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Measured versus predicted thoracic gas volume in college students

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Abstract. The aim of this study was to evaluate if there is a difference between measured and predicted thoracic gas volume using the Bod Pod® in college students. *Material and Method*: sixty healthy college students (27 females and 33 males) between the ages of 18 and 25 ([mean ± SD] 21.4 ± 1.2 years) performed body composition testing using the Bod Pod. Thoracic gas volume (TGV) was measured (MTGV) during the testing. Upon completion of the test the predicted (PTGV) TGV was determined from the software. Measured variables included percent body fat (MTGV and PTGV), body volume (MTGV and PTGV), and TGV. *Results*: Results showed no significant difference in MTGV and PTGV ($p = 0.295$), body volume (BV) ($p = 0.248$), and percent body fat (% BF) ($p = 0.316$). The 95% CI established ranges of 3.33 L to 3.82 L, 20.2% to 25.3%, and 65.6 L to 71.3 L for the measured TGV, %BF, and BV, respectively. A Bland-Altman plot was used to reveal any variability about the mean for individual participants MTGV and PTGV and the averages of each. *Conclusion*: Based upon these results, PTGV can be used instead of MTGV when measuring body composition using the Bod Pod®.
Keywords: *body composition, fat mass, fat-free mass, air-displacement plethysmography, thoracic gas volume, Bod Pod®*

Introduction

The National Health and Nutrition Examination Survey (NHANES) have reported that more than two-thirds of adults are considered overweight or obese (1,2). Similarly, more than one in three adults are considered obese (1,2). Increased body fatness, or excess body weight, has been negatively associated with physical performance and health (3). This increased body fatness has increased the need for accurate measurement of body composition in all settings and populations.

The Bod Pod® (COSMED USA Inc., Concord, CA) is such a device that is found in the clinical, research, wellness, and athletic environments to estimate percent body fat (% BF) based upon estimation of a two compartment model similar to hydrostatic weighing (HW). The Bod Pod®, an air displacement plethysmograph, is a device available for estimating % BF, and has increased in popularity in use since the late 1990's. This device has demonstrated reliability and validity when compared to HW since its inception (4,5) and the procedure is quicker and easier (6). The Bod Pod® has also been validated against reference methods in healthy children, adolescents, adults, and elderly (7-10).

The Bod Pod ® utilizes the inverse relationship between pressure and volume (Boyle's law) to determine body volume (V_b) (11). Once V_b is determined, body density and % BF can be computed. As with HW, correction of volume of air in the body must be accounted for.

Failure to account for this volume of air will result in an overestimation of total body density (Db), and thus an underestimation of % BF. In the Bod Pod®, this volume of air is called thoracic gas volume (TGV). TGV is the amount of air in the lungs during normal tidal breathing (4). The Bod Pod® measures TGV (MTGV) while the person is in the device by performing a breathing maneuver. There is an option to predict TGV (PTGV) if a measurement is not collected. The regression equations by Crapo et al. were used to calculate PTGV (12).

Previous studies have reported good agreement with MTGV and PTGV (4,13-15); however, there have been studies that have found significant differences (8,16). The participant populations in previous studies (8,17,18) were collegiate athletes and presently no study has recruited college-aged students only. Thus, the purpose of this study was to compare MTGV and PTGV measurements in college aged students using the Bod Pod®.

Material and Method

Sixty healthy college students (27 females and 33 males) between the ages of 18 and 25 ([mean ± SD] 21.4 ± 1.2 years) performed a body composition test using the Bod Pod® (COSMED, Concord, CA, USA). Seven participants were unable to perform the TGV maneuver; thus data analysis was completed on only those 53 participants that completed the test. Inclusion criteria were: 1) being a full-time student (minimum of 15 units), and 2) between the ages of 18 and 25 years. The exclusion criteria for this study included any participant that was or thought they may be pregnant, history of lung disease, or greater than 25 years of age.

Physical characteristics of the participants and the variables collected from the Bod Pod® in this study are presented in Table 1. The ethnic composition of the sample was 31.7% Caucasian, 51.7% Hispanic, 8.3% African American, and 8.3% other. Before the study, the study was explained to each volunteer. Prior to collection initiation of the study, the California State University, Bakersfield (CSUB) Institutional Review Board (IRB) reviewed all study materials and consent forms to confirm the study met guidelines for human subjects. The CSUB IRB approved the study and all participants signed a consent form approved by the CSUB IRB. Subjects were asked not to eat or drink two hours prior to testing and asked to void their bladder prior to testing.

