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FFM Index, FM Index and PBF in Subjects with Normal, Overweight, and Obese BMI in Saudi Arabia Female Population

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Abstract

Aims: To assess Fat Free Mass Index, Fat Mass Index and Percent Body Fat in subjects with normal, overweight, and obese BMI and to examine if FFMI and FMI as compared to BMI have higher predictability in identification of high risk groups as defined by metabolic measurements among female college students and employees in Hail, Northern part of Saudi Arabia.

Methods: Sample of 514 female college students and employees were enrolled and body composition was measured by using bioelectrical impendence technique. FFMI and FMI are calculated using the standard formula. Blood pressure (BP) and pulse were measured using automatic BP reader in a resting sitting position. Random blood glucose was tested using strip method (One touch, Simple).

Results: Around 11 percent of study subjects were underweight while 25 percent were overweight and another 22 percent were obese. Only 42 percent of study population had normal weight. Except for height there were significant differences for weight, BMI, FM, FFM and %BF across age groups. Weight, FM, FFM shows a linear trend till the age 40 yrs after which an inverse trend begins. BMI continues to show linear trend across all ages. Mean FFMI was around 14 kg/m2 (range 5th – 95th percentile: 12.5 – 17.8 kg/m2) and was modestly but significantly higher ($P < 0.001$) in the higher age group. Similarly, Mean FMI was 8.4 kg/m^2 (range 5th – 95th percentile: 3.8 – 18.3 kg/m2) and significantly higher ($P < 0.001$) in the higher age group. In Regression models for SBP, BMI and %BF explain 18.7 % of variance; while for DBP, WC and %BF explain 11.2 % of variance. For blood glucose, it is FFMI, FMI and Visceral fat which explain maximum variance.

Conclusion: BMI alone cannot provide information about the respective contribution of FFM or fat mass to body weight. This study presents FFMI and BFMI values that correspond to low, normal, overweight, and obese BMIs. FFMI and BFMI provide information about body compartments, regardless of height.

Keywords: body mass index, fat mass, fat free mass, bioelectrical impedance

1. Introduction

Research also has indicated that body composition, more than BMI, is a primary determinant of health5 and a better predictor of mortality risk than BMI (Van Itallie et al., 2000). According to Ng and Zaghloul (2011), Musaiger (2012), KSA is witnessing rapid rise in obesity because of urbanisation and lifestyle changes. The available literature indicates that obesity is emerging as a major health problem with approximately three quarters of females and nearly two-thirds of males of adult population in the Kingdom being either overweight or obese (El-Hazmi, 2002). Most public health interventions are aimed primarily at prevention of obesity. Body mass index (BMI) is the most popular simple assessment tool for the degree of obesity in most epidemiological studies.

Obesity traditionally defined by Body mass index (BMI) may not accurately represent the complex scenario of obesity. The major limitation in using BMI as a measure for body fat is that BMI doesn't reflect actual composition of body weight. BMI cannot essentially differentiate between excess body weight coming from increased adipose tissue or lean muscle tissue which is certainly a limitation for the index. Heber D and Ingles S suggested in their researches that underweight as indicated by BMI could be a result of either fat-free mass (FFM) deficit (sarcopenia) or adipose tissue (fat mass- FM) deficit or both combined.

Body composition Analysis is opening up new paradigm shift in our understanding related to differences in phenotypes which can explain complex obesity. The relatively newly developed concepts of fat-free mass index (FFMI) and fat mass index (FMI) as compared to BMI could be of apparent interest in classification of overweight/over fat patients (respectively underweight/under lean) (Van Itallie & Yang, 2004).

Calculation of FFM and FM indexes

The following definition of FFM and FM indexes suggests they are are equivalent concepts to the BMI (Van Itallie & Yang, 2004):

$$\text{FFMI} = \frac{\text{fat-free mass}}{\text{height}^2}\left(\frac{\text{kg}}{\text{m}^2}\right)$$

$$\text{FMI} = \frac{\text{fat mass}}{\text{height}^2}\left(\frac{\text{kg}}{\text{m}^2}\right)$$

Note that, mathematically, BMI $(\text{kg/m}^2) = \text{FFMI}$ $(\text{kg/m}^2) + \text{FMI}$ (kg/m^2).

