# Three-Dimensional Body Scanning: A Novel Technique for Body Composition Assessment

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**By**

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**The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled:**

Three-Dimensional Body Scanning:

A Novel Technique for Body Composition Assessment

**Presented by Justin Ryder,**

**A candidate for the degree of master of arts, and hereby certify that, in their opinion, it is worthy of acceptance.**

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**Professor Steve Ball**

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**Professor Tom Thomas**

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**Professor Lynn Boorady**

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# THREE-DIMENSIONAL BODY SCANNING: A NOVEL TECHNIQUE FOR BODY COMPOSITION ASSESSMENT

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## ABSTRACT

**INTRODUCTION:** Accurate body composition assessment is crucial for determining health consequences due to excess body fat (BF). While several techniques exist there are few that are accurate, non-invasive, fast, and comfortable for subjects. The Three Dimensional (3D) body scanner is a new body composition assessment method that might serve as another option for investigators and practitioners. The purpose of this study was to determine the accuracy of the 3D body scanner at measuring body composition using dual energy x-ray absorptiometry (DXA) and Air displacement plethysmography (Bod Pod) as criterion measures. The 3D body scanner was evaluated on its ability to work with differences in normal versus overweight subjects as determined by BMI. Also, a new prediction equation was created and compared to that of an existing equation used by the 3D body scanner developed by the Department of Defense (DoD).

**METHODS:** Eighty-Five male subjects (21.70 ± 2.28 yr old; 81.00 ± 12.21 kg; 25.37 ± 3.40 kg/m$^2$) completed all body composition assessment techniques on the same day. Tests preformed included: DXA, Bod Pod, and 3D body scanning. Subjects did not eat or drink 2 hr previous to testing and did not exercise 4 hr previous to testing. Data was analyzed using SPSS version 17.0. Bland-Altmand plots, Pearson correlations, and a one-way ANOVA comparing means were performed. A prediction equation (3D MU) was created using a stepwise regression based on correlation to DXA.

**RESULTS:** Mean comparison of body composition techniques were as follows: DXA BF 16.30 ± 4.67; Bod Pod 12.17± 7.19; DoD 13.53 ± 6.43; 3D MU 16.49 ± 4.16. 3D MU had a SEE=3.09 over the entire sample compared to DoD SEE=3.67 and Bod Pod SEE=2.45. Although body volumes of Bod Pod and 3D Scanner were highly correlated (r = 0.984; p =0.001), the 3D Scanner underestimated body volume. Improvement in making consistent estimations of head, hand, and feet are necessary for the 3D body scanner to be used for body composition assessment.

**CONCLUSION:** Although the 3D body scanner shows promise as a method of evaluating BF, more work is needed before it can be considered an acceptable laboratory method of assessment. A 3D MU prediction equation was created that appears to be more accurate for young men than the current DoD equation. 3D body scanning shows potential as a method for determining body composition in overweight subjects.

**INTRODUCTION**

Body composition is the specific amount of adipose tissue, muscle tissue, and bone present in the body. Although not technically correct, most often the term is used to represent only the amount adipose tissue or percentage of body fat (BF) present. High amounts of adipose tissue or BF have been shown to be detrimental to one's health and increased disease risk (1, 58-59, 78-79, 88). Obesity, which is defined as having excess BF (69), is a leading cause of hypertension, hyperlipidimia, and type II diabetes (6, 18, 59, 82, 96). These conditions are two to three times more prevalent in obese individuals according to the National Institutes for Health (37). Understanding and accurately measuring BF is a valuable resource for fitness and health professionals. Accurate BF assessment is needed in order to assess health risk, monitor change in BF with certain diseases, to formulate dietary recommendations and exercise prescription, to estimate ideal body weight of clients and athletes, and to monitor growth, development, maturation, and age related changes in body composition (39).

The basic theoretical model of body composition is the two compartment model (2C). The 2C model divides the body into two categories: fat mass (FM) and fat-free mass (FFM). FM consists of all extractable lipids from adipose and other tissues, while FFM includes all residual chemicals and tissues ( i.e., water, muscle, bone, connective tissue, and internal organs) (56). This theoretical two compartment model is the most basic model of body composition and has been the foundation for estimating BF. The 2C model is the basis for popular assessment techniques such as hydrostatic weighing (HW) (26), air displacement plysmography (Bod Pod), (8, 21) and skinfolds (27, 56).

Multicompartment models (3C, 4C, 5C) add additional accuracy by measuring one or more constituents of the FFM. For example, Dual Energy X-Ray Absorptiometry (DXA) measures bone density making it a 3C model of body composition. Unfortunately, the cost and difficulty of using multicompartmental models, especially 4C and 5C, limit their use in most settings.

Choosing the most accurate method of BF assessment most often depends on accessibility to equipment. Although, laboratory methods (DXA, HW, and Bod Pod) are considered to be the most accurate assessments, unfortunately most practitioners do not have access to these techniques (24, 76, 85, 95, 97). Field methods, which are accessible to most professionals, include Body Mass Index (BMI), skinfolds (SKF), anthropometric measurements, and bioelectrical impedance (BIA) (7-9, 40, 72). Most practitioners are forced to use field methods due to their availability and cost. Therefore it is critical that researchers continue to improve the accuracy of these methods.

**Field Methods**

**Body Mass Index**. Weight-for-height ratios, such as BMI, are often used in clinical and epidemiological studies as substitute measures of BF. Although a crude measure, BMI is fast, easy, cost effective and requires little technician skill. The American College of Sports Medicine (ACSM) defines a BMI of greater than or equal to 30 kg/m$^2$ as obese and a BMI between 25 and 29.9 kg/m$^2$ as overweight (69). While this is the simplest and easiest field method of assessing ones risk it does not take in account muscle mass which makes it a less effective method of assessing risk. Thus, better methods are needed in order to accurately assess risk based upon BF.

**Skinfolds.** SKF are among the most popular field method of assessing BF (27, 43-45). SKF measure subcutaneous adipose tissue deposits in various site specific areas. SKF predict BF by using regression equations based on the subcutaneous fat folds, age, and gender. Since SKF testing is easy to administer and low in cost, it is ideal for large-scale epidemiological studies (49). There are several sources of measurement error which include technician's skill, type of SKF caliper, subject factors (hydration status, previous exercise, pliability of subcutaneous fat) and the prediction equation used. Variability among technicians is also a major source of error. Approximately 3% to 9% of the variability in SKF measurements can be attributed to the difference between technicians (57, 73). Nevertheless, SKF are a practical way to measure BF in the field. Compared to Laboratory methods, SKF can predict BF with a total error of approximately 2-3% (8-9, 34) and are considered an acceptable means to measure and track BF in the field (9, 34, 47).

