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## Resulting Shifts in Percentile and Standard Placements after Comparison of the BOD POD and DXA

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### ABSTRACT

*Int J Exerc Sci* 1(3) : 113-124, 2008. The purpose of this study was to determine the validity of the BOD POD® when compared to the DXA and if placement on a percentile chart and standard table is affected by any differences between the two measures. A total of 244 ( $27.7 \pm 10.8$  yrs,  $77.3 \pm 16.1$  kg,  $171.4 \pm 10.1$  cm,  $26.31 \pm 5.42$  BMI) males and females between the ages of 18 and 52 were recruited to participate in this study. The participant's body fat percentage (%BF) was tested in random order on the BOD POD® and DXA during a 30-minute session following manufacturer's guidelines and procedures. Dependent t-test indicated the %BF measured by the BOD POD® ( $23.4\% \pm 12.8$ ) was significantly lower when compared to the DXA ( $29.5\% \pm 12.1$ ),  $p = .001$ . The Pearson's Product moment correlation was 0.95 ( $p = .001$ ), indicating a very strong relationship between the two instruments. Using estimates of %BF from the BOD POD® also resulted in more favorable shifts on a percentile chart and standard table. Since a high correlation was evident between the two, the BOD POD® can be used as an instrument to track %BF changes over time during a diet and/or exercise intervention. However, caution should be made when classifying %BF with percentile charts or standard tables using the BOD POD® %BF estimates.

**KEY WORDS:** Dual energy x-ray absorptiometry, air displacement plethysmography, body fat

### INTRODUCTION

Body fat percentage (%BF) is an important element of an individual's health and physical fitness. Body fat percentage is widely used to help individuals establish a target, desirable, or optimal weight, can be used in assessing the effectiveness of diet and exercise interventions, and can also be used to identify certain risks associated with particular body fat levels (9). Excess

body fat decreases life expectancy and increases the risks of certain cancers, coronary artery disease, hyperlipidemia, hypertension, obstructive pulmonary disease, osteoarthritis, stroke, and type II diabetes (1, 9). Insufficient body fat levels also pose health risks and can impair normal physiologic function (9). Although there are no universally accepted standards for %BF, a range of 10% - 22% for males and 20% - 32% for females is considered ideal

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for preventing chronic disease and impaired physiologic function (1). There are several different techniques used to estimate %BF, each differing in accuracy, cost, and complexity. Two popular clinical and laboratory techniques are air displacement plethysmography (BOD POD®) and Dual Energy X-Ray Absorptiometry (DXA) (9).

The BOD POD® and the DXA have both been shown to be reliable predictors of %BF (2, 7, 14-16, 20). However, in the literature there are some discrepancies in the validity of the BOD POD®, particularly when compared to the DXA. Two studies comparing the BOD POD® to the DXA using active and non active Caucasian females concluded that the BOD POD® is a valid predictor of %BF when compared to the DXA (2, 14). On the contrary, two other studies using collegiate football players (5) and Caucasian men (19) concluded that the BOD POD® significantly underestimated %BF when compared to the DXA by an average of 2.0% and 2.6%, respectively. Another study found that the BOD POD® significantly overestimated %BF when compared to the DXA in Caucasian men by an average of 2.2% (3). The BOD POD® has also been shown to underestimate %BF in non-obese children and adolescents by an average of 2.9% (12), in adolescent females by an average of 3.9% (17), and in overweight and obese children by an average of 2.9% (18).

The BOD POD® is not as expensive as the DXA making it more widely used in many clinical and research settings (2, 8-9, 14). Since there are differences in estimations of %BF between the BOD POD® and DXA, then perhaps people who are overweight or

obese are being mistakenly classified as having a healthy %BF, where as people at the low end of a healthy %BF may be mistakenly classified as having too low %BF. Such misclassifications may prevent someone from intervening when there should be an intervention. Thus it is important to have reliable and valid measures of %BF. With such discrepancies in the literature regarding validity, more research needs to be performed before any definitive conclusions can be suggested. Not only will this study attempt to clarify the difference in estimation of %BF between the BOD POD® and DXA, but will also present differences between the two instruments when classifying with percentiles and standards, something that has not yet been explored. Therefore the purpose of this investigation is to compare the BOD POD® to the DXA using the DXA as the criterion in a university population. A secondary purpose is to determine if one instrument places the population higher or lower on a percentile chart and a standard table. It was hypothesized that there would be a strong correlation between the two measures and %BF estimates will not be significantly different, and that placement on the percentile chart and standard table would be no different.