Table 1. Physical Characteristics of subjects (n = 53)

	Mean ± SD	Range
Age (y)	21.4 ± 1.2	18 – 25
Height (cm)	170.9 ± 11.4	152.4 – 205.7
Weight (kg)	71.5 ± 11.1	48.0 – 99.3
BMI ($kg \cdot m^{-2}$)	24.5 ± 3.4	18.8 – 35.3
MTGV (L)	3.61 ± 0.96	2.09 – 6.27
PTGV (L)	3.51 ± 0.55	2.72 – 5.21
BVM (L)	67.71 ± 10.76	46.19 – 98.73
BVP (L)	67.67 ± 10.78	46.48 – 99.12
BFM (%)	22.4 ± 9.78	8.7 – 44.1
BFP (%)	22.1 ± 10.18	9.4 – 44.0

Range = lowest to highest values.

Height was measured to the nearest 0.1 cm using a standiometer (Detecto 439 Balance Beam Doctor/ Physician scale with height rod, Webb City, MO) after participants voided their bladder. Participants stood erect, without shoes, and with their hands at their sides. Height was measured at the end of a normal inspiration. Participants wore only the clothing they would be measured in the Bod Pod®.

Body volume was measured by the Bod Pod® (COSMED USA, Concord, CA, USA) using the standardized published procedures (4). The Bod Pod® is a dual chamber air-displacement plethysmography device (11). Prior to testing, the device was calibrated using a 50.280-L cylinder following manufacturers guidelines. Participants were required to wear clothing according to manufacturer guidelines (males – compression shorts or swimsuit, females – compression shorts and sports bra or one-piece swimsuit and all subjects wore a swim cap) to reduce the possibility of air trapping in their clothing and hair. Prior to entering the Bod Pod®, each subject was weighed on the calibrated scale (Tanita Corporation, BWB 627A, Japan) that is connected to the Bod Pod®. Body volume was measured twice by the device to ensure measurement reliability. If the first two measurements differed by more than 150 ml, a third measurement was taken. If the measurements were not reliable the Bod Pod® was recalibrated and the testing was started over. Body fat was calculated from the D_b obtained by the Bod Pod® using the Siri equation (19).

Thoracic gas volume was measured after measurement of body volume in the Bod Pod®. The technique was described to each subject and then the subject performed the test. Each subject was visually able to see the computer to perform the breathing technique.

The technique of measuring TGV is performed by having the subject breathe via a disposable breathing tube and antimicrobial filter, plugging their nose, and performing a "huffing" maneuver mid-expiration against a shutter valve. TGV is defined as:

$$TGV = FRC + 0.5\ TV$$

where FRC is functional residual capacity, and TV is the tidal volume estimated during normal breathing.

Predicted TGV was determined by Bod Pod ® proprietary software which are based upon formulas developed by Crapo et al. (12).
The formulas are calculated as:

Women and Men: FRCpred = 0.472 (Ht) + 0.0090 (A) – 5.290
Women RVpred = 0.1970 (Ht) + 0.0201 (A) – 2.421
Men RVpred = 0.2160 (Ht) + 0.0207 (A) – 2.840

where predicted FRC (FRCpred) and RVpred are in liters, Ht is height in centimeters, and A is age in years.

All analyses were produced using SPSS (SPSS for Mac, version 22, Chicago, IL). Normality of MTGV and PTGV were analyzed with the Shapiro-Wilk test. Mean differences between MTGV and PTGV, as well as Vb, and %BF from MTGV and PTGV, were evaluated with paired samples t tests. Individual error scores were evaluated with a Bland Altman analysis (20). Statistical significance was established a priori as $p < 0.05$.

Results

Measured thoracic gas volume was normally distributed ($p = 0.062$); however, PTGV was not ($p = 0.004$). Seven of the participants (12%) were unable to complete the MTGV during the collection of TGV even after 5 trials; these participants were excluded from analysis, leaving 53 participants for data analyses. The mean differences for the variables of interest (TGV, BV, and % BF) were not statistically different when MTGV was compared with PTGV (Table 2). The 95% CI established ranges of 3.38 L to 3.66 L, 19.9% to 25.3%, and 65.5 L to 71.2 L for the predicted TGV, % BF, and BV, respectively. The 95% CI established ranges of 3.33 L to 3.82 L, 20.2% to 25.3%, and 65.6 L to 71.3 L for the measured TGV, %BF, and BV, respectively. The Bland-Altman analysis (Figure 1) to evaluate individual variability revealed a significant bias ($r = 0.629$, $p < 0.000$) such that PTGV was systematically overestimated in subjects with a small TGV and underestimated in those with a large TGV.

Table 2. Predicted-Measured TGV paired samples t-test (n = 53).

