the ratio of body fat mass (kg) to height (m) squared.

Calculated anthropometric indices

BMI (kg/m^2) was estimated from the ratio of weight to height (in meters) squared. WHtR and WHR were estimated as a ratio of WC to height and hip, respectively. BAI and AVI were estimated using the formulae

below:

$$\textbf{BAI} = \frac{\text{hip circumference (cm)}}{\text{height}^{1.5}} - 18 \qquad [10]$$

$$\textbf{AVI} = \frac{2\text{cm} \times (\text{waist})^2 + 0.7\text{cm} \times (\text{waist} - \text{hip})^2}{1000} \qquad [19]$$

Definitions of overweight/obesity

Subjects were categorised as overweight if BMI was in the range 25.0–29.9 kg/m^2, and obese if BMI ≥30.0 kg/m^2[2]. Classification for overweight and obesity according to PBF criteria is shown in *Table S1.* Values for WC for overweight and Obesity were 94.0–101.9 and ≥102.0 cm for males; 80.0–87.9 and ≥88.0 cm for females, respectively. ROC analyses *[Figure S1]* were performed to generate FMI cut-offs for male and female students; overweight (male = 4.5–6.5 Kg/m^2, female = 7.4–9.8 Kg/m^2); Obesity (male >6.5 Kg/m^2, female >9.8 Kg/m^2), respectively.

Statistical analyses

Prevalence of underweight, overweight, and obesity was standardised by age and sex. The correlation of WC, BMI and BAI with PBF and body fat mass (BFM) were investigated using linear regression models with Pearson’s correlation coefficient (r), and the agreement was assessed by intraclass correlation coefficient (ICC). Multiple linear regression analysis was performed with FMI as the dependent variable to create predictive models of FMI for university undergraduate students. The following independent variables were assessed: age, WC, WHtR, BMI, and BMI^2. Analyses were performed separately for male and female students because of the higher BFM at any given height seen in female compared to male students. The coefficients of determination (R^2) were reported as a measure of the proportion of the variability of FMI explained by the independent variables. To test whether the equations adequately predicted FMI in our entire study sample, we randomly split the dataset into two to (a) derive predictive equations in one dataset (N = 985) and (b) predict FMI in the other dataset (N = 567). In general, the following regression coefficients were obtained: 0.7–1.0, for strong correlation; 0.4–0.7, for a slight correlation. In the case of ICC evaluation score, 0.20 was considered slight, 0.21–0.40, fairer; 0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81, almost perfect. A two-sided *p*-value of 0.05 was considered statistically significant. Statistical analyses were performed using MedCalc Software for Windows, version 18.91 (https://www.medcalc.org/).

Results

The descriptive summary of demographic and anthropometric data among male and female students is shown in *Table 1.* Male students were older than female students (mean age = 20.6 vs 19.8 years, p-value <0.0001). More males than females (p-value <0.0001) occasionally exercises (48.1% vs 37.8%) or exercises almost every day (16.3% vs 11.5%). The percentage of alcohol drinkers was higher in males (11.3%) compared with females (5.6%, p-value <0.0001). Also, a positive family history of diabetes was seen more in females than males (22.4% vs 17.3%, p-value = 0.012). The mean values of BAI, BMI, PBF, and BFM were higher among females (p-value <0.0001) whereas WC was higher in males than females (p-value <0.0001).

Table 1: Characteristics of the study participants by sex

Variable	Male (n=700)	Female (n=852)	Total (n=1552)	P-value
Age (years)	20.6±2.07	19.8±1.8	20.2±2.0	**<0.0001**
Exercise history^				**<0.0001**
None	26 (3.7)	62 (7.3)	88 (5.7)	
Rarely	223 (31.9)	370 (43.3)	593 (38.2)	
Occasionally	337 (48.1)	322 (37.8)	659 (42.5)	
Almost everyday	114 (16.3)	98 (11.5)	212 (13.7)	
On diet^	22 (3.1)	46 (5.4)	68 (4.4)	**0.031**
Alcohol drinking^	79 (11.3)	48 (5.6)	127 (8.2)	**<0.0001**
Smoking^	8 (1.1)	9 (1.1)	17 (1.1)	0.871
Family history of hypertension^	121 (17.3)	171 (20.1)	292 (18.8)	0.162
Family history of obesity^	59 (8.4)	85 (10.0)	144 (9.3)	0.296
Family history of diabetes^	121 (17.3)	191 (22.4)	312 (20.1)	**0.012**
WC (cm)*	74.6±10.9	71.3±8.9	72.7±10.0	**<0.0001**
BMI (Kg/m^2)*	21.8±3.5	23.0±4.5	22.5±4.1	**<0.0001**
BAI*	23.4±4.1	30.0±5.5	27.0±5.9	**<0.0001**
PBF (%)*	15.3±7.2	31.5±8.7	24.2±11.4	**<0.0001**
BFM (Kg)*	10.6±7.0	19.9±9.2	15.7±9.5	**<0.0001**