## METHOD

### *Participants*

This study was first approved by the Institutional Review Board at Southern Illinois University Edwardsville. Participants were recruited from classes within the Kinesiology and Health Education program, ongoing research within the department, and word of mouth. Exclusion criteria included being pregnant,

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under 18 years of age, and being over 136.3 kg. The participant characteristics are listed as means plus/minus standard deviations in Table 1.

Table 1. Participant Characteristics

	Total (N = 244)	Males (n = 119)	Females (n = 125)
Age (yrs)	27.7 ± 10.8	25.7 ± 7.5	29.7 ± 12.9
Weight (kg)	77.3 ± 16.1	70.2 ± 2.7	64.9 ± 3.2
Height (cm)	171.4 ± 10.1	182.4 ± 28.3	158.4 ± 37.5
BMI	26.31 ± 5.42	26.1 ± 3.7	26.6 ± 6.7

### *Protocol*

After signing the informed consent, participants were scheduled for a single, 30-minute session in the Human Performance Laboratory and were tested on both the BOD POD® (Life Measurements Inc, Concord, California, USA) and DXA (Lunar, GE Healthcare Systems, Waukeshia, Wisconsin, USA), with no specific order to the testing. Participants were asked to refrain from exercise on the day of testing and to eat no later than three hours before testing. Prior to having %BF assessed on the two instruments, participants voided their bladder and bowels, height was recorded using a height rod (Seca 214, Itin Scale Co., Inc, Brooklyn, New York, USA) and weight was assessed with a balance scale (Detecto, Webb City, Missouri, USA).

### *BOD POD®*

The BOD POD® was calibrated prior to use according to the manufacturer's specifications. The unit was turned on and warmed up for at least 30 minutes prior to calibration. Calibration commenced by placing a 49.782 liter cylinder into the chamber, closing the chamber door, and measuring the cylinder volume by air

displacement. After measuring, the door was opened and this was repeated four more times. Calibration passed if the standard deviation was  $\leq 75$  milliliters and the mean volume was within  $\pm 100$  among the trials. Calibration was again conducted after 10 participants were measured or at least an hour had passed between measurements, whichever came first. The operating environment of the BOD POD® was in a room where the temperature was automatically controlled and ranged between 21 and 26 degrees Celsius and the relative humidity was between 20% and 70%. The BOD POD® was not next to any opening doors or air vents and the altitude of the laboratory is above sea level and below 10,000 feet, all of which are within the manufacturers recommendations. Participants wore skin-tight clothing, such as bathing suits or exercise tights, and a head cap over the cranium to compress the hair during measurement. All other clothing, jewelry and eyeglasses were removed for testing. Age, height, and gender were entered into the computer, the participant's body weight was measured on the BOD POD® scale, and they were instructed to sit still in the chamber and to breathe normally with hands flat on the lap until testing was complete. Two measurements were taken to ensure consistency and averaged for body volume to estimate %BF using the Siri equation, all of this performed by the BOD POD® software. If the two measures were deviated at an unacceptable range determined by the BOD POD® software, then a third was taken and the two closest measured were averaged for body volume. If all three measures were not consistent, the unit was recalibrated and the participant was re-tested.

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### DXA

The DXA, which was housed in the same room as the BOD POD®, was also calibrated according to the manufacturer's specifications. The unit was turned on and a quality assurance was performed. A calibration block of known density was placed at the head of the scanner and the DXA then scanned the block and the rest of the bed. This was performed once a day (as recommended) before the first participant. Participants were measured without jewelry and with the same clothing (with the exception of the headcap) as described above. Birth date, age, height, and weight from the balance scale were entered and the participant was positioned on the DXA bed. The assessment was started with the DXA software selecting the tissue thickness and scanning the body. The participant was instructed to lie still until the scan was complete.

### *Statistical Analysis*

Statistical analyses were performed with SPSS 14 for Windows (SPSS Inc, Chicago, Illinois, USA). A dependent *t*-test was used to determine differences of %BF estimated from the BOD POD® and DXA. A Pearson's Product Moment correlation was used to examine the relationship between the %BF estimated from the two instruments. Since a high correlation may not necessarily imply agreement, the Bland & Altman (4) plot was used to provide an indication of over and under representation of %BF within  $\pm 2$  standard deviations of the difference scores.

Participants were also divided into three even groups according to body weight (heavier, middle, and lighter) in order to determine if the BOD POD® and DXA

estimate %BF consistently. This was performed by running the frequency function in SPSS and establishing cut-offs for the three groups. The middle weight group was not used in the analysis because some scores at the lower end of the heavier group could be close to some scores at the higher end of the middle group, and scores at the lower end of the middle group could be close to scores at the higher end of the lighter group. In order to keep two distinct groups, only the difference between the BOD POD® and DXA scores in the highest group was compared with the difference scores in the lowest group.

