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Assessment of Body Fat Percent and Reliability of Using BMI, WHR, ABSI and BAI with DEXA as Gold Standard

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Abstract: ***Background:*** *Urbanization has brought about a significant change in our lifestyle and eating patterns along with an increase in obesity levels with accumulation of fat in the body. ABSI and BAI are two newly developed anthropometric measures which are used in the determination of body fat percent. The aim of this study was to assess the reliability of different anthropometric measures including ABSI and BAI to determine the body fat percent and to evaluate their effectiveness in determining the levels of obesityusing DEXA as the gold standard.* ***Methods:*** *135 subjects in the age group of 21 – 45 years (93 females and 42 males) participated in the study. Height, weight, waist and hip circumferences were measured and REAP questionnaire was used along with 24-hour recall to gather the dietary habits of the study subjects. BMI, WHR, ABSI and BAI was calculated and a sub sample of 20 subjects underwent DEXA scan to determine the body fat percent which was compared with BMI, ABSI, WHR and BAI to assess which is nearest to DEXA in determining the body fat percent.* ***Results:*** *The relationship of different anthropometric measures was determined which showed strong correlation between DEXA and BMI (0.01 and 0.00) and DEXA and BAI in females (p=0.00). Whereas, WHR and ABSI was found to havenegative correlation with DEXA. BAI and WC are more closely related to DEXA in females than in males and can be used in determination of body fat in females. ABSI and WHR are less associated than BMI and BAI with DEXA.* ***Conclusion:*** *The classic method of anthropometry, i.e., BMI is a best method to assess the body fat percent in both males and females than the newly developed measures of anthropometry - ABSI and BAI.*

Keywords: Body fat percent, ABSI, BMI, BAI, DEXA

Abbreviations: ABSI- A Body Shape Index, BAI- Body Adiposity Index, BMI- Body Mass Index, DEXA- Dual Energy X-ray Absorptiometry, WHR- Waist-Hip ratio

1. Introduction

Obesity is a problem that nearly every nation in the world is facing, but there is much that we can do to fix it. Overweight and obese people are most at risk for developing lifestyle diseases such as: diabetes, cardiovascular diseases, arthritis and respiratory problems. Some of the major causes of obesity being sedentary lifestyle, consumption of food high in calories and physical inactivity.

According to WHO, in 2014, more than 1.9 billion adults are overweight or obese. The worldwide prevalence of obesity has nearly doubled since 1980. Overall about 13% of world's population(11% of men and 15% of women) were obese (BMI ≥30 kg/m2), compared with 5% for men and 8% for women in 1980. Overweight and obesity are linked to more deaths worldwide than underweight.

Obesity is generally measured using anthropometric measurements. Anthropometry is a measure of size, shape and composition of the body.Some of the measures of anthropometry used are: height, weight, waist circumference, hip circumference, BMI.

Body mass index (BMI) is strongly associated with measures of adiposity derived from dual energy x-ray absorptiometry (DEXA) (Lindsay, et al., 2011).DEXA provides precise composition analysis with a low radiation exposure (less than 0.1 microGy) (Mazess, et al., 1990).

A Body Shape Index (ABSI) and Body Adiposity Index (BAI) are the recently developed tools. ABSI is an index developed by Krauker. The study conducted showed that ABSI expresses the excess risk from high WC in a convenient form that is complementary to BMI and to other known risk factors (Krakauer, Krakauer, 2012).Another study showed that ABSI is less predictive than WC and BMI in predicting the incidence of hypertension (Cheung, 2014).A study carried out to compare the health risk between BMI, WC and ABSI at individual level showed that ABSI had low agreement with BMI and WC. Hence more studies need to be conducted to explore the predictive power of ABSI (Meredith, Madden, 2014).

BAI was an index proposed by Bergman, et al., in a study carried out in Mexican-American and African-American using the Beta Gene study. Later in this study, BAI was

compared to DEXA to assess its reliability and for validation.The study undertaken to compare BAI with BMI in Caucasian population concluded that BAI can be used as a tool to measure the body adiposity, but it does not overcome the limitations of BMI and the only advantage of using BAI over BMI is that weight is not required (Lopez, et al., 2012).