In view of the foregoing observations, the present investigation was undertaken to assess FFM Index, BFM Index and PBF in subjects with normal, overweight, and obese BMI in a sample of female students from the University of Hail (UOH) in Hail City, KSA.

2. Objectives

- To assess the prevalence of overweight and obesity using BMI among study subjects
- To describe percentile values for FFMI and FMI.
- To assess FFM Index, FM Index and PBF in subjects with normal, overweight, and obese BMI.
- To examine if FFMI and FMI as compared to BMI have higher predictability in identification of high risk groups as defined by metabolic measurements.

2.1 Significance of the Present Study

There are very few studies done from Saudi Arabia investigating the relationship of BMI classification with FFM and FM indexes. The potential advantage of doing this study is that only one component of body weight, i.e., FFM or FM is related to the height squared. These two new indexes are not yet widely popular probably because of the absence of population wise reference standards availability. According to Van Itallie and Yang (2004) these indexes can be helpful in quantification of the amount of excess (or deficit) of FFM, respectively FM which can be calculated for each individual.

3. Material and Methods

Study design: A cross sectional survey was planned and conducted in female campus of University of Hail, Hail, KSA during Sep., 2014 to Nov., 2014. The study protocol was approved by University of Hail Deanship of Scientific Research.

Sample: Approximately, a random sample size of 514 female students and employees (representing both Science and Humanities Colleges) participated in the survey. Posters were pasted throughout college informing the days of data collection and who ever visited labs were included in the study. Exclusion criteria followed included females with pregnancy, lactation and menstruation cycle during examining days.

Data collection: For body composition analysis, subjects were to undergo bioelectric impedance analysis (BioSpace, Inbody 720) for anthropometric measurements. Manufacturer's instructions were followed strictly for accurate measurement with InBody 720. WHO classification was followed for Body mass index (BMI) stratification. Normal ranges for percent body fat (BF%) were considered as follows: 18–28 % for females as suggested from manufacturers of Inbody 720. Blood pressure (BP) and pulse were measured using automatic BP reader in a resting sitting position. Subjects were made to relax for 10 minutes before taking BP measurements. Random blood glucose was tested using strip method (One touch, Simple).

4. Statistical Analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (version 16.0, SPSS, Inc) software. Descriptive statistics such as means and standard deviations were calculated for the continuous variables and frequencies for qualitative data. Analysis of variance (ANOVA) and chi-square analysis was used to examine differentials in variables. Results were expressed as either mean ± SD or counts and percentages. All reported P values were 2-sided and differences were considered statistically significant at $P<0.05$.

5. Results

Statistical analysis for the study sample of 514 has been presented in this section. Table 1 presents the mean ± SD of anthropometric and body composition characteristics of subjects. Mean age of the study subjects was 23 since majority of the subjects participated in the study were students as compared to employees of the university. The mean height of the subjects was 158 cm and mean weight was 64 kg. Mean BMI was in overweight category while BF% were in high risk range. Mean FM was 25.8 kg while mean FFM is 38.2 kg.

Table 1. Anthropometric and body composition characteristics of subjects

VARIABLES	Mean	Standard Deviation
Age (yr)	23	6
Height (cm)	158	5
Weight (kg)	64.1	16.4
BMI (kg/m^2)	25.59	6.31
Percent Body Fat (%)	38.5	8.9
Fat Mass (kg)	25.8	11.9
Fat free mass (kg)	38.2	5.5

Figure 1 shows BMI distribution in the study population. Accordingly around 11 percent are underweight while 25 percent were overweight and another 22 percent were obese. Only 42 percent of study population had normal weight.