A 2 X 2 X 3 univariate analysis of variance with weight (heavier and lighter), gender (male and female) and age (younger, middle, and older) was used to determine if interactions existed among the independent variables. Significance was set at  $p < .05$  and in cases where pairwise comparisons were needed, adjustment was made using the Bonferonni technique.

A 2 X 2 X 3 univariate analysis of variance with weight (heavier and lighter) as the fixed factor and gender (male and female) and age (younger, middle, and older) as covariates was performed to determine if the heavier group had greater difference scores than the lighter weight group. Significance was set at  $p < .05$ .

Finally, the %BF scores were compared to percentile charts from the Institute of Aerobics Research (1) and a standards table (13). Using the DXA results, participants were classified in percentiles and standards, which were then compared with the BOD POD® percentiles and standards. It was then noted if the BOD POD® placed

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the participant into a higher or lower category, or if there was no change. The total for each category (higher, lower, or the same) was then divided by the total number of participants to get the percentage of the participants who were either higher, lower, or the same in the BOD POD® compared to the DXA scores.

### RESULTS

The dependent *t*-test indicated a significant difference between the %BF estimated from the DXA and the %BF estimated from the BOD POD® ( $29.5 \pm 12.1$  and  $23.4 \pm 12.8$ , respectively),  $t(243) = 22.9$ ,  $p = .001$ . Using the DXA as a criterion, the BOD POD®

underestimated %BF by  $6.1 \pm 4.1\%$  in this study.

The Pearson Product moment correlation (Figure 1) between the two measures was very strong  $r(243) = .95$ ,  $p = .001$ . This indicated that participants with a high %BF measured on the BOD POD® were also measured with a high %BF on the DXA.

The mean difference of 6.1% is indicated by the solid black line on the Bland & Altman plot (Figure 2), with the upper dashed line 2 standard deviations above (14.3%) and the lower dashed line 2 standard deviations below (-2.18%) the mean difference. Note