Objectives

- To determine the anthropometric measures including height, weight, BMI, waist circumference, hip circumference, WHR, ABSI and BAI of the subjects.
- To determine body fat percentage using DEXA scan.
- To evaluate the effectiveness of using anthropometry in determination of obesity levels.
- To assess the reliability of the anthropometric measures (BMI, WHR, ABSI, BAI) in comparison to the gold standard, DEXA.

2. Materials and Methods

A sample size of 135 subjects (93 females and 42 males) in the age group of 21to 45 years underwent a correlation study in which different anthropometric measurements (BMI, WHR, ABSI, BAI) were correlated with DEXA (gold standard) in determining the level of obesity in an individual. The target population for the study were hospital staffs and health check patients. Their physical activity patterns and eating habits were also captured with the help of lifestyle questionnaires, 24-hour recall and food frequency questionnaire. A validated Rapid Eating Assessment for Patients (REAP) questionnaire was used for this purpose. Pregnant and lactating mothers, surgical implant bearers and people falling above 45 years and below 21 years were excluded.The data was collected from subjects' by interviewing them face to face using the questionnaire and other tools like weighing scale and measuring tape.

Anthropometry: Height was measured using stadiometer, weight using weighing scale, waist and hip circumference was measured using SECA tape. The subjects were requested to be in minimum clothing without footwear while taking measurements. Waist circumference was measured at a level midway between the lowest rib and the iliac crest. Hip circumference measurement was taken around the widest portion of the buttocks.

BMI: From the height and weight of the subjects, BMI was calculated using the formula; **BMI=weight in kg/ (height in m)^2**

WHR: with the waist and hip measurements WHR was calculated using the formula; **WHR=waist in cm/hip in cm**

ABSI: BMI, waist circumference and height measurements were used to calculate ABSI. The formula used was **ABSI = WC / (BMI$^{2/3}$ x height$^{1/2)}$**

BAI: With hip and height measurements BAI was calculated using the formula;

BAI = (Hip in cm)/〖(Height in m)〗^1.5 – 18

DEXA: DEXA scan was conducted on a sub sample of 20 subjects after taking their consent, using the DEXA machine to determine the body fat percent of the study subjects.

Questionnaire: A lifestyle questionnaire was used to gather general information of the subjects. One-day 24-hour recall along with food frequency questionnaire (REAP questionnaire, Brown University) was also used to determine the eating patterns of the subjects.

Statistical Analysis: Statistical tests were performed on the data collected using the SPSS software. Different statistical tests like frequency, mean, standard deviation, t-test were performed. The Karl Pearson's correlation co-efficient at significant levels of $p<0.01$ and $p<0.05$ was also considered for the analysis and comparison was done.

3. Results and Discussions

The study included 68.9% females and 31.1% males, of which 51.6% females were in the age group of 21-25 years and 42.5% males were between 26-30 years. 66.7% females and 59.5% males were unmarried with graduate or post graduate degree were 79.5% females and 78.6% males.

42.9% males and 43% females consumed outside food only sometimes. 71.4% males and 74.2% females rarely consumed less than 3 servings of grains/ day. The consumption of fruits was often less than 2-3 servings/ day in 54.8% males and 38.7% females. It showed that consumption of vegetables was usually less than 3-4 servings/ day in 59.55 males and 24.7% females. It was also observed that the consumption of dairy products was also less than 2-3 servings/ day in majority of the subjects (40.5% males and 34.4% females). It was seen that 54.8% males and 54.8% females rarely consumed fats and oils whereas 2.4% males and 6.5% females often consumed fried foods. It was seen that only 19% males and 7.5% females often consumed red meat and 64.3% males and 52.7% females rarely preferred high fat red meat over lean meat. 38.1% males and 58.1% females rarely consumed carbonated beverages and soft drinks more than 16 ounces per day and 40.5% males and 41.9% females rarely consumed sweets on regular basis. The data also showed that only 16.7% males and 3.2% females consumed alcoholic beverages only sometimes.

