AN EMPIRICAL STUDY AND ANALYSIS ON AIR DISPLACEMENT PLETHYSMOGRAPHY VERSUS DUAL-ENERGY X-RAY ABSORTIOMETRY IN UNDERWEIGHT, NORMAL-WEIGHT, AND OVERWEIGHT INDIVIDUALS

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Abstract

Background: The determination and assessment of body composition can provide important information about a wide variety of populations including the diseased, the apparently healthy, the obese, and the athletic. Estimating fat percentage accurately is critical for assessing health and selecting treatment options. However, methods for determining body composition, such as hydrostatic weighing or dual-energy x-ray absorptiometry (DEXA), can be costly, need significant operator training. These drawbacks underlie the importance of finding one device or method for estimating body composition which can accommodate a wide variety of different members of the population, provide the greatest accuracy.

Objective: The primary purpose of this investigation was to compare estimations of percentag e body fat (%fat) using air displacement plethysmography (ADP) and dual-energy x-ray absorptiometry (DEXA), in a heterogeneous (%fat) sample of the population.

Method: The study was conducted in MYAS-GNDU, Department of Sports Sciences and Medicine. Determination of body fat percentage was done by two different methods (DEXA, BOD POD) among underweight (n = 10), normal weight (n = 10) and overweight (n = 10) subsets of the sample classified according to their BMI. Each subset of the sample was further divided in 5 males and 5 females.

Result: Higher body fat percentages were observed for DEXA values in all the three weight categories as compared to BOD POD. Significant differences ($p<0.005$) were observed in fat percentage in males and females and between the subjects of the three considered BMI categories (underweight, normal and overweight). No statistically significant differences were observed in body fat percentage values for the entire range of BMI by DEXA and BOD POD.

Keywords:-DEXA, BMI, BOD POD

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Introduction

Body composition is one of the most important long-term indicators of nutritional status and it is directly related with health status. In the two compartments model of body composition, bodyweight (Body Weight, BW) is considered as the sum of body fat mass (BF) and fat-free or leanmass (Fat Free Mass, FFM). Consequently, change in body weight does not give us information on body composition and often generates diagnoses of obesity without considering the relationship between fat mass and lean body mass. [1]

Throughout the past several decades, there have been numerous research studies exploring the reliability and validity of body composition assessments[2]. At the population level, indices such as Body Mass Index (BMI) are widely used because of its ease of use and ease of interpretation [3], however at the individual level BMI may not be the most valid assessment because of its inability to distinguish between fat mass and fat-freemass[4]. Therefore, more direct assessments of body composition are needed. Unfortunately, many studies that examine agreement among body composition assessments only examine a limited number of lab and/or field assessments, making it difficult to determine psychometric characteristics across a range of modalities [5].

Accurate body composition assessment, particularly fat mass is critical to assess an individual's health and deciding on a treatment plan. Due to the limitations in assessment of body fat measurement with other methods, researchers frequently depend on dual-energy x-ray absorptiometry (DEXA) to accurately quantify body composition [6]. DEXA is widely used for measurement of total body composition, bone mineral content (BMC),lean tissue mass (LM) and fat tissue mass (FM). In the total body composition measurement the radiation exposure is minimal, equivalent to 0.1. This technique is frequently used in obesity related research and when evaluating the effect of surgery for obesity. Recent DEXA computer software can automatically calculate abdominal fat in regions according to bony anatomical landmarks. Regions on DEXA images may be set also with great accuracy manually. This alternative method has been used in several analyses of abdominal fat studies.[7]

ADP calculates body density by determining body volume and mass [8]. It calculates body volume by utilizing the pressure-volume relationship. The BOD POD then uses equations published by Siri [9] and Brozek and colleagues [10] to compute body fat percentages from body density data. Extensive information about ADP and the BOD POD's specific technique, including its physical construction, are accessible elsewhere [4] and from the company. Most significantly, the BOD POD places no strain on participants. The patient just sits in the BOD POD, breathes via a tube, and exhales in three brief spurts. Furthermore, the BOD POD may be operated by anybody, and the expenditures connected with each test run are negligible.