**Bioelectrical impedance.** A popular alternative field method to SKF is BIA. BIA is a simple and fast method of establishing the amount of FFM a person possesses (60, 84). The device commonly uses electrodes that attach at the wrist and ankle. A small electrical current is sent between electrodes and the resistance to flow or impedance is measured. BIA uses the principle that lean tissue has a greater electrolyte and water content than fat. As a result, water has less impedance than fat (15). Tissues that contain high amounts of water and electrolytes such as cerebrospinal fluid, blood, or muscle are highly conductive whereas fat, bone, and air-filled spaces such as lung are highly resistant (2). Precision in using BIA can be obtained as long as standardized procedures are followed. Most importantly hydration status must be normal. In healthy

subjects, the majority of factors that affect hydration status are controllable, such as recent exercise, liquid intake, and stage of menstrual cycle (11). Variations in ambient temperature can also affect BIA and therefore should be considered if BIA is selected as the field method of choice (11, 19). Body positioning can also alter results since gravitational effects can cause fluid redistribution. Subjects should lay supine and on a nonconductive surface (36). Time spent in the supine position must also be standardized. Compared to laboratory methods BIA can predict BF with a total error of approximately 4-10% (28, 38, 75, 81, 91), giving the device high variability.

Although not as accurate as laboratory methods, field methods are critically important to practitioners and serve an important role in body composition assessment. However, when accessible, laboratory methods should be chosen over field methods due to their increased accuracy and reliability. There are several popular laboratory methods currently available.

**Laboratory Methods**

**Hydrostatic weighing.** HW has often been considered the "gold standard" method of body composition assessment techniques (23). HW uses Archimedes's principle to determine total body volume and thus density by measuring the difference between a subject's weight in water and that in air (12). HW is considered to be the original and most acceptable 2C model. In lay terms, since fat is less dense than water, it floats while lean body tissue (muscle and bone) is denser than water, and thus sinks. While HW is an acceptable laboratory method, it has several methodological issues, including: subject position, determining residual volume, number of trials, comfort level

in water, and head placement (14, 26, 77, 90, 99-100).  Recently, HW has lost favor due to in part to its complicated procedure but mostly because more technologically advanced methods have been developed.

**Bod Pod.**  Air displacement plethysmography, commercially known as the Bod Pod, is a 2C model that determines body volume by measuring the amount of  air displaced by the body (7, 21, 31).   Body density (BD) and thus BF can be determined using the Siri equation (86).  The Bod Pod is widely used in laboratories due to its ease of use, speed, and portability.  The Bod Pod tends to accurately measure BF compared to other laboratory methods (8, 13, 61).  Bod Pod is not without drawbacks however. Subjects must wear minimal clothing which may be uncomfortable for some subjects (31).  A thoracic lung volume must also be assessed and some subjects have difficulty with the required breathing procedure. Nevertheless, the Bod Pod is a popular laboratory method that has replaced HW in many settings.

**Duel X-ray absorbtometry.**  DXA is a 3C model that measures bone mineral density, lean body mass, and fat mass.  DXA has been shown to be an effective, easy, and safe method of assessing body composition across populations (8).  Although DXA uses radiation the dosage is very low (<5 mrem) (9) and therefore many researchers refer to it as the new "practical gold standard" of body composition assessment (3, 4).   While there are many advantages of DXA (speed, accuracy, ease of use), it is limited in its use due to its high cost and accessibility.  Thus it is relegated to laboratory use and is not a practical method for mass testing.  Due to DXA's high cost some research facilities have turned to a different technology, air displacement plethysmography, to assess BF.  In fact, DXA

has replaced HW as the "gold standard" in body composition assessment (5, 50-51, 89, 98).

Although there are several acceptable Laboratory methods available (HW, DXA, Bod Pod), body composition researchers and practitioners alike are constantly searching for more accurate, unproblematic, and cost effective methods of determining BF. The assessment techniques discussed above will continue to be used by researchers and field professionals until a new method emerges that is accurate, quick, easy to perform and cost effective. One possible technique might be Three-dimensional (3D) body scanning.

**Three-dimensional body scanning**. The 3D body scanner was originally developed to be used in the apparel industry. Body scanners use light to illuminate an object, or in this case the human body, while a series of cameras capture reflected light resulting in a detailed digital 3D image. The scanner allows for linear, two- dimensional and three-dimensional measurements of the body's surface. The body measurements are very precise and are much more accurate than typical anthropometric measurements determined by tape measures, sliding calipers, and other devices (33). More importantly, since the scanner measures total body volume, BF should be able to be predicted by calculating body density. The scanner is thus a 2C model that might have promise as another method of BF assessment. The scanning procedure is very fast (5 seconds) and completely non-invasive which allows for mass testing.

No one has yet compared 3D scanner produced percent BF to DXA or any other laboratory method. Previous studies by the United States Department of Defense (DoD) have looked at using 3D body scanning as a novel, effective method of assessing body

composition (33). However, instead of using body volume to calculate density and thus fatness, they used circumferences to predict BF. Comparing BF of 37 white males attained from DXA and 3D body scanning, linear regression analysis from circumferences revealed moderate and statistical significance (p<0.05) and Pearson correlation coefficients with moderate standard errors ($R^2$=0.74, SEE= 3.3). Generally, using circumferences as a measure of BF is considered to be a crude measure with much variability (27, 41, 55). In fact, the study was not published. Currently, no one has compared 3D scanner produced percent BF from body volume to DXA or any other laboratory method.

In a pilot study, the current researchers found body volume from the 3D scanner to be highly correlated to that of Bod Pod body volume ($R^2 = 0.79$) in a group of 27 men. As previously stated, body volume can be converted to body density (Mass (kg)/ Volume (L)) and using the Siri equation (BF= (495 / Body Density) – 450) BF can be determined. More data needs to be collected in order to compare 3D scanner BF to a criterion measure such as DXA.

**Purpose.** The purpose of this study is to determine if 3D body scanning can be used as an accurate method of body composition assessment. Scanner BF will be compared to DXA BF. If a regression equation needs to created in order to better determine BF, the new regression equation will be compared with the DoD equation to determine which has a lower error. Additionally, 3D body scanning body volume will be compared with Bod Pod body volume to help determine where the error, if any, may exist. It is hypothesized that 3D body scanning will be as accurate as other 2C models

(Bod Pod) at predicting BF compared to DXA.  Also, the 3D body scanner will be evaluated on its ability to work with differences in normal versus overweight subjects as determined by BMI.

**METHODS**

**Subjects.**  97 male subjects were recruited for the study and 85 were used for final analysis.  Subjects were between the ages of 18-30 years old were recruited to participate in this study.  All participants were informed of the procedures and risks of the study prior to participation.  All subjects signed an informed consent form in accordance with the policies and procedures of the University of Missouri Human Subjects Institutional Review Board.