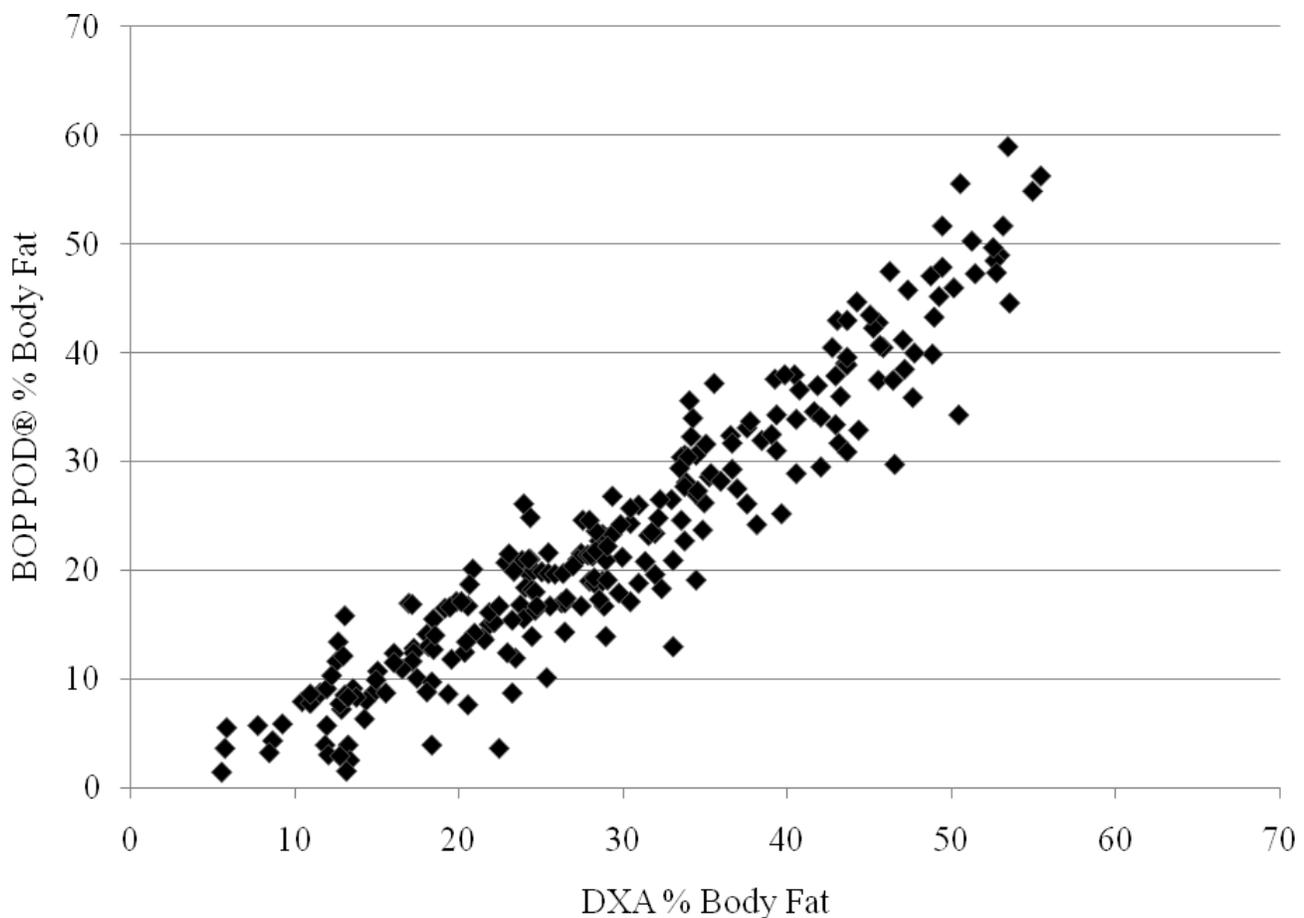


Figure 1. Correlation between body fat percent measured by the DXA and BOD POD® ( $r = .95$ ,  $p = .001$ ).

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that approximately 10 scores (less than 1% of the sample) fall outside this interval.

The univariate analysis of variance indicated there was no interaction among age, gender, and weight,  $F(2, 149) = 1.08$ ,  $p = .34$ , nor was there a two-way interaction when averaged across age,  $F(1, 149) = 2.18$ ,  $p = .14$ , gender,  $F(2, 149) = 1.33$ ,  $p = .26$ , and weight  $F(2, 149) = 0.21$ ,  $p = .80$ . Normal distribution of the dependent variable of each group was determined by dividing the skeweness value by its standard error and the kurtosis value by its standard error. All skeweness and kurtosis statistics were below 1.96, indicating the difference scores are normally distributed.

Since the lack of interaction suggests that differences on the dependent variable among groups do not vary as a function of the independent variables, age and gender were then moved to covariates in this model. Prior to this, Levene's test indicated homogeneity of variance (homoscedasticity), suggesting equal variances between the groups. Linearity was subjectively confirmed with bivariate scatterplots between the covariates and the dependent variable. After adjustment for age and gender, the difference scores in %BF from the DXA and BOD POD® were significantly higher in the lighter weight group ( $6.8 \pm 3.3\%$ ) compared to the heavier