WC- waist circumference; BMI- body mass index; BAI- body adiposity index; PBF- percentage body fat; BFM: body fat mass

Age-specific prevalence of overweight/obesity for male and females is shown in *Table 1.* Using the PBF criterion, 16.4% vs 21.9% overweight and 8.5% vs 19.9% obese male and female students were identified, respectively. BMI criterion also, identified 10.8% vs 19.3% overweight and 3.5% vs 7.6% obese, male and female students, respectively. Central obesity defined by waist circumference was prevalent among 1.6% of men and 5.1% of women *[Table 1] (Tables S2 and S3).*

In a multivariate logistic regression analysis, female sex [OR = 2.2 (95%CI: 1.8–2.88), p <0.0001], age between 20–29 years [OR = 1.43 (95%CI: 1.14–1.79), p = 0.002], Family history of obesity [OR = 2.64 (95%CI: 1.80–3.89), p<0.0001] and being on diet [OR = 2.00 (95%CI: 1.16–3.32), p = 0.011] were significantly associated with overweight/obesity *[Table S4].*

Table 2: Age-standardised prevalence of underweight, overweight, obesity and abnormal visceral fat status among the study participants

Index	Classification	Male (N=700)	Female (N=852)	*P*-value
BMI (kg/m^2)	Overweight (%)	10.8 (8.6-13.2)	19.3 (14.2-25.0)	**<0.0001**
	Obesity (%)	3.5 (2.3-5.0)	7.6 (5.2-10.4)	**<0.0001**
PBF (%)	Overweight (%)	16.4 (13.7-19.2)	21.9 (15.7-28.9))	**<0.0001**
	Obesity (%)	8.5 (6.6-10.7)	19.9 (15.6-24.5)	**<0.0001**
WC (cm)	Overweight (%)	2.3 (0.6-5.1)	7.9 (5.0-11.5)	**<0.0001**
	Obesity (%)	1.6 (0.8-2.6)	5.1 (2.6-8.3)	**<0.0001**
FMI (kg/m^2)	Overweight (%)	16.0 (13.3-18.8)	21.2 (18.4-24.1)	**<0.0001**
	Obesity (%)	9.2 (6.2-12.7)	22.0 (15.6-29.2)	**<0.0001**

Values represent mean percentage (confidence interval, CI); BMI-body mass index, WC- waist circumference PR-prevalence risk (male = reference category)

Association of BMI, FMI, WC with %BF and other body composition measures

BMI strongly correlated with FMI and PBF in both men and women; Pearson's correlation [*Table 3]* was 0910 for FMI and 0.810 for PBF in men, and 0.962 for FMI and 0.866 for PBF in women (all p<0.001). Also, WC showed a fair-moderate correlation with FMI and PBF in both male and female students. BAI correlated substantially with BFM and PBF in both male and female students.

Poor-moderate agreement was observed between WC measures and PBF in males [ICC = 0.43 (95CI: 0.36–0.49), p<0.0001] and substantial agreement in female [ICC = 0.69 (95%CI: 0.66–0.73), p<0.0001). Also, substantial agreement was observed between BMI and PBF in both male [ICC = 0.62 (95%CI: 0.58–0.66)] and female [ICC = 0.70 (95%CI = 0.67–0.73)]. BMI perfectly agreed with FMI in both males and females *[Table 3].*

Tables 3: Correlation of WC and BMI with body composition indices and total body fat percentage

