



*ORIGINAL RESEARCH*

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## **Effect of Capris in Validity of Air-Displacement Plethysmography in Female College Students**

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### ABSTRACT

*International Journal of Exercise Science* 12(4): 1315-1322, 2019. Body composition testing is completed in human performance laboratories, local health clubs, and many other locations each day. Maintaining proper technique is required to make sure the results are reliable and valid. The purpose of this study was to compare traditional clothing (spandex shorts and sports bra) and non-traditional clothing (Capri-length spandex pants and sports bra) in females while utilizing the Bod Pod to determine body composition. Nineteen female participants ages 18 - 25 years ( $M_{age} = 21.2$  years) performed two Bod Pod tests either wearing traditional or non-traditional clothing when completing the test. Measured variables included percent body fat, body volume, body density, fat mass and fat-free mass. Results indicated percentage of body fat was greater when wearing spandex shorts with a mean difference of 0.84%, and body density was greater when wearing capris relative to shorts, with a mean difference of .002 g/cm<sup>3</sup>. A Bland-Altman plot was used to reveal any variability about the mean for individual participants MTGV and PTGV and the averages of each. Reliability of the Bod Pod does not appear to be compromised by clothing; however, wearing Capri-length spandex pants results in a statistically significant reduction in body fat percent estimations by just less than 1%, compared with the recommended spandex shorts.

**KEY WORDS:** Bod Pod, body composition, body volume, body fat, densitometry

### INTRODUCTION

There are a multitude of techniques currently being utilized to determine body composition in athletes, as well as the general public. These techniques include hydrodensitometry (underwater weighing (UWW)), dual-energy x-ray absorptiometry (DEXA), skinfold measurement, and various other methods. While these are all reasonably accurate methods, the downfall is that most of these forms of testing are expensive, time-consuming, and may expose a person to a small amount of radiation (1). One alternate technique that is both a convenient and accurate form of testing is air-displacement plethysmography (ADP); a

technique utilized by the Bod Pod technology. This form of testing provides a quick and convenient method for measuring body composition. The Bod Pod when compared to UWW causes limited discomfort to the participant, as well as alleviating submission in water, of which some participants are apprehensive (2, 8). The Bod Pod is a very convenient resource to observe changes in body fat percentage, thus it is increasingly more common in a non-clinical setting. Universities and sports clinics have been utilizing the Bod Pod for the past few decades.

There are multiple models of body composition testing that divide the body into a various number of compartments. Testing for the general public tends to have a simpler breakdown and focuses on two compartments: fat mass (FM) and fat-free mass (FFM). Fat mass consists of adipose tissue that is stored throughout the body, whether that be viscerally, subcutaneously, or in and around organs. This value (percentage) varies from person to person, yet it is essential for humans to have a specific amount of fat storage in order for proper bodily functions to occur. Fat-free mass consists of all other compartments, which make up the body's mass such as muscle, bone, and water. Because excess storage of adipose tissue in and around organs can become a health risk, healthier people tend to have high measures of FFM and lower measures of FM.

Bod Pod testing requires subjects to wear as minimal clothing as possible. The reasoning behind this is due to the pressure/volume relationship. This can be understood by Boyle's law, which states that at constant temperature (isothermal conditions) the product of pressure and volume is constant (5). Thus, a quantity of air compressed under isothermal conditions will decrease its volume in proportion to the increasing pressure, or

$$P_1V_1 = P_2V_2$$

where  $P_1$  and  $V_1$  represent the pressure and volume in one condition and  $P_2$  and  $V_2$  represent a second condition. However, under adiabatic conditions the temperature of air does not remain constant as its volume changes. Once a subject is placed into the Bod Pod adiabatic conditions are no longer maintained. In order to maintain isothermal conditions, the subject is asked to wear minimal clothing and compress their hair with a swim cap. Because of this, materials such as cloth will be more easily compressed and show a negative volume when measured by ADP because of isothermal conditions within the material (13).