**Subject preparation.**  Subjects were instructed not to eat or consume water 2 hr previous to testing.  Subjects were asked to refrain from exercise 4 hr prior to testing. Subjects removed all jewelry and wore non-metallic or plastic clothing.  Subjects wore a swim cap and were measured in their underwear or small shorts for the Bod Pod. Subjects wore shorts only for anthropometric measurements.  In the 3D body scanner subjects wore grey boxer briefs.  For the remainder of the tests subjects wore shorts and a T-shirt.  All tests were completed on the same day within 2 hrs of each other.  Testing order for each subject will be as follows: height, body weight, DXA, Bod Pod, anthropometric measurements, hand volume, foot volume, and 3D body scanning.

**Anthropometric Measurements.** Anthropometric measurements were taken following American College of Sports Medicine guidelines (69).  Subject's body weight

was taken to the nearest 0.5 lb using (Toledo scale, Mettler-Toledo Inc., Columbus, OH, USA) and height were measured to the nearest 0.25 inch using (Seca 216, Seca gmbh & co. kg., Hamburg, Germany). Circumference of the waist (narrowest point between the umbilicus and rib cage) and hip (largest protrusion of the buttock) were taken to the nearest 0.5cm using a Medco Tape Measure (Medco Sports Medicine, Tonawanda, NY, USA). Body mass index (BMI; $kg/m^2$) and waist to hip ratio (WHR) was calculated as descriptive data.

**DXA.** Body composition was assessed with DXA (QDR 4500A, Hologic, Inc., Bedford, MA, USA) using fan beam technology. The subjects wore minimal clothing and removed all metal objects before being scanned. Subjects laid supine on the DXA table and were manually positioned by the researcher to manufacture specification. Subjects were scanned once. Body composition was estimated using computer software (QDR Software for windows XP, Version 12.4, Hologic, Inc., Bedford, MA). Bone mass, fat mass, and lean tissue mass were represented in grams. BF was calculated by software that represented fat mass (g)/ total mass (g) x 100.

**Three-Dimensional body scanner.** Body scans were collected on all subjects using Textile/Clothing Technology Corp. ([TC]²), 3D body scanner (Cary, NC, USA). Subjects were instructed to remove all clothing and jewelry. Subjects wore only gray knit cotton undershorts while in the scanner. A 3D body image was created using [TC]² body imaging software. Subjects were required to remain in the 3D body scanner until a good body image was output by the software. From the body image a bulk body volume was obtained. Bulk volume removes hands, head, and feet from the total volume. In

addition to comparing BF from the scanner to BF via DXA, the [TC]² fitness

equation(33), created by the DoD, was compared to BF by DXA.  All scans were

conducted by the same trained technician.

**Head, hand and foot volume.**  Since the 3D body scanner cannot effectively

measure head, hands, or foot volume, these measures were obtained independently in

order to accurately determine if they are needed in assessing total body volume.

Hand volume was measured by water displacement using a volumeter. Subject's

wrists were marked at the wrist (articulatio radiocarpea) joint. Subjects were instructed to

slowly lower their wrists into the water, as to avoid splashing.  Subjects held their arm

steady; water overflow was monitored until the overflow was slowed by more than 2 sec

between overflow water drops.  Displaced water was then measured to the nearest 5 ml

using a graduated cylinder.

Foot volume was measured using water displacement using a volumeter.

Subject's feet were slowly lowered into water with the researcher's assistance until the

water reached the ankle (talofibrial) joint at the mid-point of the lateral malleolus and

held their leg steady until water overflow was slowed by more than 2 sec between drops.

The amount of displaced water was then measured in order to obtain an accurate volume

of the object place in the water (12, 42, 86).

Head volume was estimated using anthropometric measurements of head length

and head circumference.  The two measures was placed into a regression equation

developed by McConville et al (66).  The accuracy of the equation is acceptable (R =

0.798; SEE 4.2%).

**Bod Pod.**  Body Composition was assessed using the Bod Pod (Life

Measurements, Inc., Concord, CA, USA) in order to compare the BF from Bod Pod to

that of the 3D body scanner.  The Bod Pod is a dual chambered air-displacement

plethysmograph that employs the densitometric approach to assess body composition.

Subject mass was measured using an electronic scale, attached to the Bod Pod, which was

calibrated to within $\pm$ 0.05%.  Subject body volume was measured in an enclosed

chamber using the relationship between pressure and volume.  Chamber air volume was

determined both with and without a subject in the test chamber, with the difference

between the two measures yielding the subject's body volume.  Body volume was

measured at least twice and possibly three times if the first two measurements were not

within 150ml or 0.3%.  If no two measures met the acceptance criteria for a subject, the

entire test procedure was repeated.  Body volume was corrected for thoracic gas volume

in the lungs via a prediction equation (67). BF was derived by using the two-

compartment Siri equation (61, 67, 86).  All calculations were performed by the Bod

Pod's software (version 1.91).

**Statistical Analysis.**  SPSS version 17.0 was used for statistical analysis.  Pearson

correlation and coefficient of determination, $R^2$, were assessed in order to determine the

reliability of the measures. Standard estimation of error (SEE) was used in order to assess

the quality of the regression equation created.  DXA was used as the criterion measure of

body composition assessment to which scanner and Bod Pod BF was compared.

**Reliability.**  For the DXA, 3D body scanner, and Bod Pod each test was

performed twice on 10 subjects on the same day in order to assess reliability. .

**RESULTS**

Ninety-seven male subjects were recruited for the study and 85 were used for final analysis. Table 1 shows subject characteristics with outliers removed. Outliers were determined to be ± 3 standard deviations from the mean using 3D body scanner BF (3D SCAN) as the method of evaluation. Percent BF via DXA, Bod Pod, 3D SCAN, and the scanner's current prediction equation developed by the Department of Defense (DoD) are compared in Table 2. 3D SCAN and Bod Pod BF were computed using the Siri equation (16, 86). A new prediction equation using 3D body scanning was also computed using a DXA correction factor equation labeled 3D MU (Table 2).