Variable	Mean ± SD	SEM	Significance
TGVP – TGVM	0.10 ± 0.69	0.095	0.295
BVP – BVM	0.37 ± 0.27	0.037	0.316
BFP – BFM	0.29 ± 1.80	0.247	0.248

TGV (L) = thoracic gas volume in liters; BV (L) = body volume in liters; % BF = percentage body fat; P = predicted; M = measured; $p < 0.05$

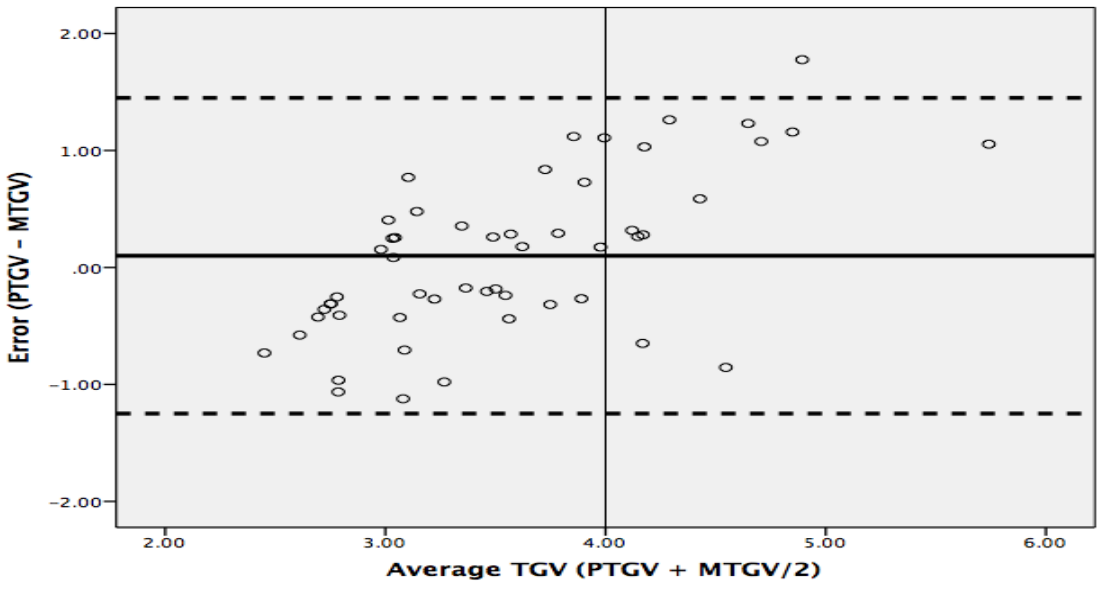

Figure 1. Plot of the thoracic gas volume (TGV) residual scores. The solid line is the constant error. The dashed lines are the 95% CI (*MTGV = measured thoracic gas volume; PTGV = predicted thoracic gas volume*)

Discussion

The aim of the study was to determine if there was a difference between the predicted and measured thoracic gas volume measurements from the Bod Pod® in college-aged students. The main findings of the study there were no differences between the two measurements. The results agree with the seminal study of McCrory et al. (4) in which they reported no difference between MTGV and PTGV in a population of 50 adults' subjects. Other studies have reported similar findings in adolescents to adults (21,22). Thus; the use of PTGV is acceptable when estimating % BF in college aged students.

McCrory et al. (4) compared Bod Pod ® with hydrostatic weighing in adults. The data was reported in % BF using measured and predicted TGV values and found no significant differences utilizing either measurement on % BF. The authors concluded that Bod Pod® is a valid tool in measuring % BF, and they recommended the use of measuring TGV in experimental and clinical practice in young to middle-aged individuals (4). Demerath et al. (13) concluded that there were no differences in % BF when comparing MTGV and PTGV in adults (13); however, they did find a significant difference in children due to the prediction equation was generated from data collected on adults 19 – 71 years of age (5).

Despite the results of this study demonstrating no difference in MTGV and PTGV when estimating % BF in college aged student's other studies have demonstrated significant differences in estimated % BF. Minderico et al. (16) reported an overestimation of PTGV by approximately 0.2 L in adult females. The authors concluded a strong relationship between TGV methods and % fat mass changes (16). They also concluded that PTGV should not be utilized in a weight loss program. Collins et al. (8) reported a weak relationship between measured and predicted TGV ($r = 0.207$) with a large SEE of 0.65 L in college football players. They also reported on average the measured TGV were lower than predicted TGV values.

Limitations to this study were collection of MTGV for some participants is difficult to complete. In nearly 10% of the subjects that participated in the study failed the MTGV procedure. This failure rate has been seen in previous studies ranging from 13% to 31% (18,21,22). The majority of failures were due to high merit scores. The manufacturer suggests that the subjects do not maintain a tight seal around the breathing tube or performed the puffing maneuver too hard.

This study confirms that the predictive thoracic gas volume technique can be utilized when estimating body composition in college-aged individuals. The findings support previous research that the predicted thoracic gas volume is a valid measurement tool when utilizing the Bod Pod®. Future research may aim to determine if there should be more than two ethnicity criteria when determining thoracic gas volume.

Conflict of Interest Statement. The author has no conflict of interest to declare.

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