Variables	Agreement statistics	Male (N= 700)		Female (N=852)	
		FMI (Kg)	PBF (%)	FMI (Kg)	PBF (%)
BMI	r	0.910	0.810	0.962	0.866
	ICC (95%CI)	0.84 (0.82-0.86)	0.63 (0.59-0.68)	0.94 (0.93-0.94)	0.70 (0.67-0.73)
	p-value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
WC	r	0.529	0.464	0.761	0.695
	ICC (95%CI)	0.21 (0.14-0.28)	0.43 (0.36-0.49)	0.52 (0.47-0.57)	0.69 (0.66-0.73)
	p-value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
BAI	r	0.737	0.702	0.820	0.782
	ICC (95%CI)	0.63 (0.57-0.67)	0.61 (0.56-0.65)	0.75 (0.72-0.78)	0.70 (0.67-0.74)
	p-value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
AVI	r	0.404	0.342	0.758	0.686
	ICC (95%CI)	0.32 (0.25-0.38)	0.31 (0.24-0.38)	0.74 (0.71-0.77)	0.40 (0.34-0.46)
	p-value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
WHtR	r	0.560	0.560	0.787	0.722
	ICC (95%CI)	0.03 (-0.04-0.10)	0.03 (-0.04-0.10)	0.03 (-0.04-0.09)	0.0 (-0.05-0.08)
	p-value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
WHR	r	0.037	0.009	0.082	0.050
	ICC (95%CI)	0.0 (-0.07-0.08)	0.0 (-0.07-0.08)	0.0 (-0.06-0.07)	0.0 (-0.06-0.07)
	p-value	0.362	0.859	**0.017**	0.150

ICC- inter-class correlation coefficient, r- Pearson's correlation coefficient, AVI-abdominal volume index, BAI= body adiposity index

There was almost perfect agreement between FMI criteria and PBF criteria for defining overweight and obesity among males (Kappa = 0.855) and female (kappa = 0.865). The percentage of men classified by BMI as being normal body weight and as overweight but classified as obese by PBF was 3.0% and 29.3%, respectively. In women, 1.3% and 61.4% of those classified by BMI as being normal body weight and as overweight, respectively, were found to be obese by PBF. When comparing BMI and FMI categories, 1.8% and 42.7% of the men in the normal and overweight BMI categories, respectively, were obese by FMI, whereas 61.4% of females in the overweight BMI category were obese by FMI. Poor agreement in overweight and obesity classification was observed between WC and PBF (kappa = 0.09) and FMI (kappa = 0.082) in males.

Table: 4: Agreement between BMI, WC, PBF and FMI criteria for defining overweight/Obesity

	Male (N=700)			Female (N=852)		
	Overweight	Obesity	Kappa	Overweight	Obesity	kappa
			PBF criteria			
FMI Criteria			0.855			0.867
Normal	1.5%	0.0		2.7%	0	
Overweight	82.9%	6.3%		84.4%	2.8%	
Obese	21.2%	78.8%		12.6%	86.8%	
BMI Criteria			0.537			0.431
Normal	10.0%	3.0%		20.9%	1.3%	
Overweight	66.7%	29.3%		34.4%	61.4%	
Obese	16.7%	79.2%		3.1%	92.3%	
WC criteria			0.09			0.217
Normal	16.6%	6.4%		23.1%	11.6%	
Overweight	14.3%	71.4%		26.5%	67.6%	
Obese	0	60.0%		0	86.4%	
			FMI criteria			
BMI Criteria			0.514			0.395
Normal	11.5%	1.8%		22.5%	0.6%	
Overweight	54.7%	42.7%		23.5%	74.1%	
Obese	4.2%	95.8%		1.5%	96.9%	
WC criteria			0.082			0.194
Normal	16.3%	7.2		22.8%	13.2%	
Overweight	7.1%	78.6		16.2%	79.4%	
Obese	0	60.0		0	86.4%	

Sex was identified as an effect modifier in the relationship of BMI with PBF and FMI *[Figure 1A].* BMI explained 91% variability in FMI among female participants and 77% in male participants. The proportional variability in PBF by BMI was lesser in females compared males (61% vs. 74%). BMI shows a slightly curvilinear relationship with PBF [Figure 1D], and a more linear relationship with FMI in a second-order polynomial regression analysis [Figure 1C]. The curvilinear relationship between BMI and PBF is more accentuated in females than in males (R^2 = 0.78, $p < 0.0001$).

From *Table 5,* FMI was significantly predicted by BMI and BMI^2 in both male and female. The following predictive equations explained approximately 91% of the variance of FMI in female students and approximately 77% of the variance of FMI in male students. FMI = –8.539 + 0.505 (BMI) + 0.002 (BMI^2) for male students and FMI = –11.229 + 0.877 (BMI) - 0.002 (BMI^2) for female student. Adding age, WC, and WHtR to the model marginally improved the model’s predictability.