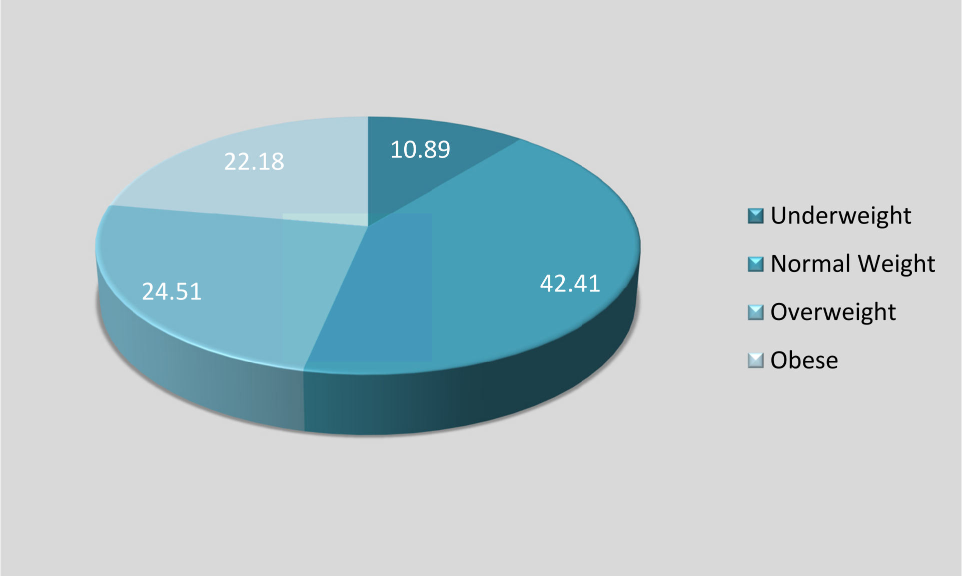

Figure 1. Distribution of BMI groups in study population

Table 2 presents body composition analysis of the subjects (mean ± SD). Except for height there were significant differences for weight, BMI, FM, FFM and %BF across age groups. Weight, FM, FFM shows a linear trend till the age 40 yrs after which an inverse trend begins. BMI continues to show linear trend across all ages.

Table 2. Body composition analysis of the subjects according to age

	Age (yr)	N	Mean	Std. Deviation	F Value
Height	18-20	212	157.83	5.216	1.182
	21-30	261	158.21	4.995	
	31-40	26	159.77	5.121	
	>40	15	158.57	5.934	
Weight	18-20	212	60.097	14.8133	32.817*
	21-30	261	63.898	15.3091	
	31-40	26	86.858	15.2639	
	>40	15	83.113	13.1724	
BMI	18-20	212	24.1365	5.88174	31.424*
	21-30	261	25.4863	5.72169	
	31-40	26	34.0731	6.23103	
	>40	15	33.1913	5.77625	
	Total	514	25.5888	6.31183	
FM	18-20	212	22.937	10.8089	26.582*
	21-30	261	25.874	11.3519	
	31-40	26	40.273	11.0011	
	>40	15	39.027	10.5136	
	Total	514	25.775	11.8912	
FFM	18-20	212	37.022	4.8072	33.127*
	21-30	261	38.018	5.1089	
	31-40	26	46.200	5.6469	
	>40	15	44.100	4.7301	
	Total	514	38.199	5.4543	
PBF	18-20	212	36.554	8.9400	14.917*
	21-30	261	38.813	8.6247	
	31-40	26	46.192	4.7296	
	>40	15	46.280	6.2650	
	Total	514	38.473	8.8948	

Table 3 presents the results of the FFMI and FMI categorized by age, where they are distributed into different percentiles values. Mean FFMI was around 14 kg/m^2 (range 5th – 95th percentile: 12.5 – 17.8 kg/m^2) and was modestly but significantly higher ($P < 0.001$) in the higher age group. Similarly, Mean FMI was 8.4 kg/m^2 (range 5th – 95th percentile: 3.8 – 18.3 kg/m^2) and significantly higher ($P < 0.001$) in the higher age group.

Table 3. Percentiles values for FFM and FM index by different age categories

	Age (yr)	Percentiles						
		5	10	25	50	75	90	95
FFMI	18-20	12.5590	12.7603	13.6338	14.6534	15.6876	16.9229	17.8305
	21-30	12.6134	13.1165	14.1571	14.9573	15.9695	17.3569	18.2491
	31-40	14.6559	15.3746	16.5029	18.0419	19.1590	20.9136	22.2343
	>40	15.1796	15.5884	16.1938	17.3153	18.3443	19.9441	.
FMI	18-20	3.8624	4.5059	5.8900	8.4169	11.5692	15.2910	18.3265
	21-30	4.3385	5.1600	7.0157	9.5744	13.2925	16.2721	18.8188
	31-40	9.5477	10.1593	12.0788	15.5569	18.6628	22.9466	26.2633
	>40	9.0065	9.3950	11.2378	15.7016	18.9778	22.1450	.