Table 1. Subject characteristics.

|  | Mean ± SD | Range |
|---|---|---|
| *n* | 85 | |
| **age (y)** | 21.7 ± 2.3 | 18-30 |
| **Height (M)** | 1.7 ± 0.7 | 1.41-1.96 |
| **Weight (kg)** | 81.0 ± 12.2 | 56.1 - 127.1 |
| **BMI (kg/M$^2$)** | 25.37 ± 3.40 | 19.38 - 40.77 |
| **Waist Circumfrence (cm)** | 82.2 ± 8.7 | 63.1 - 122.3 |
| **Hip Circumfrence (cm)** | 97.9 ± 6.6 | 84.3 - 120.8 |
| **WHR** | 0.84 ± 0.06 | 0.60 - 1.01 |

BMI = body mass index
WHR = waist-to-hip ratio

Table 2. Body composition comparisons.

|  | Mean ± SD | Range | Mean diff. from DXA |
|---|---|---|---|
| **n** | 85 | | |
| **DXA BF** | 16.30 ± 4.67 | 8.20 - 32.80 | |
| **Bod Pod BF** | 12.17 ± 7.19 | 1.23 - 37.68 | -4.13 |
| **3D SCAN BF †** | 9.60 ± 12.22 | -15.11 - 53.89 | -6.70 |
| **DoD BF\*** | 13.53 ± 6.43 | 5.35 - 54.45 | -2.77 |
| **3D MU BF** | 16.49 ± 4.16 | 11.03 - 31.73 | 0.19 |

*Based upon the Department of Defense equation used by the [TC$^2$] Software (23)

† 3D Body Scanner BF using Siri equation

## Inter-method body composition comparisons

Body composition correlations using DXA as the criterion are shown in Table 3. Figures 1, 2, 4, and 5 represent the correlation of DXA BF with 3D SCAN, 3D MU, Bod Pod, and DoD respectively. Figure 3 represents correlation for 3D MU BF to Bod Pod BF.

Table 3. Correlations of body composition methods to DXA.

|  | Pearson Correlation |
|---|---|
| **Bod Pod BF** | 0.856 ** |
| **3D SCAN** | 0.237 * |
| **DoD** | 0.629 ** |
| **3D MU** | 0.759 ** |

** Denotes significance at 0.01 level

* Denotes significance at 0.05 level

Figure 1. Correlation of 3D SCAN to DXA.



Adj. $R^2 = 0.045$
SEE = 4.59
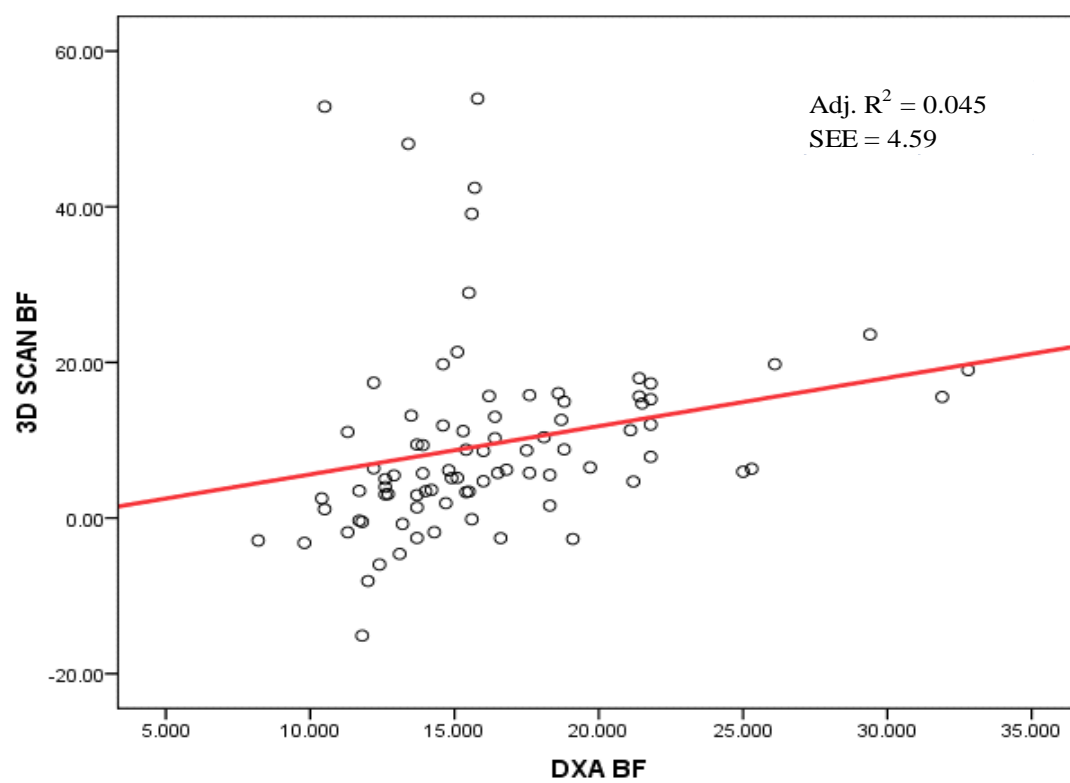
Figure 2.  Correlation of 3D MU to DXA.
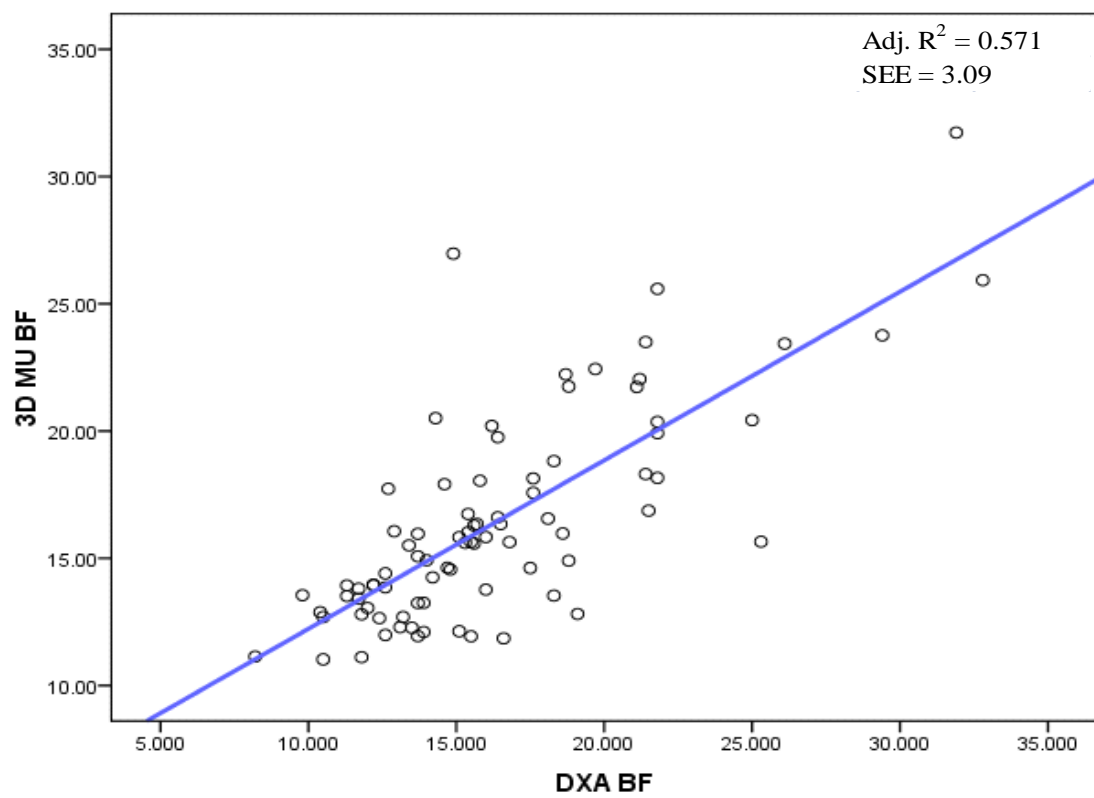
Figure 3. Correlation of 3D MU to Bod Pod.