Although less time-consuming than hydrostatic weighing, DEXA exposes patients to radiation and needs specific training and certification to use. The current study's purpose was to investigate air displacement plethysmography (ADP) using the BOD POD [8], a less onerous, less costly, and easier to use technique of evaluating adiposity than DEXA that may avoid these problems.

The BOD POD and DEXA are popular and sophisticated methods of %BF assessment. Currently, both methods are considered acceptable measures of fatness. It is likely that these methods will be used extensively in the future to determine which individuals might be eligible for obesity treatment covered by health care. It is important that if differences exist between these methods, they be identified and quantified for as many different populations as possible.

The goal of this study was to see if the BOD POD, when compared to DEXA, offered comparable estimations in people at the relative extremes of Body Mass Index.The purpose of this study was, therefore, to further assess the precision of the plethysmograph as well as its respective accuracy compared with DEXA, a more established method of assessing body composition. Researchers have identified a pressing need to investigate BOD POD estimations in slim people in particular. Conducting example, Viscoid and colleagues [11] advocated for BOD POD research in people with fat percentages lower than the usual fat percentage range. This research fills a gap in the literature.

Methods

The study was carried out in MYAS-GNDU, Department of Sports Sciences and Medicine, Guru Nanak Dev University, Amritsar after the approval of the Institutional Ethical Committee and all subjects provided written informed permission. All of the subjects were in the age group of 18-30 years. Table 1 provides the descriptive statistics of the subjects. Total 30 subjects (15 males and 15 females) were recruited for the study. According the The subjects were further classified according their BMI as Underweight (n=10, 5 males and 5 females), Normal weight (n=10, 5 males and 5 females) and Overweight (n=10, 5 males and 5 females). Subjects came to the laboratory after a 12-h fast, and all measurements and tests were carried out on the same morning.

Measures

BMI. Body weight measurements were taken using a stadiometer with individuals wearing light clothes. Body height was determined by taking repeated measurements using a wall-mounted audiometer. These measurements were used to compute BMI.

BOD POD. The BOD POD Gold Standard Model 2007a (COSMED, USA, Inc.) is put in a room inside a room on the CCRC utilizing software version 5.2.0 to reduce potential inaccuracy due to airflow between doors and windows. BOD POD was caliberated every day with a predetermined volume (50 L) and then performed a second calibration right before the participant session. The weight scale on the BOD POD was calibrated on a weekly basis. To reduce the possibility of inaccuracy caused by isothermal air trapped in clothes and hair, all volunteers wore bathing suits or tight-fitting athletic gear, as well as swim caps. Participants were also requested to urinate to reduce the possibility of mistake owing to extra water volume. We followed the normal BOD POD methodology and tested till the merit value was less than one.

DEXA: DEXA(Model No. 010-1547, Hologic, Inc., Bedford) Scan needs to be calibrated in the morning once before starting the procedure. Before performing the DEXA scan participants were asked to remove all their metal accessories(for example - belt, metal zips, clips, rings etc.). Participants were asked to lie in supine position on a DEXA machine and close their eyes for a few minutes. Their fat mass, bone density, bone mineral content and regional fat were recorded.

Statistical Methods

All analyses were carried out using SPSS version 21.0. Using the Siri and Brozek equations [9,10], we calculated body fat percentages from the BOD POD. To see if body fat percentage estimations from the BOD POD and DEXA differed statistically in the three different groups (Underweight, Normal and Overweight), we used Multivariate ANOVA (MANOVA) to compare body fat % estimates from the BOD PODand DEXA. The data were presented in the form of a mean, standard deviation, and percentage. A P value of less than 0.05 was judged significant.

Results

The demographic characteristics of male subjects are depicted in Table1. The mean age of underweight males was 22.00±0.63 years, mean height was 166.40±5.08 cm, mean weight was 49.94±3.55 kg and mean BMI values of 18.16±0.25 kg/m^2. Normal weight males presented mean age of 22.60±1.36 years, mean height of 170.70±3.37 cm mean weight of

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63.78±4.08 kg and mean BMI of 21.90±0.80 kg/m^2. In case of overweight males mean values of age were 23.80±3.19 years, mean height was 178.98±5.27cm, mean weight was 84.88±4.12 kg and mean BMI of 26.61±7.59 kg/m^2.