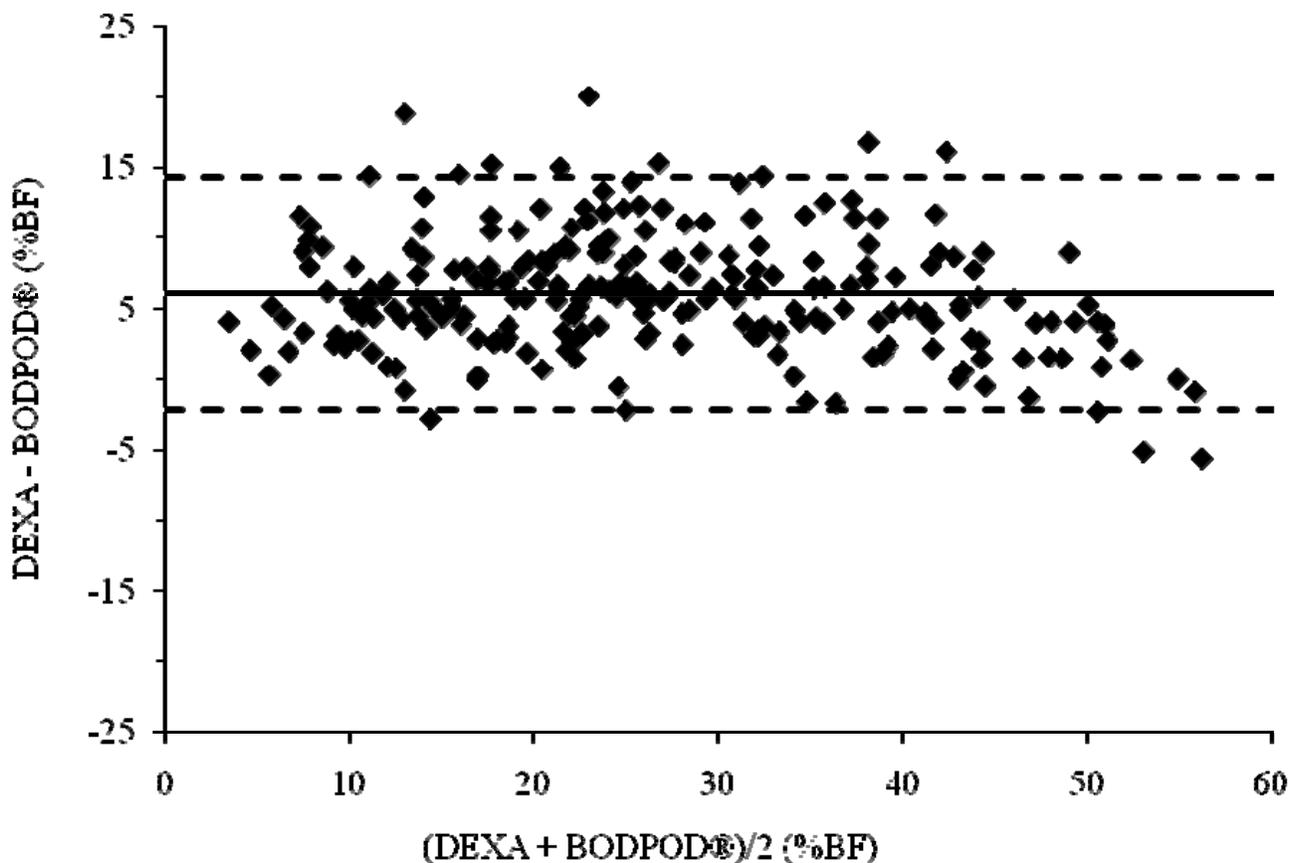


Figure 2. Bland & Altman plot depicting the agreement between the two estimates of percent body fat.

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weight group ( $5.0 \pm 4.5\%$ )  $F(1, 157) = 4.26, p = .041$ . The characteristics of these two groups can be seen in Table 2.

Table 2. Characteristics of Heavier and Lighter Weight Groups.

	Heavier (n = 81)	Lighter (n = 81)
Age (yrs)	31.7 $\pm$ 12.6	24.5 $\pm$ 7.3
Weight (kg)	95.7 $\pm$ 22.6	60.4 $\pm$ 5.8
Height (cm)	174.8 $\pm$ 10.2	165.5 $\pm$ 9.4
BMI	31.6 $\pm$ 5.4	22.2 $\pm$ 2.7
DXA (%BF)*	34.8 $\pm$ 12.8	27.2 $\pm$ 8.4
BOD POD® (%BF)*	29.9 $\pm$ 14.7	20.4 $\pm$ 8.3

\*Unadjusted means and standard deviations.

Since no significant interactions were evident, main effects were then explored. There was no significant main effect of gender,  $F(1, 149) = 0.32, p = .57$  or weight,  $F(1, 149) = 0.38, p = .53$ , but a significant main effect of age did exist,  $F(1, 149) = 3.48, p = .03$ . After pairwise comparisons were made based upon the estimated marginal means using the Bonferroni technique, there was no significant difference between younger, middle, or older age groups.

The BOD POD® had a tendency to place participants higher on the percentile chart compared to the DXA. Table 3 illustrates the percentage of participants who were affected by the difference in %BF estimated by the two modalities. Using the DXA as a criterion, the BOD POD® increased the percentile ranking of just a little less than two-thirds of all participants, with a greater percentage of men being affected compared to women.

The BOD POD® also had a tendency to place participants in a standard other than what was assigned from the DXA. Table 3 shows the percent of participants who would be shifted into a new standard when estimating %BF from the BOD POD®. Approximately half of all participants were placed into a lower standard than what was originally assigned by the DXA.

Table 4 compares where participants were placed on the standard chart using the BOD POD® and DXA. It is evident that results from the BOD POD® place more

Table 3. Percent of participants who were placed in a lower or higher percentile<sup>a</sup> and standard<sup>b</sup> after measurement on the BOD POD® using the DXA as the criterion.