The subject's body surface area (BSA) and the air inside of their lungs are the two contributors to the isothermal conditions within the testing chamber (6). The Bod Pod is programed to account for these two measurements, but what it does not account for is the air that is found in the interweaving's of the clothing and hair of the subject in the chamber (8). As stated earlier, in an attempt to reduce this potential source of error, the subjects are required to wear a tight-fitting swim cap to compress their hair. Resultantly, the error from the isothermal air within the hair can be reduced, thus leaving the air that is found on the body's surface and within clothing. To address this error, previous studies have identified which form of clothing is the

most ideal to be worn in the Bod Pod. Vescovi et al. addressed this error by using ADP to compare body fat percentage in subjects wearing a swimsuit, hospital gown, and in the nude. The authors reported that clothing has a drastic effect on body fat measurements found using ADP (13). Multiple studies have also addressed the effect of other types of clothing on Bod Pod results but have not specifically compared Capri-length spandex pants to spandex shorts (6 - 8, 11). Fields, Hunter, and Goran concluded that caution should be taken if a person is wearing something other than a tight-fitting swimsuit (7). Additionally, it was determined that females could wear either a one- or two-piece bathing suit without any significant differences. King et al. reported that females could wear personal undergarments when measuring body composition in the Bod Pod, but males could not when compared to wearing a swim suit (8). Shafer et al. compared multiple types of clothing ranging from scrubs, spandex t-shirt and shorts, and proper attire depending upon sex and reported significant differences in percent body fat when compared to DEXA (8).

Traditionally, it is ideal that participants are as comfortable as possible. Requiring individuals to wear proper clothing is ideal, however, when performing body composition testing females may feel uncertain about the proper attire and may wish to wear Capris or full-length spandex. The longer the length of the spandex may result in an increase in isothermal air trapped on the body, which could potentially lead to a source of error, resulting in an inaccurate test result. Because of the large population that would prefer to wear Capri-length spandex instead of spandex shorts, it is important to address whether or not this will have a significant impact on the test result. Therefore, the purpose of this study was to compare traditional clothing (spandex shorts and sports bra) and non-traditional clothing (Capri-length spandex pants and sports bra) in females while utilizing the Bod Pod to determine body composition.

## **METHODS**

### *Participants*

The sample size was estimated a priori, assuming  $d = 0.70$  effect size. Using a within participants design an  $\alpha$ -level of 0.05, a power  $(1 - \beta)$  of 0.80, it was calculated that at least 8 participants would be needed to detect a significant difference between traditional clothing and Capri-length spandex (G\*Power; Heinrich-Heine-Universität Düsseldorf, Germany). Nineteen female college students between the ages of 18 - 25 years participated in the study ( $M_{age} = 21.2$ ;  $SD = 1.7$  years). All participants were recruited from flyers posted on campus. Inclusion criteria was all participants were to be female, college-aged. Participants were excluded if they were pregnant or believed themselves to be pregnant. Prior the data collection, all subjects signed a consent form approved by the Institutional Review Board of (Removed for blinding during review only). The participants, all over the age of 18 years, received full explanation of the nature, purpose, and risks associated with the study and were given an opportunity to ask questions prior to participation.

### *Protocol*

Participants were asked not to eat or drink four hours prior to testing, no strenuous exercise 12 hours prior, and to void their bladder prior to testing when reporting to the laboratory. Participants were randomized to perform the Bod Pod test in shorts and sports bra (ADP<sub>T</sub>) or perform the test wearing three-quarter length Capri pants (ADP<sub>C</sub>) to determine if there is a difference in percent body fat (BF%) and body density (BD) in the non-traditional clothing first and then the other condition was completed immediately afterwards. All participants wore similar three-quarter-length Capri pants to address any possible issues with different styles. All measurements were performed in a thermoneutral laboratory that met established guidelines from the manufacturer.

Prior to data collection height was measured to the nearest 0.1 cm using a stadiometer (Seca 216, Chino, CA, USA). Subjects stood erect, without shoes, and with their hands at their sides. Height was measured at the end of a normal inspiration.

Body volume was measured by the Bod Pod (COSMED USA, Concord, CA, USA) using the standardized published procedures (3, 4, 9). The Bod Pod is a dual chamber air-displacement plethysmography device (4). Prior to testing, the device was calibrated using a 50.280-L cylinder following manufacturer's guidelines. Participants were required to wear clothing according to manufacturer's guidelines (compression shorts, sports bra, and swim cap) to reduce the possibility of air trapping in their clothing and hair. Prior to entering the Bod Pod, each participant was weighed on the calibrated scale. Body mass was measured to the nearest 0.01 kg using a calibrated digital platform scale that is connected to the Bod Pod (Tanita Corporation, BWB 627A, Japan). Participants wore only the clothing, which they would be measured in while inside the Bod Pod. Body volume was measured twice by the device to ensure measurement reliability for each test as per manufacturer guidelines. 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 to manufacturers guidelines and the participant was retested. Body fat was calculated from the BD obtained by the Bod Pod using the Siri equation (12). A prior study by this laboratory reported no significant differences in predicted thoracic gas volume (TGV) compared to measured TGV, so the predicted TGV was utilized in the calculation of percent body fat (10).