Adj $R^2$ = 0.515
SEE = 2.89
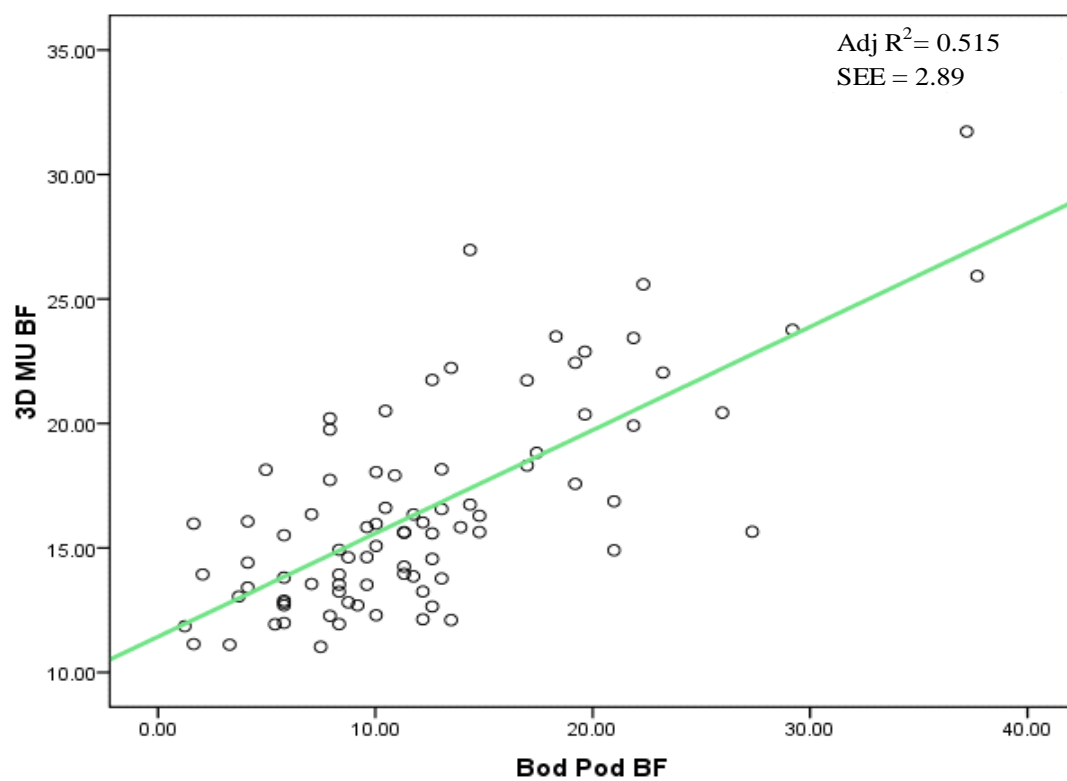
Figure 4. Correlation of Bod Pod to DXA.



Adj. $R^2 = 0.729$
SEE = 2.45
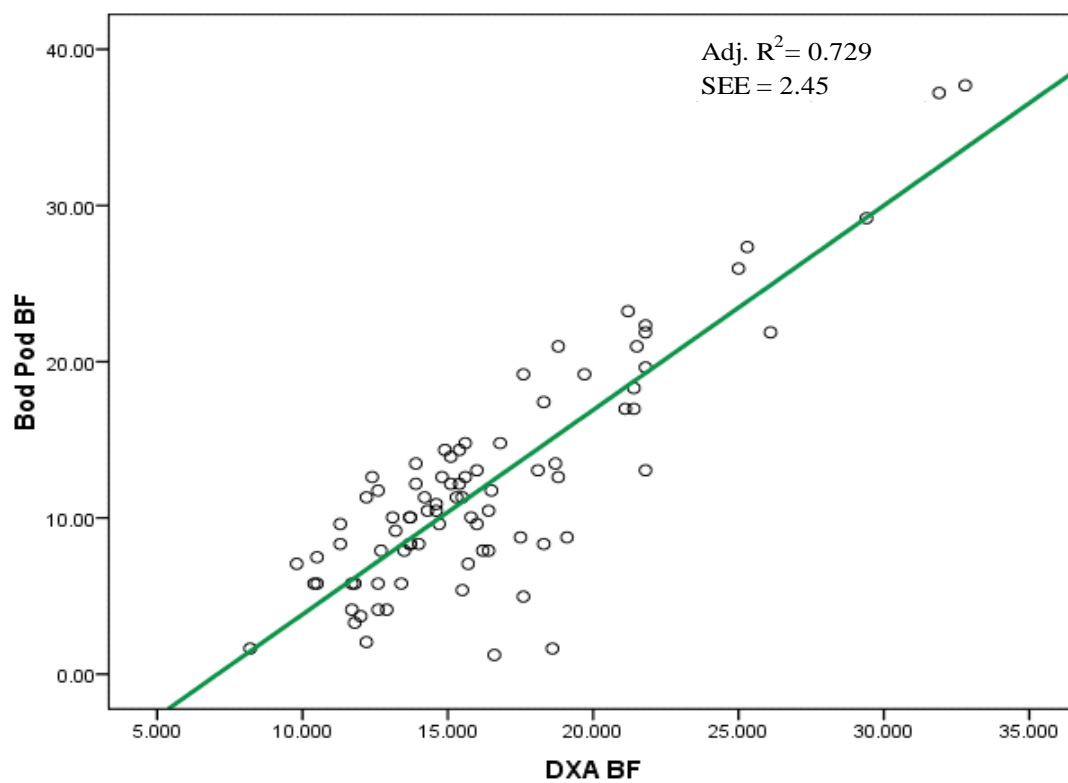
Figure 5. Correlation of DoD to DXA.