	All (N = 244)	Men (n = 119)	Women (n = 125)
Higher			
Percentile	64.0%	70.0%	57.0%
Standard	01.2%	02.5%	00.0%
Lower			
Percentile	00.8%	01.7%	00.0%
Standard	50.0%	50.0%	49.3%
No Change			
Percentile	35.2%	28.3%	43.0%
Standard	48.8%	47.5%	50.7%

<sup>a</sup> Data compared using percentiles from reference 1.

<sup>b</sup> Data compared using standards from reference 13.

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Table 4. Total number of participants that were placed in each standard using the BOD POD® and DXA body fat percentage.

	Males		Females	
	BOD POD®	DXA	BOD POD®	DXA
At risk	12	0	29	4
Below Average	46	30	15	7
Average	8	6	28	32
Above Average	35	49	9	16
Obesity	18	34	44	66
Total	119	119	125	125

Note: Data compared using standards from reference 13.

participants in the below and at risk categories (lower standard), while the DXA placed more participants in the above average and obesity categories (higher standard).

### DISCUSSION

The purpose of this study was to assess the relationship between %BF estimates of two different technologies, the BOD POD® and the DXA. The first hypothesis was supported, reinforcing the findings of significant direct correlations of  $r = .94$  (3),  $r = .94$  (12),  $r = .89$  (14),  $r = .90$  (18), and  $r = .93$  (19) between the two instruments in past studies. This indicates a strong relationship exists between %BF estimates from the BOD POD® and DXA in both the present and existing literature.

Since neither the BOD POD® nor DXA provide an unequivocally correct measurement of %BF, the Bland & Altman (4) plot was used to determine if either measurement technique sufficiently agrees. Most of the differences in %BF lie within  $\pm 2$  standard deviations, suggesting that the two instruments are consistent. However,

these differences may be clinically important and it is suggested caution be used when estimating %BF from these two instruments for clinical, job, or insurance related purposes since placement in a certain category or percentile can be affected. This study demonstrated that %BF estimated from the BOD POD® will provide more favorable placements than the DXA, and that the DXA will categorize in lower percentiles and higher standards.

The significant 6.1% difference in %BF estimates between the BOD POD® and DXA is more than 2% greater than that of several other studies that found significant differences (3, 5, 11, 17-18). This may be a result of certain methodological limitations. The Siri equation was used to predict %BF in the BOD POD® (18) while other studies used Brozek's (5, 11) or both the Siri and Lohman equations (17). Any equation contains error itself, and while the sample in this study was predominantly Caucasian, the few participants of African and Asian descent did not use an ethnic specific equation to estimate their %BF. Additionally, the predicted thoracic lung volume method was used in this study

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rather than the measured thoracic lung volume. This was performed because most service facilities that use the BOD POD® lack the funding to purchase the materials needed to measure thoracic lung volume and/or do not have sufficient time to measure thoracic lung volume (2). The BOD POD® also provides its own method of measuring lung volume, but it has been shown using the predicted volumes works equally well (3). Since measured thoracic lung volume is seldom used in the field and there is evidence using predicted volumes is sufficient, it was decided not to use that method in this study. It must be emphasized, however, that using predicted lung volumes can certainly contribute to error and thus affect differences in %BF between the BOD POD® and DXA.

The BOD POD® also requires the participant to wear a cap over the scalp so isothermal air within the hair will not affect body volume in the chamber. Although the participants in this study wore a cap over their hair to control for this, one thing not controlled for was facial hair, which has been shown to cause the BOD POD® to underestimate %BF by approximately 1% (10). Body hair (back, chest, legs, etc) was not controlled for either, and no research to the author's knowledge has explored this. This is perhaps something future research with the BOD POD® should include. Finally, the DXA requires less effort and skill on the part of the client and technician compared to the BOD POD®, but validity issues have been identified. One study compared the DXA to an autopsy using eight pig carcasses and found that the DXA appears to underestimate the total amount of fat mass by 13% (6). Also, different DXA manufacturers use different software in

their models and perhaps this contributed to the large average difference that was found (3, 7). Because of this, some have questioned using the DXA as a criterion measure (3). It should be noted that the manufacturer's guidelines for both the BOD POD® and DXA were followed precisely to limit any measurement error from the technician and participant.

The DXA was chosen as the criterion measure because there is less technician/patient error than the BOD POD®. While this study controlled for calibration procedures, subject preparation and testing, comparisons between this and other studies may reflect differences due to laboratory temperature or location of the BOD POD®, such as next to a room door or air conditioning vent. It is also easier for both the technician and the participant to test %BF using DXA technology when compared to the BOD POD® (3), as reflected in the methods section. Lastly, the DXA uses a three component (bone mineral, fat mass, fat free mass) model and takes into account bone mineral density. The BOD POD® is a two component model (fat and fat free mass) and does not measure bone density. Since the DXA can account for individual variability in bone mineral density, it is considered a better predictor than the BOD POD® (2, 8-9). It should be cautioned, however, that the difference in %BF between the BOD POD® and DXA may be negatively associated with bone mineral content in men and women (11). Our study did not account for bone mineral content, which may be contributing to these difference scores.