Figure 2 presents mean FFMI and FMI across age groups, which suggest a linear trend for both indexes with increasing age. For FFMI there was a slight decrease in mean after 40 years indicating the loss of muscular tissue with aging process.

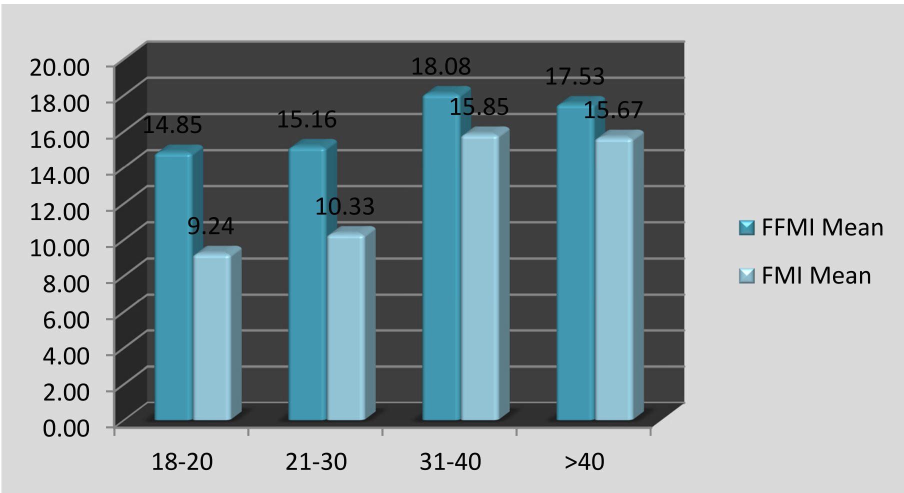

Figure 2. Mean FFMI and FMI across age groups

Table 4 presents mean BMI, BF%, FMI and FFMI across BMI groups, which were significantly lowest ($P<0.01$) for underweight and highest for obese groups.

Table 4. BMI, BF%, FFMI and FMI according to BMI groups (Mean±SD)

BMI Groups (*n*)	**BMI**	**BF %**	**FMI**	**FFMI**
Underweight (56)	17.27 ± 0.99	24.69 ±4.40	4.23 ± 0.99	13.04 ± 0.79
Normal BMI (218)	21.87 ± 1.82	33.85 ± 5.01	7.46± 1.56	14.37 ± 1.01
Overweight (126)	27.18 ± 1.40	42.19 ± 3.57	11.73 ± 3.19	15.49 ± 0.84
Obese (114)	35.02 ± 4.27	49.19 ± 3.77	17.24± 3.19	17.68 ± 1.57

Table 5, 6 and 7 presents stepwise regression analysis for SBP, DBP and blood glucose as dependent variables and anthropometric variables (BMI, %BF, WHR, WC, VF, FFMI and FMI) as independent variables. For SBP, BMI and %BF explain 18.7 % of variance; while for DBP, WC and %BF explain 11.2 % of variance. For blood glucose, it is FFMI, FMI and Visceral fat which explain maximum variance.

Table 5. Regression model for SBP and anthropometric variables

Coefficients							
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R2
		B	Std. Error	Beta			
1	(Constant)	85.217	2.550		33.414	.000	0.176
	BMI	1.016	.097	.422	10.499	.000	
2	(Constant)	87.832	2.707		32.444	.000	0.187
	BMI	1.522	.208	.632	7.321	.000	
	%BF	-.405	.147	-.237	-2.746	.006	

Table 6. Regression model for DBP and anthropometric variables

Coefficients							
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R2
		B	Std. Error	Beta			
1	(Constant)	55.095	2.277		24.193	.000	0.102
	WC	.196	.026	.319	7.609	.000	
2	(Constant)	53.326	2.380		22.409	.000	0.112
	WC	.327	.060	.533	5.485	.000	
	%BF	-.251	.103	-.237	-2.438	.015	