Scatter plot with x-axis labeled "DXA BF" ranging from 5.000 to 35.000 and y-axis labeled "DoD BF" ranging from 0.00 to 60.00. Annotations on the plot: Adj. $R^2 = 0.388$ and SEE $= 3.67$.
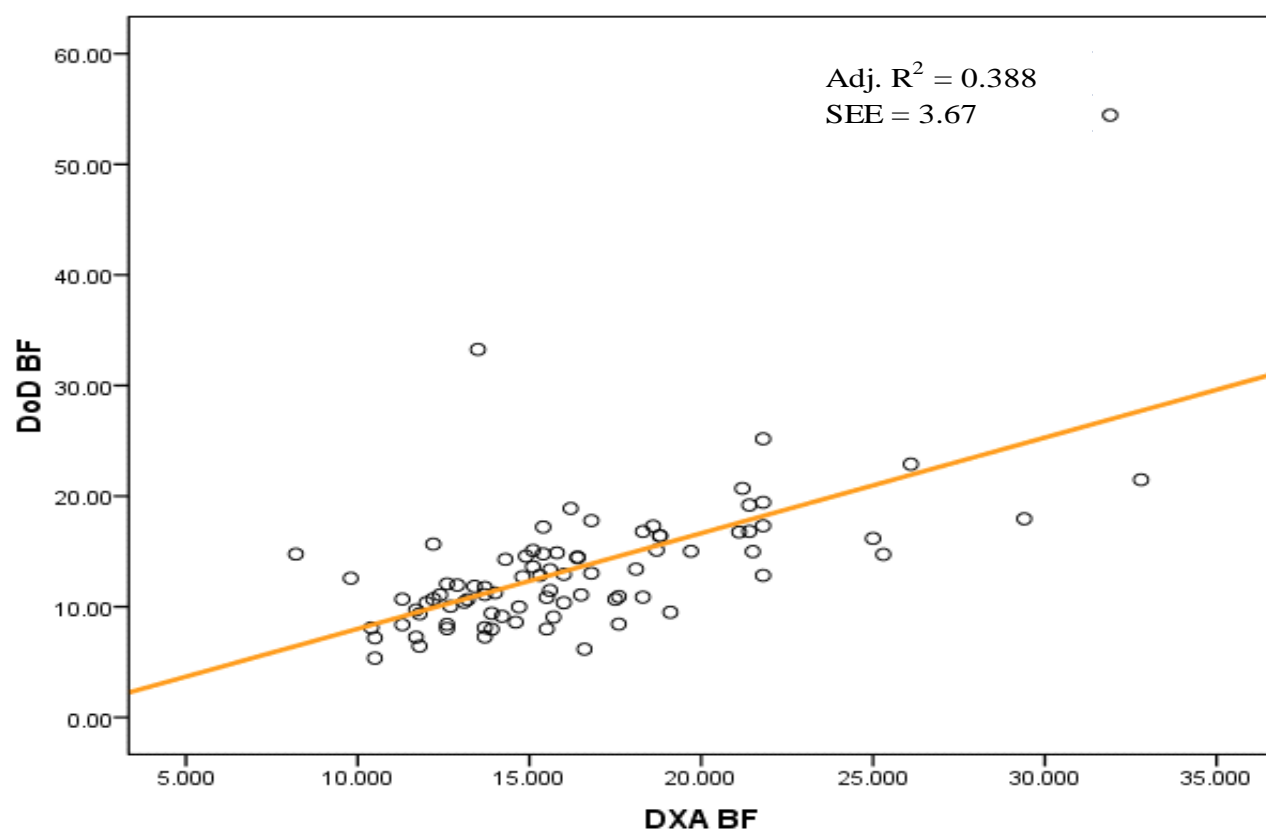
**Body volume comparisons**

      Table 4 represents the comparisons of body volume taken via the Bod Pod versus

that of the 3D SCAN.  The Bod Pod measures volume in liters (L), while the 3D body

scanner measures volume in cubic feet (ft$^3$ ) which was converted to L for comparison.

Figure 6 graphically compares the Bod Pod and 3D SCAN volumes.

Table 4.  Body volume comparisons.

|  | Mean + SD | Pearson Correlation |
| --- | --- | --- |
| **Bod Pod volume (L)** | 75.18 ± 11.65 | |
| **3D SCAN volume (L)** | 74.85 ± 11.14 | 0.984** |

\** Denotes significance at 0.01 level

Figure 6. Comparison of 3D SCAN volume to Bod Pod volume.



Adj. $R^2$ = 0.969
SEE = 2.06
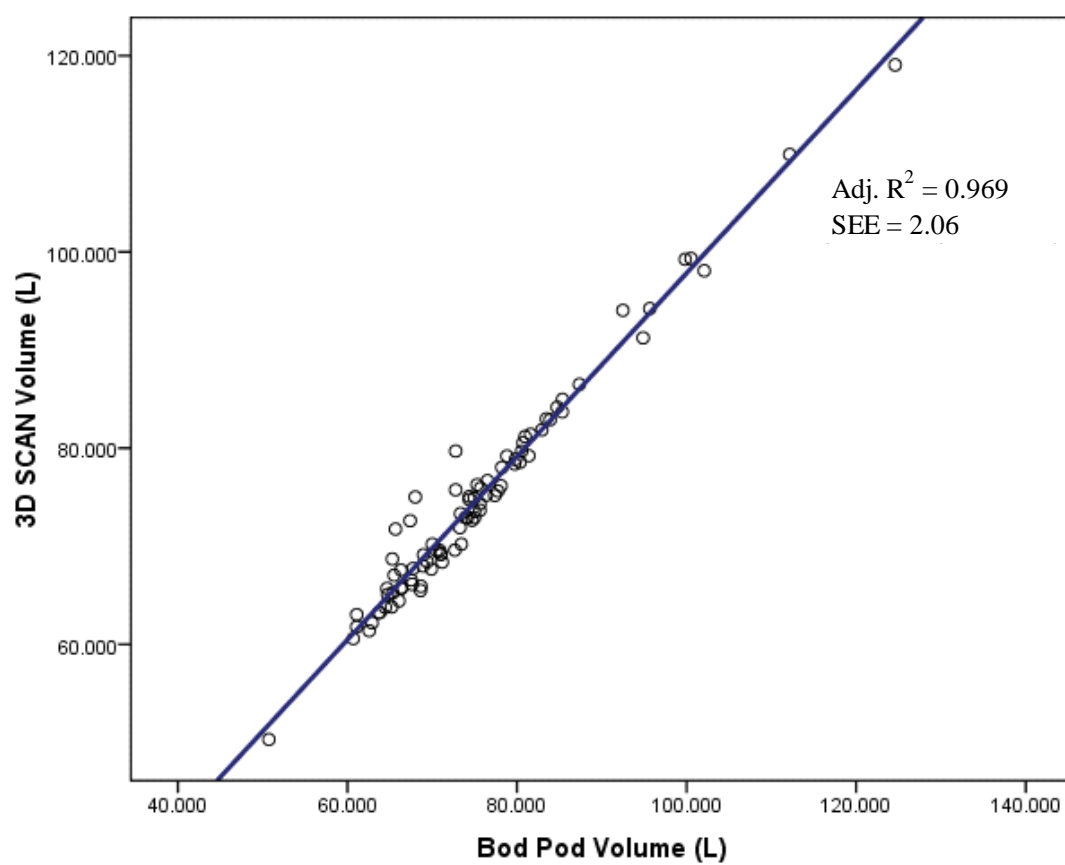
**Development of the 3D MU correction equation**

Table 5 shows the 3D MU correction equation created from a random samples of 60 subjects and then cross validated on the remaining 25 subjects. Predictors in the correction equation were determined via stepwise regression based upon the correlation to DXA. Abdominal circumference determined by the scanner combined with 3D SCAN explained the most variance with the least amount of error.