Table 5: Multiple linear regression analysis of FMI for Ghanaian undergraduate male and Female University Student

Model	Variable	Coefficient	SE	P-value	R^2	Model Constant
		Female students (N= 532)				
	BMI	0.877	0.081	<0.0001	0.910	-11.229
	BMI^2	-0.002	0.002			
	BMI	0.868	0.082	<0.0001	0.911	-11.794
	BMI^2	-0.002	0.002			
	Age	0.035	0.023			
	BMI	0.704	0.015	<0.0001	0.914	-11.225
	WC	0.037	0.008			
	BMI	0.812	0.081	<0.0001	0.915	-12.776
	BMI^2	-0.002	0.002			
	Age	0.020	0.023			
	WC	0.043	0.014			
	WHtR	-1.263	2.277			
		Male Students (N=453)				
	BMI	0.505	0.119	<0.0001	0.768	-8.539
	BMI^2	0.002	0.002			
	BMI	0.498	0.119	<0.0001	0.770	-9.317
	BMI^2	0.002	0.002			
	Age	0.043	0.022			
	BMI	0.581	0.018	<0.0001	0.772	-11.099
	Age	0.047	0.022			
	WC	0.013	0.006			
	BMI	0.573	0.018	<0.0001	0.774	-11.236
	Age	0.045	0.022			
	WHtR	3.011	1.010			

A Bland-Altman plot comparing measured and predicted FMI for both male and female students shows good agreement between the methods with a mean difference of −0.10 [Figure 2].

Discussion

Using the internationally accepted threshold for BMI, we observed an overweight prevalence of 11.0% among male students and 22.1% among female students. Further, 3.9% of male students and 7.6% of female students were obese. These figures were doubled when overweight/obesity prevalence was defined by PBF. The prevalence estimates of overweight and obesity observed in this study are similar to those observed among University students from Botswana [20] and Ghana [21] who used the internationally accepted threshold for BMI. Also, Peltzer*, et al.* [22] in a cross-sectional study among university students from 22 countries reported that the prevalence rates of overweight and obesity were 18.9% and 5.8% among male students; 14.1% and 5.2% among female students, respectively which is similar our present findings. Currently tertiary enrolment rate in Ghana stands at 16.2% [23], and overweight/obesity rates exceeding 10% reflect a significant national obesity problem. This rate may be biased towards high-income groups. This present study did not record data on the socio-economic status,

detailed physical activity, and calorie intake by the students, which limits the study's ability to make conclusions regarding the lifestyle and dietary habits of students. However, we observed that female-participants between the ages of 20–29 years, those with family history of obesity, and being on diet were significant factors for overweight/obesity prevalence among undergraduate university students in the Kumasi Metropolis.The finding is consistent with reports from other related studies [20, 22].

The ability to estimate or quantify fat stores accurately is central to the prevention and treatment of obesity-related conditions. Out of the commonest methods used, we selected BMI, WC, WHtR, BAI, AVI, WHR, and BIA for comparison in a sample of university undergraduate students. Results from the present demonstrated a strong correlation between BMI and PBF as estimated by BIA. However, 29.3% of males and 61.4% of the females categorized as as normal weight by BMI were identified as overweight by PBF. Similarly, 3.0% of male and 1.3% of females defined as normal weight by BMI were obese when examined by BIA. This indicate that BMI has the limitation to differentiate between free fat mass and fat mass. Similar findings had been reported by Pasco*, et al.* [5] and Pasco*, et al.* [7] among the general population. This finding reflects the phenomenon that increasing BMI only accurately mirrors increased weight-for-height but mask changes in body composition [5]. In a study by Peltz*, et al.* [15] 46.2%% of the men and 50.7% of the women with a BMI below 30 were found to be obese by PBF criteria when analysed by BIA.

Our results are in concordant with reports from other related studies that have provided evidence of the burden of obesity among the young adult population [4, 20, 22] and the limitation of BMI in defining obesity despite its wider applicability in clinical and epidemiological studies. To overcome these limitations, some studies [5, 7] have suggested lower cut-offs for BMI by sex and specific ethnic groups. Our results were not different as we observed a strong correlation but weak inter-rater agreement between BMI and PBF in both male and female students. Similar findings have also been reported among different population groups [5, 15, 24, 25].