The demographic characteristics of female subjects are depicted in Table2. The mean age of underweight females was 22.20±0.75 years, mean height was 162.20±6.49 cm, mean weight was 47.03±6.04 kg and mean BMI values of 17.34±1.32 kg/m^2. Normal weight females presented mean age of 22.40±0.49 years, mean height of 162.92±3.04 cm mean weight of 57.66±4.65 kg and mean BMI of 21.77±0.49 kg/m^2. In case of overweight females mean values of age were 22.60±0.49 years, mean height was 160.10±5.27cm, mean weight was 68.16±6.49 kg and mean BMI of 26.23±1.56 kg/m^2.

Table 3 shows mean and standard deviation of fat percentage between DEXA and BOD POD in male and female categorized according to their BMI (underweight, normal weight, overweight). For underweight females the mean % body fat values assessed by DEXA were 32.80 (SD=5.89) and by BOD POD were 25.44 (SD=4.46). For normal weight females mean % body fat values evaluated by DEXA were 35.56 (SD=3.58)and by BOD POD were 32.62 (SD=3.58). For overweight females mean % body fat values assessed by DEXA and BOD POD were 42.36 (SD=4.85) and 38.06 (SD=6.27).

For underweight males the mean % body fat values assessed by DEXA were 13.39 (SD=3.75) and by BOD POD were 10.92 (SD=3.10). For normal weight males mean % body fat values evaluated by DEXA were 23.12 (SD=4.09) and by BOD POD were 17.22 (SD=6.69). For overweight males mean % body fat values assessed by DEXA and BOD POD were 24.92 (SD=3.39) and 20.36 (SD=2.61).

Table 4 shows the tests of between subject effects. Statistically significant differences (P<0.000) were observed in % body fat values and % fat free mass values for the selected methods (DEXA, BOD POD), for gender classification (males and females) and for different weight categories (underweight, normal and overweight). No statistically significant interaction was observed between the effects of method and gender group, method and weight category, gender and weight category on body fat percentage and fat free mass.

Table 1: Basic Demographic Traits of Males

Category	Variable	Mean ± SD	95% Confidence Interval
Under-Weight	Age	22.00 ± 0.63	21.21– 22.79
	Ht	166.40 ± 5.08	160.09–172.71
	Wt	49.94±3.55	45.54–54.35
	BMI	18.16± 0.25	17.85–18.47
Normal Weight	Age	22.60 ± 1.36	20.92 – 24.28
	Ht	170.70 ± 3.37	166.52 – 174.88
	Wt	63.78 ± 4.08	58.71 – 68.85
	BMI	21.90 ± 0.80	20.91 – 22.89
Over-Weight	AGE	23.80 ± 3.19	19.84 – 27.76
	Ht	178.98 ± 5.27	172.44 – 185.52
	Wt	84.88 ± 4.12	79.77 – 90.00
	BMI	26.61 ± 1.59	24.64 – 28.58

[Ht -Height (cm), Wt-Weight (kg), BMI-Body Mass Index (kg /m^2)]

Table 2: Basic Demographic Traits of Females

Category	Variable	Mean ± SD	95% Confidence Interval
Under-Weight	Age	22.20±0.75	21.27–23.13
	Ht	162.20±6.49	154.14–170.26
	Wt	47.03±6.04	39.53–54.53
	BMI	17.34±1.32	15.70–18.98
Normal Weight	Age	22.40±0.49	21.79–23.01
	Ht	162.92±3.04	159.15–166.69
	Wt	57.66±4.65	51.88–63.43
	BMI	21.77±1.30	20.16–23.39
Over-Weight	Age	22.60±0.49	21.99–23.21
	Ht	160.10±8.01	150.15–170.05
	Wt	68.16±6.49	60.10–76.21
	BMI	26.23±1.56	24.29–28.17