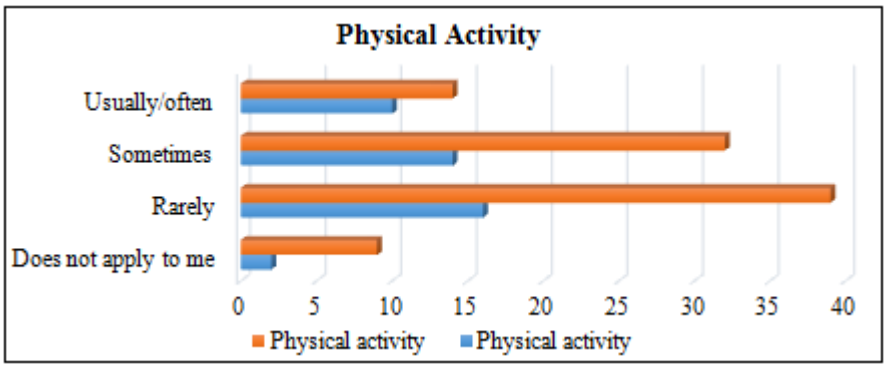

Figure 1: Physical Activity Patterns of the study subjects – Males and Females

The figure (1) shows the physical activity patterns of the study subjects. 38.1% males and 41.9% females rarely involved in less than 30 minutes 3 days a week of physical activity, whereas 33.3% males and 34.4% females sometimes involved in less than 30 minutes of activity and 4.8% males and 9.7% females did not involve in any physical activity. Test of significance indicated that, average height, weight, WC and HC of males and females were significantly different with it being greater in males.

Table 1: Correlation between Anthropometric measures - Males

	BMI	WC	WHR	ABSI	BAI
BMI	----	0.829**	0.234	-0.203	0.865**
WC	0.829**	----	0.530**	0.326*	0.710**
WHR	0.234	0.530**	----	0.649**	0.134
ABSI	-0.203	0.326*	0.649**	-----	-0.032
BAI	0.865**	0.710**	0.134	-0.032	----

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 2: Correlation between Anthropometric measures - Females

	BMI	WC	WHR	ABSI	BAI
BMI	----	0.871**	0.397**	0.099	0.862**
WC	0.871**	----	0.700**	0.557**	0.758**
WHR	0.397**	0.700**	----	0.803**	0.218*
ABSI	0.099	0.557**	0.803**	----	0.163
BAI	0.862**	0.758**	0.218*	0.163	----

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

From the tables 1 and 2, it was observed that:
BMI had strong positive correlation with BAI (r=0.865, p=0.000 and r=0.862, p=0.000 in males and females respectively) and WC (r=0.829, p=0.000 and r=0.871, p=0.000 in males and females respectively).

WHR showed a significant correlation with ABSI in females (r=0.803, p=0.000) when compared to males (r=0.649, p=0.000) which shows moderate correlation. WHR was significantly correlated with WC (p=0.000) which was more strongly correlated in females (r=0.700) than in males (r=0.530).

ABSI had a significant correlation with WHR (r=0.649, p=0.000 and r=0.803, p=0.000 in males and females respectively) and WC (r=0.326, p=0.035 and r=0.557, p=0.000 in males and females respectively) but ABSI had no correlation with BMI and BAI.

BAI showed strong positive correlation with BMI (r=0.865, p=0.000 and r=0.862, p=0.000 in males and females respectively) and WC (r=0.710, p=0.000 and r=0.758, p=0.000 in males and females respectively). It was also observed that BAI had negative correlation with ABSI.

Table 3: Correlation of DEXA with BMI, ABSI, WHR, BAI and WC

	DEXA	*BMI*	*WHR*	*ABSI*	*BAI*	*WC*
Males	r value	0.975	-0.434	-0.510	0.189	0.173
Females	r value	0.795**	0.407	0.065	0.753**	0.704**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

From the table it is observed that DEXA has a strong positive correlation with BMI (r=0.975, p=0.142 and r=0.795, p=0.000 in males and females respectively). It also showed a correlation with BAI (r=0.753, p=0.000) and WC (r=0.704 and p=0.002) in females rather than in males (r=0.189 and 0.173) which shows no relationship. This is in tune with a study in which it showed that BMI had strong correlations with body fat percent than BAI and WC (Schulze, et al., 2012).