#### *Statistical Analysis*

Statistics were determined using SPSS version 22. Statistical significance was established a priori as  $p < 0.05$ .

## **RESULTS**

Participant characteristics are presented in Table 1. Table 2 provides statistics for all body composition measures, and inferential analyses. Importantly, results indicated two significant differences in body composition for participants when they were wearing ADP<sub>T</sub> compared to ADP<sub>C</sub>. First, percentage of body fat was greater when wearing ADP<sub>T</sub> with a mean difference of 0.84 %. Second, BD was greater when wearing ADP<sub>C</sub> relative to ADP<sub>T</sub>, with a mean

difference of 0.002 g/cm<sup>2</sup>. No significant differences were found for fat mass, fat free mass, or body volume. The Bland-Altman analysis (Figure 1) to evaluate individual variability revealed a moderate bias ( $r = 0.547$ ,  $p = 0.015$ ) such that BFC was systematically overestimated percent body fat compared to participants wearing traditional clothing.

**Table 1.** Participant characteristics ( $n = 19$ ).

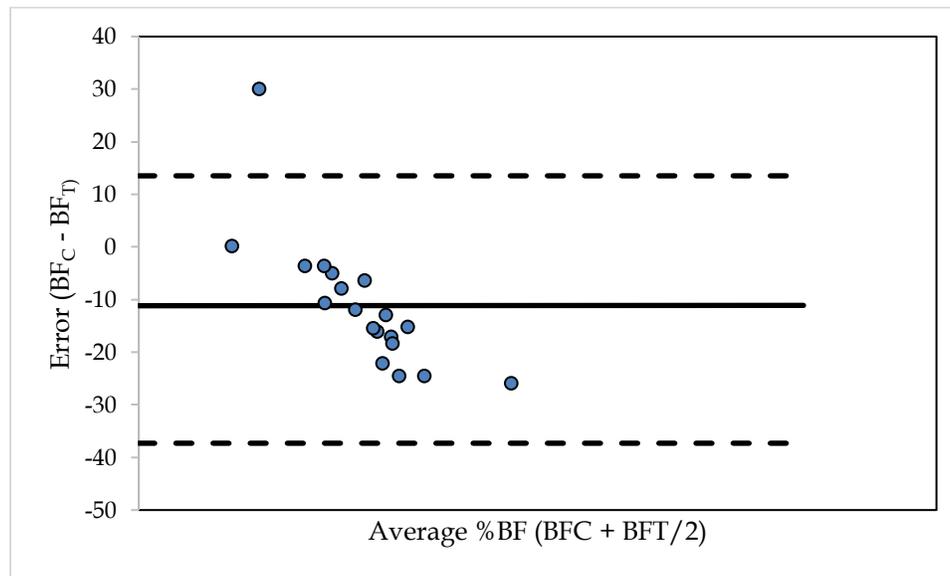
Anthropometrics	Mean	SD	Range
Age (years)	21.2	1.7	18 - 25
Height (cm)	64.9	5.6	47.8 - 74.0
Body Mass (kg)	67.7	12.7	41.6 - 86.8
BMI (kg/m <sup>2</sup> )	24.8	3.1	20.1 - 31.5

**Table 2.** Statistics on Body Composition

	ADPT	ADPC	t-value
% BF	28.1 + 5.6	27.2 + 5.5	t (18) = 2.974, $p < .001^*$
FM (kg)	20.6 + 6.6	17.9 + 6.7	t (18) = 1.857, $p = .080$
FFM (kg)	49.0 + 8.5	49.3 + 9.4	t (18) = -.332, $p = .744$
Bv (L)	65.0 + 13.0	65.5 + 12.6	t (18) = -1.315, $p = .205$
B <sub>D</sub> (g/cm <sup>2</sup> )	1.036 + 0.01	1.037 + 0.01	t (18) = -2.910, $p = .009^*$

Values are mean ± SD.  $n = 19$ .