Taking into consideration the strength of PBF, we compared FMI to PBF and tested its predictive accuracy to categorize obesity. This is to provide alternatives to the many simple and inexpensive indices for assessing adiposity alongside their limitation. FMI accurately classified overweight and obesity when compared to PBF in males (82.9% vs. 78.8%) and females (84.4% vs 86.8%) with an almost perfect agreement. ROC analysis for FMI and PBF showed area under the curve of 0.99 for both male and female students for classifying overweight; 0.92 and 0.97 for males and females for classifying obesity. The use of BMI and BMI^2 as independent predictors for FMI in a regression model showed a coefficient value of 0.91 in females and 0.77 in males ($p < 0.0001$). Adding WC and age to the model marginally increased the coefficient among men. To maintain the simplicity of the model, BMI and BMI^2 were selected as independent variables. In a study by Peltz*, et al.* [15], the authors used a similar approach and recorded a regression coefficient value of 0.92 for men and 0.99 for women ($p<0.001$) were observed, and these findings are congruent to our results. Additionally, previous studies have reported similar regression values using BMI, and BMI^2 [16, 26, 27].

The inconsistency observed between BMI and PBF reflects the major limitation of BMI in assessing adiposity. That is, BMI among the young adult population cannot be completely relied upon as a measure of adiposity. Therefore, its limitations must be taken into account when interpreting body weight classifications based on BMI. FMI appears to provide not only accuracy but an economical advantage together with convenience for assessing obesity.

The study had some limitations. First, the BAI principle and device used in the study was limited by overestimating body fat in lean individuals and underestimating in very obese individuals. Second, we did not do a comparison to reference methods for the assessment of body adiposity. Nevertheless, the strength of the study lies in the large sample size, and the sampling technique employed, reducing bias in our findings. Notably,the usefulness of FMI has not been explored in the Ghanaian population and not fully explored in literature, possibly due to the lack of specific cut-offs [15]. So far, BMI is the simplest and most convenient method of assessing body adiposity. However, since BMI is mathematically equal to the sum of FMI and fat-free mass index according to studies [16, 17], the use of FMI as a measure of adiposity is more appropriate and relates to the adiposity content of BMI.

Conclusion

Our study highlighted that the prevalence of overweight/obesity is high among university undergraduate students in the Kumasi Metropolis. Secondary, we highlighted that BMI is not reliable or sufficient for identifying overweight/obesity. This suggest that defining the incidence or prevalence of obesity based on BMI is likely to be substantively biased. PBF is also superior to BMI in correctly classifying obesity based on accurate estimates of body fatness. FMI is as convenient to use as BMI and PBF for defining overweight/obesity. Moreover, FMI can be predicted from BMI and BMI^2 with much accuracy.

Declarations

Ethical Approval and Consent to Participate

Ethical approval was obtained from the Committee on Human Research, Publications and Ethics (CHRPE), School of Medicine and Dentistry, Kwame Nkrumah University of Science & Technology. Permission to carry out the study on the university campus was obtained from the university authorities. Written informed consent were obtained from all participants who opted to participate.

Competing interests

The authors declare that they have no competing interests.

Availability of data and material

The datasets used and/or analysed during the current study are within the manuscript and supplementary material.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

The authors wish to express gratitude to the entire student's population for their active participation in the study.

References

1.Organization WH: *Controlling the global obesity epidemic.* In.*;* 2003.

2.Organization WH: *Obesity and overweight fact sheet. 2016. Department of Sustainable Development and Healthy Environments* 2018.

3.Nugent R: *Chronic diseases in developing countries: health and economic burdens. Annals of the New York Academy of Sciences* 2008, *1136(*1):70–79.

4.Ofori-Asenso R, Agyeman AA, Laar A, Boateng D: *Overweight and obesity epidemic in Ghana-a systematic review and meta-analysis. BMC Public Health* 2016, *16(*1):1239–1239.

5.Pasco JA, Holloway KL, Dobbins AG, Kotowicz MA, Williams LJ, Brennan SL: *Body mass index and measures of body fat for defining obesity and underweight: a cross-sectional, population-based study. BMC Obesity* 2014, *1(*1):9.

6.Snijder M, Van Dam R, Visser M, Seidell J: *What aspects of body fat are particularly hazardous and how do we measure them? International journal of epidemiology* 2006, *35(*1):83–92.