Table 4: Dietary assessment of the study subjects (24-hour recall)

Nutrients	Total	Gender		t-Test
		Male	Female	P value
	Mean±SD	Mean±SD	Mean±SD	
Average energy intake (kcal)	1363.31 ± 385.15	1544.77 ± 476.40	1281.36 ± 4.37	0.000
Average protein intake (g)	45.99 ± 14.7	52.1 ± 15.80	43.21 ± 13.38	0.001
Average carbohydrate intake (g)	215.27 ± 64.54	244.50± 77.00	202.07 ± 53.47	0.000
Average fat intake (g)	39.41 ± 15.37	43.50 ± 18.07	37.59 ± 13.69	0.037

The table reports that the mean energy of the study subjects was 1363.31 Kcal. The mean for males being 1544.77 and 1281.36 for females. The p value was 0.000 which indicates that mean BMI differs significantly between males and females.
The overall mean of protein was 45.99, that of males was 52.1 and of females was 43.21. the average carbohydrate intake of the study subjects was 215.27. 244.50 and 202.07 of males and females respectively. The overall average fat

intake of the study subjects was 39.41 and that of males and females was 43.5 and 37.59 respectively. The p value of average protein, carbohydrate and fat intake was less than 0.05 (0.001, 0.000, 0.037 respectively) which shows that a significant difference between males and females exists in the nutrient intake.

Table 5: Correlation between anthropometric measures BMI, WHR, ABSI and BAI with average nutrient intake (energy, protein, fat and carbohydrates)

			Avg Energy	Avg Carbohydrate	Avg Protein	Avg Fat
Males	BMI	r value	-0.107	-0.164	-0.215	-0.087
Females		r value	0.225*	0.080	0.298**	0.203
Males	WHR	r value	0.183	0.080	0.055	0.094
Females		r value	0.174	0.268**	0.050	0.135
Males	ABSI	r value	0.233	0.183	0.152	0.089
Females		r value	0.083	0.193	0.022	0.031
Males	BAI	r value	-0.10	-0.174	-0.195	-0.088
Females		r value	0.150	-0.015	0.276**	0.112

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

From the table above it can be observed that between the anthropometric measures and the average nutrient intake there is no significant correlation. This can be due to underreporting or over reporting. This concludes that 24-hour recall dietary assessment tool is not a valid instrument in assessing the obesity levels in individuals. Underreporting is one of the most common pitfall in assessing the dietary habits of an individual (Huang, et al., 2005)

Table 6: Comparison of BMI, WHR, ABSI BAI and WC

		Low risk		Moderate risk		High risk	
		Cut-off point	Number (%)	Cut-off point	Number (%)	Cut-off point	Number (%)
BMI		18.5 – 24.9	64 (47.4)	25- 29.9	19 (14)	>30	36 (26.6)
WHR	Males	<0.9	21 (50)			>0.9	21 (50)
	Females	<0.8	54 (58.1)			>0.8	39 (41.9)
	Total	75 (55.5)				60 (44.4)	
ABSI		< -0.7	66 (48.8)	-0.7 – +0.6	17 (12.59)	+0.6- +1.4	15 (11.1)
BAI	Males	8% - 21%	2 (4.8)	21% - 26%	22 (52.4)	>26%	15 (35.7)
	Females	21% - 33%	57 (61.3)	33% - 39%	26 (28)	>39%	6 (6.4)
	Total	59 (43.7)		48 (35.5)		21 (15.5)	
WC	Males	<102	39 (92.9)			>102	3 (7.1)
	Females	<88	75 (80.6)			>88	18 (19.4)
	Total	114 (84.4)				21 (15.5)	

In the table above, classification of different anthropometric measures (BMI, WHR, ABSI, BAI, WC) was compared. Under the low risk category BMI classifies 47.4% of the study subjects, ABSI 48% and BAI classifies 43.7% of the study subjects (4.8% males and 61.3% females). Whereas, WC classifies 92.9% males and 80.6% females and WHR classifies 84.4% males and 55.5% females as low risk category.

ABSI, BAI and WC classifies 11.1%, 15.5% and 15.5% respectively as high risk category. But according to BMI and WHR 26.6% and 44.4% are classified under high risk category.

4. Conclusion

From the above results it can be concluded that BMI is closely related to DEXA and can be used to determine the body fat percent in individuals.

The newly developed anthropometric tool ABSI showed strong correlation with WHR but showed a negative correlation with BMI and DEXA. Hence ABSI is not a reliable tool to determine body fat percent. The other newly developed anthropometric tool- BAI showed a strong positive correlation with BMI, WC and DEXA in females, but not in males. BAI showed a negative correlation with ABSI in males.

It can be concluded that BMI can be used as an alternative method to DEXA in determining the body fat percent. BAI can also be used in females, alternative to DEXA but further studies are required for it to be used in males as well.

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