Table 7. Regression model for blood glucose and anthropometric variables

Coefficients							
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R2
		B	Std. Error	Beta			
1	(Constant)	60.231	9.527		6.322	.000	0.036
	FFMI	2.719	.620	.190	4.383	.000	
2	(Constant)	41.064	12.282		3.343	.001	0.047
	FFMI	4.613	.988	.323	4.668	.000	
	FMI	-.943	.384	-.170	-2.455	.014	
3	(Constant)	43.840	12.284		3.569	.000	0.058
	FFMI	4.296	.993	.300	4.326	.000	
	FMI	-1.983	.583	-.357	-3.401	.001	
	Visceral fat	.131	.056	.229	2.364	.018	

6. Discussion

Malnick (2006) concluded in their study that obesity increases risk for many chronic diseases thereby increasing mortality rates across the world. According to Sun et al. (2009), females have higher risk associated with reduced health even with increased obesity in mid-life years. Obesity therefore has become primary address for prevention efforts at both public as well as individual level. Thus, clinical detection of obese individuals has become clinically very important.

BMI does not separate body compartments into FFM and BF. Because research has indicated that body composition is a primary determinant of health (Segal et al., 2002). FFM and BF compartments should be determined as part of a health assessment. FFM and BF change with height, weight, and age. It is therefore difficult to determine whether individual subjects have low or high FFM or BF.

BMI, or Body Mass Index, is a simple formula using a person's height and weight to calculate a value which is supposed to be representing body fat level. It has gained immense popularity in epidemiological studies owing to its simplicity in measurement and non invasive nature. However recent studies done by Romero-Corral et al. (2008), indicate that BMI may not be an accurate indicator of body fat especially in normal weight categories.

Average ranges for %BF in the present study were 36.5% - 46.2%. Results of recent studies done in North American by Bartlett HL et al and on European populations by Baarends et al. (1997) indicated that significant weight gains are responsible for large numbers of subjects being above the suggested %BF ranges of 12 to 20 for men and 20 to 30 for women (Westerterp et al., 1997). Forty-five percent of all men and 38% of all women in a recent study conducted by Mostert et al. (2000), had values above these "desirable" levels.

The recent concepts of fat-free mass index and fat mass index, could provide an definitive alternative to BMI in the classification of overweight/over fat subjects or underweight/under lean subjects. There are no reference standards established till now for FFMI and FMI, at least in healthy people. Given that FFMI and FMI can explain better the complexities of body composition and their relationship with chronic diseases, developing population references for these indexes is need of the hour. It is proposed by researchers like (Engelen et al., 1999, 2000), that the development of population wide reference values could be of great value to future epidemiological studies in both clinical setting as well as field surveys for comparative analysis of nutritional status among various BMI groups.

FFMI and BFMI eliminate differences in FFM and BF due to height and offer the advantage of having one set of recommended ranges, regardless of age and height. FFMI and BFMI have been reported in studies with small numbers of healthy subjects (Schutz et al., 2002) and patients (Flegal, 2003; Seidell, 1998; Abernathy, 2001). Recently percentiles for FFMI and BFMI for healthy adults have been published by Kyle et al. (2003). However, these studies have not evaluated the FFMI and BFMI ranges for various BMI classifications. Our current study presents FFMI, BFMI, and %BF values for low, normal, overweight, and obese BMIs.

Large longitudinal studies will be necessary to determine whether an increase in weight or BMI is necessary to counteract the age-related decrease in FFMI. Schutz et al. (2002) found in their study that the effects of aging are noticeable only in adults older than 75 y and that the 25th and 75th percentiles of FFMI are lower in men older than 75 y than in men 18 to 34 y, whereas the same was not found in women. Because FFMI remained constant with aging, an adjustment in FFMI reference values does not appear to be necessary.

The present study established reference ranges for FFMI and FMI in apparently healthy female subjects but investigations in large groups of males and females across various age groups and in children is required for further understanding. Future investigations analysing the relationship between body composition measurements and chronic disease risk factors will help to understand better the contribution of FMI (respectively FFMI) to potential risk factors and subsequent mortality.

7. Conclusion

FMI vs FFMI can be useful tools for nutritional status assessment for over nutrition and under nutrition of healthy female subjects. Development of reference standards could help in prediction of risk factors. BMI alone cannot provide information about the respective contributions of FFM and FM to body weight. This study presented the FFMI, BFMI, and %BF values that correspond to low, normal, overweight, and obese BMIs. FFMI and BFMI can provide meaningful information about body composition, regardless of height. FFMI and BFMI could be more accurate indicators of nutrition status.

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