7.Pasco JA, Nicholson GC, Brennan SL, Kotowicz MA: *Prevalence of obesity and the relationship between the body mass index and body fat: cross-sectional, population-based data. PLoS One* 2012, *7(*1):e29580-e29580.

8.Organization WH: *Obesity: preventing and managing the global epidemic. Report of a WHO Consultation. Geneva, Switzerland: World Health Organization, 2000. WHO technical report series, 894.*

9.Obirikorang C, Obirikorang Y, Acheampong E, Anto EO, Toboh E, Asamoah EA, Amakwaa B, Batu EN, Brenya P: *Association of wrist circumference and waist-to-height ratio with cardiometabolic risk factors among type II diabetics in a Ghanaian population. Journal of diabetes research* 2018, *2018.*

10.Freedman DS, Thornton JC, Pi-Sunyer FX, Heymsfield SB, Wang J, Pierson Jr RN, Blanck HM, Gallagher D: *The body adiposity index (hip circumference÷ height1. 5) is not a more accurate measure of adiposity than is BMI, waist circumference, or hip circumference. Obesity* 2012, *20(*12):2438–2444.

11.Pietrobelli A, Rubiano F, St-Onge M, Heymsfield S: *New bioimpedance analysis system: improved phenotyping with whole-body analysis. European journal of clinical nutrition* 2004, *58(*11):1479–1484.

12.Sun SS, Chumlea WC, Heymsfield SB, Lukaski HC, Schoeller D, Friedl K, Kuczmarski RJ, Flegal KM, Johnson CL, Hubbard VS: *Development of bioelectrical impedance analysis prediction equations for body composition with the use of a multicomponent model for use in epidemiologic surveys. The American journal of clinical nutrition* 2003, *77(*2):331–340.

13.Peltz G, Sanderson M, Pérez A, Sexton K, Casares DO, Fadden MK: *Serum leptin concentration, adiposity, and body fat distribution in Mexican-Americans. Archives of medical research* 2007, *38(*5):563–570.

14.VanItallie T, Yang M-U, Heymsfield SB, Funk RC, Boileau RA: *Height-normalized indices of the body's fat-free mass and fat mass: potentially useful indicators of nutritional status. The American journal of clinical nutrition* 1990, *52(*6):953–959.

15.Peltz G, Aguirre MT, Sanderson M, Fadden MK: *The role of fat mass index in determining obesity. Am J Hum Biol* 2010, *22(*5):639–647.

16.Schutz Y, Kyle U, Pichard C: *Fat-free mass index and fat mass index percentiles in Caucasians aged 18–98 y. International journal of obesity* 2002, *26(*7):953–960.

17.Wells J, Williams J, Fewtrell M, Singhal A, Lucas A, Cole T: *A simplified approach to analysing bio-electrical impedance data in epidemiological surveys. International journal of obesity* 2007, *31(*3):507–514.

18.Manual OI: *Full Body Sensor Body Composition Monitor and Scale Model HBF-510. China: Omron Healthcare* 2008.

19.Guerrero-Romero F, Rodŕiguez-Morán M: *Abdominal volume index. An anthropometry-based index for estimation of obesity is strongly related to impaired glucose tolerance and type 2 diabetes mellitus. Archives of medical research* 2003, *34(*5):428–432.

20.Tapera R, Merapelo MT, Tumoyagae T, Maswabi TM, Erick P, Letsholo B, Mbongwe B: *The prevalence and factors associated with overweight and obesity among University of Botswana students. Cogent Medicine* 2017, *4(*1):1357249.

21.Mogre V, Nyaba R, Aleyira S: *Lifestyle risk factors of general and abdominal obesity in students of the school of medicine and health science of the University of Development Studies, Tamale, Ghana. ISRN obesity* 2014, *2014.*

22.Peltzer K, Pengpid S, Samuels TA, Özcan NK, Mantilla C, Rahamefy OH, Wong ML, Gasparishvili A: *Prevalence of overweight/obesity and its associated factors among university students from 22 countries. Int J Environ Res Public Health* 2014, *11(*7):7425–7441.

23.*Ghana - Gross enrolment ratio in tertiary education* [https://knoema.com/atlas/Ghana/topics/Education/Tertiary-Education/Gross-enrolment-ratio-in-tertiary-education]

24.Kontogianni MD, Panagiotakos DB, Skopouli FN: *Does body mass index reflect adequately the body fat content in perimenopausal women? Maturitas* 2005, *51(*3):307–313.