ADP<sub>T</sub>, traditional clothing; ADP<sub>C</sub>, Capris; % BF, percent body fat; FM (kg), fat mass in kilograms; FFM (kg), fat-free mass in kilograms; Bv, body volume in liters; B<sub>D</sub> (g/cm<sup>2</sup>), body density in grams per centimeter squared. \* significant difference ( $p < 0.05$ )



**Figure 1.** Plot of the percent body fat (%BF) residual scores. The solid line is the constant error. The dashed lines are the 95% CI (BF<sub>C</sub> = percent body fat in Capris; BF<sub>T</sub> = percent body fat in traditional clothing)

**DISCUSSION**

The major findings of this study were observed in the parameters of body density and percent body fat. The mean body density measurement of subjects while wearing spandex shorts (ADP<sub>T</sub>) was found to be 1.0355 g/cm<sup>3</sup>, in comparison to subjects wearing spandex capris (ADP<sub>C</sub>) where body density was found to be 1.0373 g/cm<sup>3</sup>. This difference shows that on average, body density was measured to be 0.002 g/cm<sup>3</sup> greater while subjects were wearing capris relative to shorts. Because of the longer length of body area being compressed by capris, this is a logical result. Capri-length spandex pants compress the body, therefore giving the impression of a denser composition and leading to a higher density measurement. In testing, this would lead to a false result for the subjects and would not give them accurate measurement of their body composition.

The percent body fat of subjects was found to be significantly different between subjects wearing traditional vs. non-traditional clothing as well. The average percent body fat was found to be 28.1 % in ADP<sub>T</sub>, in comparison to 27.2 % in ADP<sub>C</sub>. This means that on average, the subjects were found to have a body fat percent that was 0.84% lower simply because they were wearing capris instead of traditional spandex shorts. This is a large underestimation that would have practical application in the monitoring of body composition. For example, in the case of a patients being monitored for weight loss. If they were to wear varying forms of clothing each time, they enter the Bod Pod their progressive body fat percent would lack the desired accuracy to trend body fat changes.

The findings of this study were compatible with current research utilizing air displacement plethysmography (Bod Pod). Vescovi et al. wanted to determine if there were differences between wearing a hospital gown, a swimsuit, and completing testing in the nude in the Bod Pod (13). The authors found there to be a significant underestimation of percent body fat (approximately 8 - 9% fat) while wearing a hospital gown compared with the recommended swimsuit or nude conditions (13). The authors reported that the greater amount of material in the hospital gown lead to a higher amount of trapped isothermal air, resulting in skewed results (13). Similarities may be drawn with our participants wearing Capri length spandex with the larger amount of material causing trapping of isothermal air. These participants were also underestimated in their percent body fat measurements, likely due to the greater amount of material in capris. This result supports the concept that clothing type effects body composition measurements using ADP, though other research (6). When comparing a one piece versus a two-piece bathing suit in the Bod Pod, the authors found that the two types of bathing suits could be worn interchangeably without any significant difference in result between the two (6). The variance in results found by each study raise the question of whether or not clothing does indeed make a significant difference in body composition measurements, a question that may be difficult until further research is done.

Wearing a minimal amount of clothing when performing body composition measurements in the Bod Pod chamber is the standard for the most accurate test results. This study addressed whether or not wearing capris spandex (instead of spandex shorts) would cause a significant difference in the body composition measurements found by the Bod Pod. Between the

accessibility and accuracy of ADP testing, the Bod Pod is a key resource that can be utilized for determination and monitoring of body composition. With the various studies recently being done to determine which form of clothing is best to be worn while taking a Bod Pod measurement, the accuracy of the test will continue to improve. There were some small differences in measurements for fat mass, fat free mass, and body volume, but none of which were found to be significantly different. This study was limited in the somewhat small sample size used and the specific demographic requirements of the participants. To further improve on this aspect and strengthen the overall results, a larger and more diverse population could be used in future testing.

The overall purpose of this study was to compare traditional (spandex shorts and sports bra) and non-traditional clothing (Capri-length spandex pants and sports bra) in females while utilizing the Bod Pod to determine body composition. Based off of the results, it can be concluded that there are some discrepancies between wearing the two forms of clothing. Body density and percentage body fat had significantly different measurements. This information is important for future body composition testing using ADP. If patients want a more accurate body composition measurement, then they may need to go outside of their comfort zones and wear clothing that is more compatible with the Bod Pod technology.

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