This study was different from previous research in that our analysis took into

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consideration age, gender, and weight and tested for interactions between each of these independent variables using a more general population instead of just one specific population (ex. college football players, Japanese males and females, etc). After accounting for age and gender, the heavier weight group had a significantly lower adjusted mean difference between the two measures (5.0%) compared to the lighter weight group (6.8%). This should be interpreted cautiously, however, since the measure of association ( $\eta_p^2$ ) was small, suggesting that weight only accounted for 2.6% of the variability in the difference scores. Because age and gender were included as covariates and weight accounted for such small variability, other factors, possibly waist size, must be contributing to the difference in these difference scores.

One study using Japanese males and females (11) suggested that DXA %BF may be underestimated in people with larger waists so perhaps a smaller difference between the two measures in the higher weight group in this study is due to an underestimation of %BF by the DXA. This is assuming that all the individuals in the higher weight group had larger waists than individuals in the smaller weight group, something this study did not measure. Also, previous studies that demonstrate the greatest differences between the two instruments involve children whose weights are usually lighter (12, 17-18), and in the current study the greatest difference occurred in the lighter weight group, which consisted of mostly females. Perhaps as body weight and size decreases, the estimated %BF from the BOD POD® decreases and females elicit greater

decreases in %BF than males. This may be due to the fact that females generally have smaller bodies than males.

Although the heavier participants in our study had a greater %BF than the lighter participants when measured by the BOD POD® and DXA, the difference scores of the two instruments were only marginal between the groups, albeit significant. The lighter weight group had lower %BF and larger difference scores than the heavier weight group, which differs from previous research (3), who noted larger differences in men with greater %BF. Since gender was used as a covariate in our study, it is unlikely that the difference in %BF exists between genders and the differences must lie elsewhere.

Another possible explanation may lie in the error associated within the same models of instruments. Although calibration procedures and testing protocols of the BOD POD® and DXA are very objective, literature referring to the consistency between two of the same instruments in the same group is lacking. A BOD POD® located in a room with high use during the time of evaluation during one study and a BOD POD® in a differently configured room with little activity during the time of evaluation in another study may result in greater variability. At this time, to our knowledge, no studies have examined %BF scores in the same individuals tested in two or more BOD POD's® and only one in two DXA's, but using different models (7), thus little is known about the within variability of these two instruments. If the difference scores within an instrument are variable, then greater caution should be taken when interpreting these results.

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This is the first study to assess shifts on percentile charts and standards tables based upon estimates of %BF from the BOD POD® and DXA. The BOD POD® placed a majority of all the participants in a higher percentile and half in a lower standard compared to the DXA, resulting in more favorable classifications for those individuals. This is clinically meaningful because these shifts may cause one to be raised from the 30<sup>th</sup> percentile (below average) to the 50<sup>th</sup> percentile (average) or from the “at risk for diseases associated with obesity” classification up to the “average” classification. The misclassifications as a result of the underestimation of %BF from the BOD POD® may cause individuals to perceive themselves as being healthier than they actually are. Ultimately, individuals may think they are not at a great risk for diseases associated with having a high %BF and this may prevent them from beginning a diet and/or exercise intervention to improve their health. Many people do not like to take action to improve their health unless they absolutely have to and these misclassifications may give individuals an excuse not to intervene.

This study suggests the BOD POD® and DXA will not give a 100% accurate estimate of %BF. The %BF from the BOD POD® should be used with caution when compared to risk profile data and percentiles and standards for men and women. However, both are able to track changes over time which is important for assessing any weight loss intervention (2).

Although the BOD POD® is reliable and able to track changes over time, which is

important for assessing any weight loss intervention (2), this study suggests that the BOD POD® significantly underestimates %BF by more than 6.0% compared to the DXA. As a result of such a large difference between the two instruments this study is the first to demonstrate that the BOD POD® places individuals in more favorable percentiles and standards compared with the DXA. These differences may be clinically meaningful and it is suggested caution be used when estimating %BF from these two instruments.