[Ht-Height (cm), Wt-Weight (kg), BMI-Body Mass Index (kg /m^2)]

Table 3: Shows mean and standard deviation of fat percentage assessed by DEXA and BOD POD in male and female categorized according to their BMI (underweight, normal weight, overweight)

Method				Mean	Std. Deviation
FAT PERCENTAGE	DEXA	female	underweight	32.8000	5.89491
			normal	35,5600	3.58650
			overweight	42.3600	4.85211
		male	underweight	13.3940	3.75481
			normal	23.1200	4.09048
			overweight	24.9220	3.39812
	BODPOD	female	underweight	25.4400	4.46576
			normal	32.6200	6.03879
			overweight	38.0600	6.27559
		male	underweight	10.9200	3.10032
			normal	17.2200	6.69642
			overweight	20.3640	2.61772

Table 4: Presents Tests of Between Subject Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Fat Percentage	5487.939[a]	11	498.904	22.122	0.000
	Freefatmass	5661.776[b]	11	514.707	21.290	0.000
Intercept	Fat Percentage	41812.320	1	41812.320	1853.977	0.000
	Freefatmass	324345.244	1	324345.244	13416.165	0.000
Method	Fat Percentage	315.838	1	315.838	14.004	0.000
	Freefatmass	287.810	1	287.810	11.905	0.001
Gender	Fat Percentage	3912.338	1	3912.338	173.475	0.000
	Freefatmass	4173.836	1	4173.836	172.646	0.000
Weightcategory	Fat Percentage	1179.870	2	589.935	26.158	0.000
	Freefatmass	1125.744	2	562.872	23.283	0.000
Method * Gender	Fat Percentage	1.159	1	1.159	0.051	0.822
	Freefatmass	0.386	1	0.386	0.016	0.900

Method * Weightcategory	Fat Percentage	0.809	2	0.404	0.018	0.982
	Freefatmass	0.059	2	0.029	0.001	0.999
Gender * Weightcategory	Fat Percentage	38.209	2	19.104	0.847	0.435
	Freefatmass	59.018	2	29.509	1.221	0.304
Method * Gender * Weightcategory	Fat Percentage	39.717	2	19.859	0.881	0.421
	Freefatmass	14.923	2	7.462	0.309	0.736

a. R Squared = .835 (Adjusted R Squared = .797)

b. R Squared = .830 (Adjusted R Squared = .791)