25.Dolan CM, Kraemer H, Browner W, Ensrud K, Kelsey JL: *Associations between body composition, anthropometry, and mortality in women aged 65 years and older. American journal of public health* 2007, *97(*5):913–918.

26.Frankenfield DC, Rowe WA, Cooney RN, Smith JS, Becker D: *Limits of body mass index to detect obesity and predict body composition. Nutrition* 2001, *17(*1):26–30.

27.Kyle UG, Schutz Y, Dupertuis YM, Pichard C: *Body composition interpretation: contributions of the fat-free mass index and the body fat mass index. Nutrition* 2003, *19(*7–8):597–604.

Figures

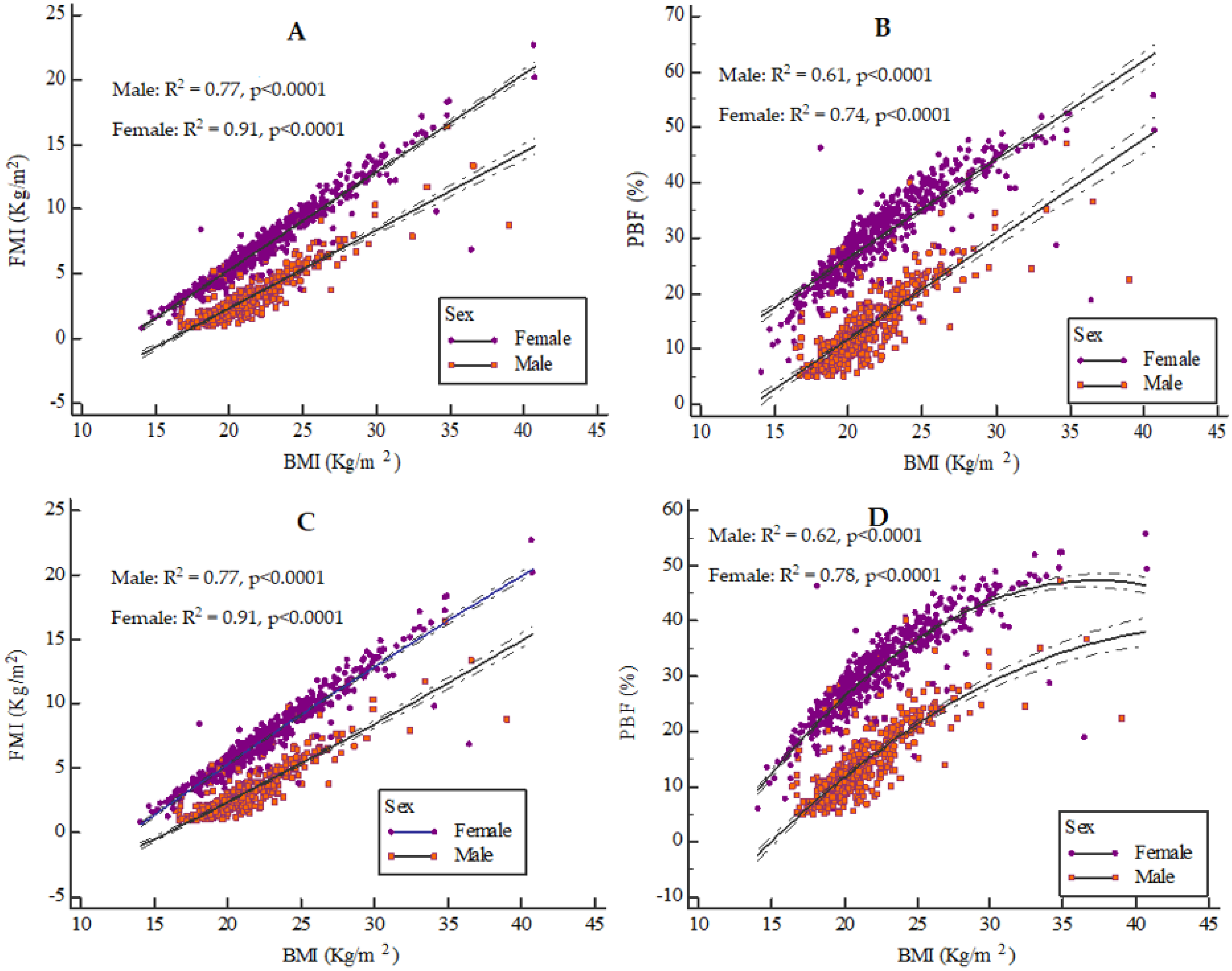

Figure 1

Scatter plot of BMI against PBF and FMI for male and female Ghanaian University undergraduate students. Predicted values are represented by lines.