Table 5. Correction equation using randomly assigned groups of 60, cross validated by 25.

| **Group 1 ($n$ = 60)** | |
| --- | --- |
| DXA BF | 16.41 ± 4.93 |
| **3D MU correction equation** | -20.361 + 1.018 (abSCAN) + 0.052 (3D SCAN) |
| **3D MU BF ($n$ = 60)** | 16.54 ± 4.26, $r^2$ adj = 0.695 SEE 2.77 |
| **Cross vadlidation ($n$ = 25)** | 16.39 ± 4.00, $r^2$ adj = 0.679 SEE 3.32 |

abSCAN = Abdominal measurment from 3D body scanner
3D SCAN = Siri equation estimated BF from 3D body scanner

Figure 7 is a Bland-Altman plot illustrating the underestimation of the 3D SCAN compared to DXA. Figure 8 is a Bland-Altman plot comparing DXA and the 3D MU BF.

Figure 7. Bland-Altman plot (Differences against mean of BF) for DXA versus 3D SCAN.
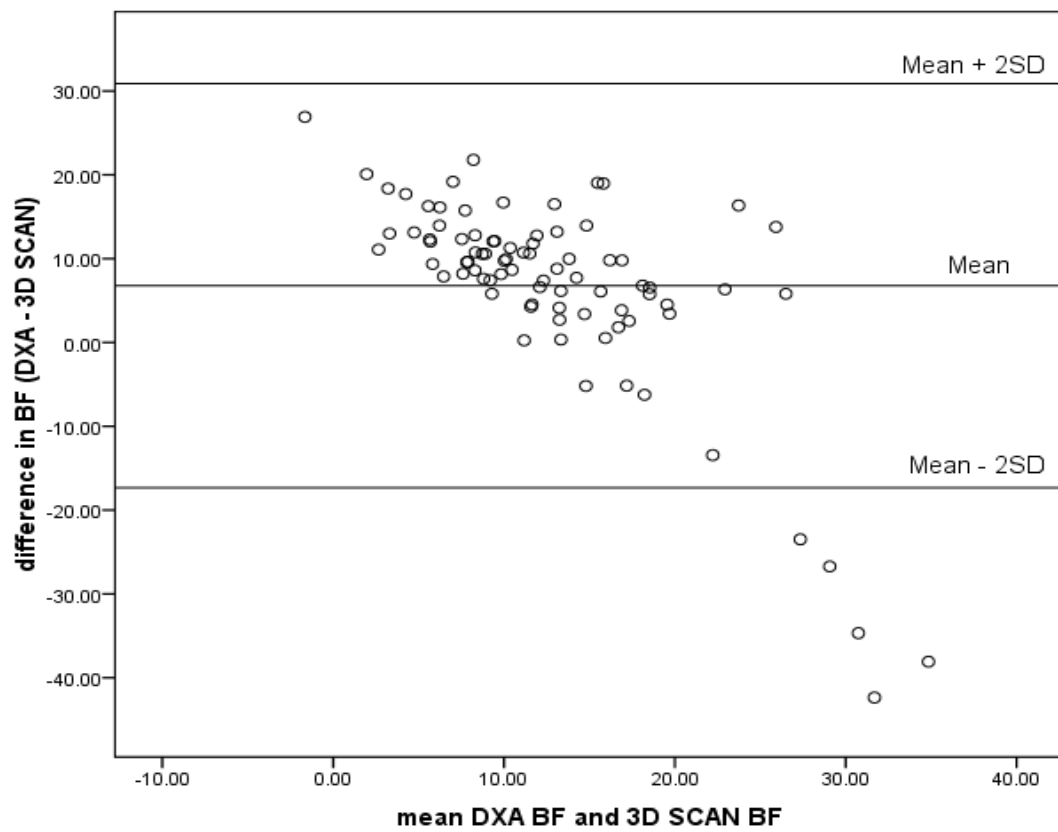
Figure 8. Bland-Altman plot (Differences against mean of BF) for DXA versus 3D MU.
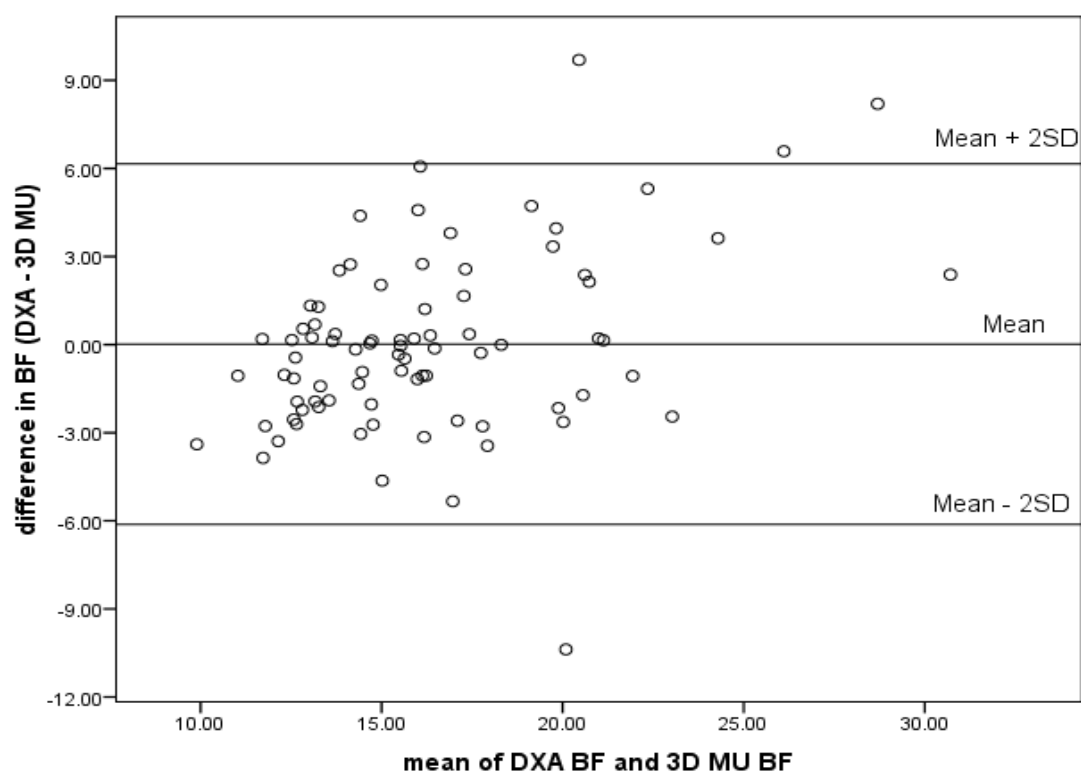
## Comparison of BMI Groupings