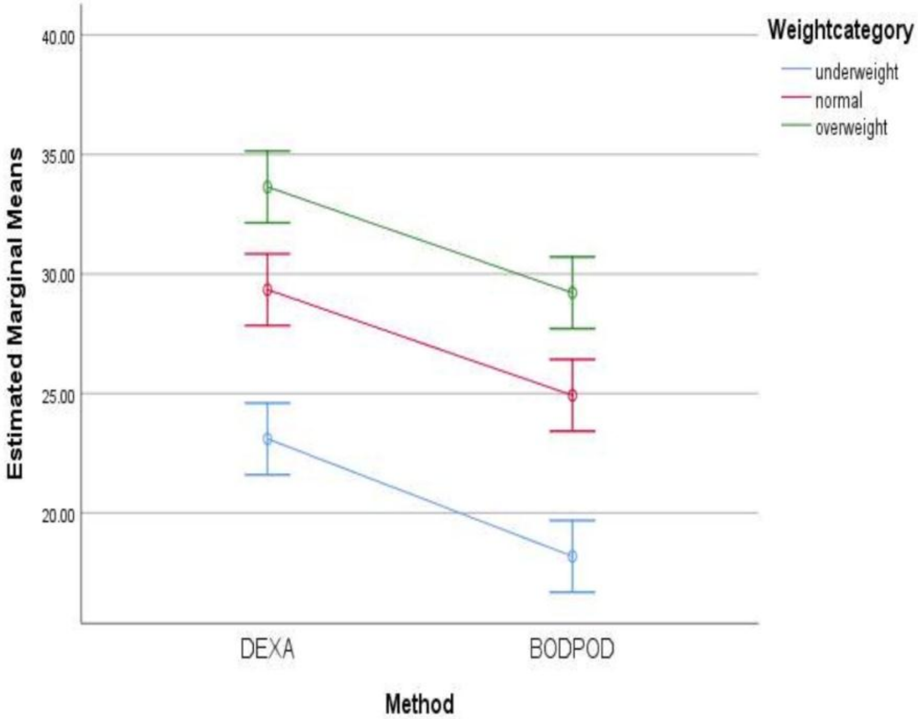

Figure1 is the graphical representation of fat percentage in DEXA and BOD POD according to underweight, normal weight and overweight

Discussion

In this work, we compared DEXA-derived estimates of body fat % to BOD POD estimates in three BMI groups and discovered that BOD POD estimations tended to depart from DEXA predictions at the entire range of BMI. The DEXA values of body fat percentage were higher as compared to body fat percentage values evaluated by BOD POD for all the three BMI categories considered for the study. Although other studies have evaluated ADP in obese patients [12, 13, 14, and 15] and found a very minor divergence between ADP and DEXA, this study is unique in that it includes data on underweight subjects and discovers greater magnitude disparities for all the BMI categories.

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The disparity in measurement between ADP and DEXA may be explained in part by the assumptions involved in calculating body fat percentage from direct measures. A two-compartment approach was utilized to calculate the ADP body fat percentage. This presupposes that the body is made up of two types of tissue: fat and lean mass. Fat-free mass is made up of bone, water, muscle, vasculature, connective tissue, and other substances. This technique does not adequately account for the degree of variation in fat-free mass. DEXA may also assess bone density, removing one degree of variable and potentially improving test accuracy.

Part of the observed difference seen in this and in other studies might be attributable to improper test conditions. It is critical that subjects wear minimal and tight fitting clothing (i.e., speedo-type swimsuit or spandex shorts) and a swim cap. The more clothing a participant wears the greater the underestimation of %BF. This is due to the difference in compressibility of isothermal air compared to adiabatic air [16]. Care was taken in this study to ensure that all subjects wore the recommended clothing. Since other environmental factors (i.e., room door being opened during a test, air blowing on the BOD POD) can influence results, all BOD POD tests were conducted in the corner of a room, protected from air drafts

Furthermore, Siri and Brozek are densitometry formulae that estimate body fat percentage based on body density. Body fat percentages at various body composition extremesthis generic formula may not be the best way to compute. Specific algorithms that can better estimate body fat percentages in underweight people may be required.

The BOD POD is popular due to its low subject load, simple operation, and inexpensive testing run costs. However, the findings of this study show that disparities were highest in underweight, more accurate approaches may be required in assessing body fat percentages in subjects at lower end of BMI. If just the BOD POD is accessible, then the BOD POD will suffice At a bare minimum, strategies [17] for controlling measurement error in the BOD POD (such as regulating room temperature, voiding bladders, wearing proper clothes, and so on) should be strictly followed.

The apparent advantage of using DEXA over the 2C model is that it does not have to make assumptions about the density of various tissues, namely bone. Nevertheless, DEXA still suffers from several limitations. In particular, differences in the model, software and type of scan used have raised questions about DEXA’s ability to be a reference standard. Other limitations such as beam hardening, the need to extrapolate bone containing pixels from nonbone containing pixels, hydration status of the subject and degree of body fatness are still being addressed and have been described in great detail elsewhere[18].

Conclusions

The most important finding from this study is that differences between these two sophisticated methods existed for our sample of males and females. There was a trend for a greater difference in %BF between methods in subjects with lower %BF. It is important that in any setting, fitness professionals and practitioners realize that differences exist between even the most current methods. Caution should be used when attempting to classify someone as obese, especially when the patient's %BF is very near the threshold value since both the precision and accuracy of any technique could affect the classification. Additional studies should focus on determining why differences exist between these two highly regarded methods. Further comparison studies should focus on borderline obese populations, as this group would be of greatest concern when attempting to identify and classify subjects as obese.

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