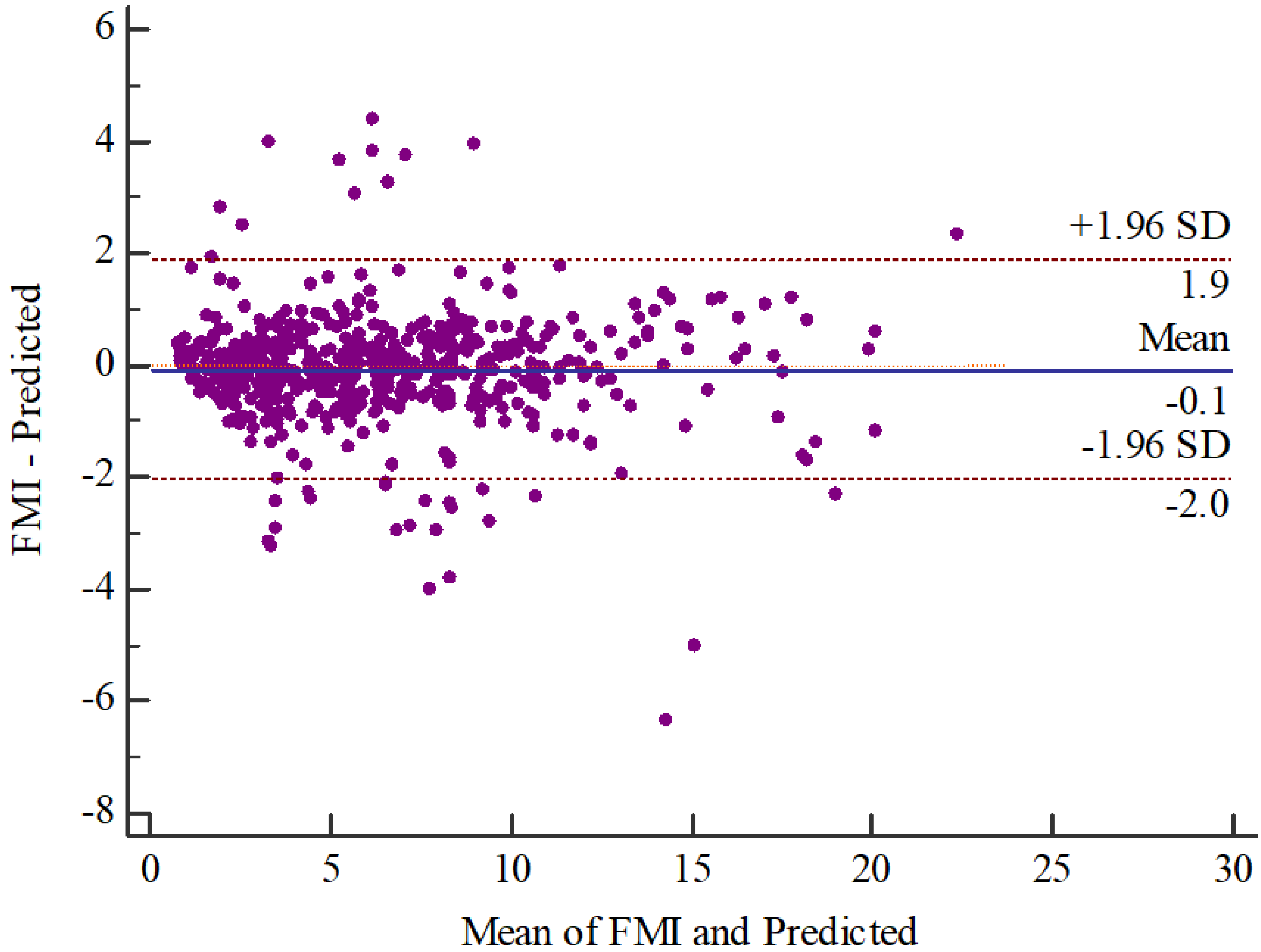

Figure 2

Bland-Altman plot showing the agreement between FMI based on measured fat mass/ (height)2 and predicted fat mass/(height)2 in University undergraduate student in Ghana

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarydata.docx