## REFERENCES

1. Armstrong LE, Balady GJ, Berry MJ, Davis SE, Davy BM, Davy KP, Franklin BA, Gordon NF, Lee IM, McConnell TR, Myers JN, Pizza FX, Rowland TW, Stewart K, Thompson PD, Wallace JP. Body Composition. In: American College of Sport Medicine's Guidelines for Exercise Testing & Prescription (7<sup>th</sup> ed.). Baltimore: Lippincott Williams & Wilkins, 57-66, 2007.
2. Ballard T, Fafara L, Vukovich M. Comparison of BOD POD and DXA in female collegiate athletes. *Med Sci Sports Exerc* 30(4): 731-735, 2004.
3. Ball S, Altena T. Comparison of the BOD POD and dual energy x-ray absorptiometry in men. *Physiol Meas* 25(3): 671-680, 2004.
4. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1: 301-310, 1986.
5. Collins MA, Millard-Stafford ML, Sparling PB, Snow TK, Roskopf LB, Webb SA, Omer J. Evaluation of the BOD POD for assessing body fat in collegiate football players. *Med Sci Sports Exerc* 31: 1350-1356, 1999.
6. Elowsson P, Forslund A, Mallmin H, Feuk U, Hansson I, Carlsten J. An evaluation of dual-energy x-ray absorptiometry and underwater weighing to estimate body composition by means of carcass analysis in piglets. *J Nutr* 128 (9): 1543-1549, 1998.

## COMPARISON OF THE BOD POD AND DXA

7. Gillette-Guyonnet S, Andrieu S, Nourhashemi F, Cantet C, Grandjean H, Vellas B. Comparison of bone mineral density and body composition measurements in women obtained from two DXA instruments. *Mech Ageing Dev* 124: 317-321, 2003.
8. Heyward V, Wagner D. *Applied body composition assessment* (2<sup>nd</sup> ed.). U.S.: Edwards Brothers, 2004.
9. Heyward V. *Assessing Body Composition*. In: *Advanced fitness assessment & exercise prescription* (3<sup>rd</sup> ed.). U.S.: Burgess Publishing Company, 145-176, 1997.
10. Higgins PB, Fields DA, Hunter GR, Gower BA. Effect of scalp and facial hair on air displacement plethysmography estimates of percentage of body fat. *Obes Res* 9(5): 326-330, 2001.
11. Koda M, Ando F, Niino N, Tsuzuku S, Shimokata H. Comparison between the air displacement method and dual energy x-ray absorptiometry for estimation of body fat. *J Epidemiol* 10(Suppl): S82-89, 2000.
12. Lockner DW, Heyward VH, Baumgartner RN, Jenkins KA. Comparison of air-displacement plethysmography, hydrodensitometry, and dual x-ray absorptiometry for assessing body composition of children 10 to 18 years of age. *Ann N Y Acad Sci* 904: 72-78, 2000.
13. Lohman TG. *Advances in body composition assessment*. Current issues in exercise science series. Monograph No. 3. Champaign, IL; Human Kinetics, 1992.
14. Maddalozzo G, Cardinal B, Snow C. Concurrent validity of the BOD POD and dual energy x-ray absorptiometry techniques for assessing body composition in young women. *J Am Diet Assoc* 102 (11): 1677-1690, 2002.
15. Norcross J, Van Loan MD. Validation of fan beam dual energy x ray absorptiometry for body composition assessment in adults aged 18-45 years. *Br J Sports Med* 38: 472-476, 2004.
16. Noreen E, Lemon P. Reliability of air displacement plethysmography in a large, heterogenous sample. *Med Sci Sports Exerc* 38 (8): 1505-1509, 2006.
17. Radley D, Gately P, Cooke C, Carroll S, Oldroyd B, Truscott J. Estimates of percentage body fat in young adolescents: a comparison of dual energy x-ray absorptiometry and air displacement plethysmography. *Eur J Clin Nutr* 57 (11): 1402-1410, 2003.
18. Radley D, Gately P, Cooke C, Carroll S, Oldroyd B, Truscott J. Percentage fat in overweight and obese children: comparison of DXA and air displacement plethysmography. *Obes Res* 13 (1): 75-85, 2005.
19. Sardinha LB, Lohman TG, Teixeira PJ, Guedes DP, Going SB. Comparison of air displacement plethysmography with dual energy x-ray absorptiometry and 3 field methods for estimating body composition in middle aged men. *Am J of Clin Nutr* 68: 786-793, 1998.
20. Vescovi J, Zimmerman S, Miller W, Hildebrandt L, Hammer R, Fernhall B. Evaluation of the BOD POD for estimating percentage body fat in a heterogeneous group of adult humans. *Eur J Appl Physiol* 85(4): 326-32, 2001.