Table 6 shows a comparison of DXA BF, Bod Pod BF and 3D MU BF when the sample is divided into two groups based upon BMI norms. BMI ≤ 25 were considered to be normal and BMI ≥ 25.1 were considered overweight. Both groups were both significantly correlated (p = 0.01) to DXA.

Table 6. Body composition comparisons, normal versus overweight based upon BMI.

|  | Mean ± SD | Range | Pearson Correlation to DXA |
|---|---|---|---|
| **Normal (BMI ≤ 25)** *n* = 43 |  |  |  |
| **BMI** | 23.06 ± 1.58 | 19.38 - 24.99 |  |
| **DXA BF** | 13.96 ± 2.63 | 8.20 - 24.99 |  |
| **Bod Pod BF** | 8.58 ± 4.21 | 1.23 - 20.98 | 0.526** |
| **3D MU BF** | 14.16 ± 2.11 | 11.03 - 19.76 | 0.481** |
|  |  |  |  |
| **Overweight (BMI ≥ 25.1)** *n* = 42 |  |  |  |
| **BMI** | 27.90 ± 2.94 | 25.14 - 40.77 |  |
| **DXA BF** | 18.76 ± 5.21 | 9.80 - 32.80 |  |
| **Bod Pod BF** | 16.22 ± 7.63 | 5.38 - 37.68 | 0.924** |
| **3D MU BF** | 19.1 ± 3.85 | 11.93 - 31.73 | 0.707** |

** Denotes significance at 0.01 level

## Comparison of anthropometric measurements

Table 7 shows anthropometrics measures of the waist and hip compared to the 3D body scanner.

Table 7. Comparison of anthropmentric measures and 3D body scanner.

|  | Mean ± SD | SE | Range |
|---|---|---|---|
| **Waist anthropometric** | 82.32 ± 8.66 | 0.95 | 122.30 - 63.10 |
| **Waist Scan** | 86.77 ± 8.14 | 0.88 | 126.43 - 72.57 |
| **Hip anthropometric** | 97.94 ± 6.51 | 0.71 | 120.80 - 84.30 |
| **Hip Scan** | 103.02 ± 6.33 | 0.69 | 129.61 - 91.05 |

*All measurements are (cm)

## Reliability of measures

Table 8 shows the reliability of DXA, Bod Pod, and 3D SCAN on 10 subjects repeated twice.

**Table 8. DXA reliability, Bod Pod reliability, and 3D body scanner reliability**

**Reliability of body composition methods, $n$ = 10 repeated twice on same day**

| method | correlations | | Paired T-Test | | | |
|---|---|---|---|---|---|---|
| | r | P | mean diff. | SEM | t | P |
| DXA | 0.997 | <0.001 | 0.1000 | 0.0538 | 1.861 | 0.960 |
| Bod Pod | 0.993 | <0.001 | 0.1400 | 0.2342 | 0.598 | 0.565 |
| 3D body scanning | 0.922 | <0.001 | 0.0899 | 0.1101 | 0.817 | 0.435 |

**Accept null hypothesis for all (means are equal)**

## DISCUSSION

The 3D body scanner shows promise as a fast, accurate, comfortable, and non-invasive method of measuring body composition.  However, until now no study has investigated its accuracy compared to DXA.  It was hypothesized that 3D body scanning would be as accurate as other 2C models at predicting BF compared to DXA.  In its current form the 3D body scanner underestimates BF compared to DXA. However, the underestimation is consistent across BMI levels (Table 6) signaling the need for a new prediction equation to be created to account for the difference.  When the 3D MU correction equation was employed the 3D scanner appears to be as accurate as other 2C models (Bod Pod) at predicting BF. The 3D MU equation had a mean difference of 0.2% BF compared to DXA with a low SEE of 2.77 (Table 5). According to Lohman's (53) subjective rating scale, the 3D scanner would score as a "very good" to "excellent"

method of estimating BF.  Further, the 3D MU equation would meet Lohman's (13-14) standard acceptability criteria outlined for cross validating equations.

**Comparison of 2C models (Bod Pod and 3D Scanner) to DXA**

DXA was chosen as the criterion method in part because it has shown to be a very reproducible method (~1% BF) (46).  In this study, DXA was found to be reliable with a mean difference of 0.1% BF between trials.  ($n = 10$; $r = 0.997$; $p < 0.001$).  Many researchers also favor DXA over multicompent models because it is fast, easy, and can be used on wide variety of populations (5, 9-10, 50). DXA is currently called the "practical gold standard" of body composition assessment techniques and is widely used to compare other techniques against (5, 46-47, 84, 93).

In the current study both the Bod Pod and the 3D MU were significantly and similarly correlated to DXA (P=0.001). Previous studies comparing Bod Pod to DXA show that the Bod Pod is an acceptable laboratory method of body composition assessment (32).  Mean differences in BF measured by the Bod Pod and DXA have varied but are similar (-3.9 to 1.7 % BF) (20, 52, 70, 83, 93).   The current study shows a mean difference between Bod Pod and DXA to be  -4.13% which is similar and consistent to previous findings by  Fields and Goran (30).  The fact that the current data comparing Bod Pod and DXA is similar to other findings helps determine where differences in 3D scanner BF might exist and allows for a comparison between a current acceptable 2C model (Bod Pod) and a possible new method of assessment (3D body scanner).

The 3D body scanner corrected by 3D MU correction equation had a mean difference of 0.2% BF and was significantly correlated to DXA (p = 0.01). The 3D MU had a more similar mean and SD with less SE than Bod Pod compared to DXA. The 3D scanner has several advantages over the Bod Pod; speed (~3 times faster), less subject cooperation is necessary, and minimal technician training required. Also, the 3D scanner doesn't suffer from environmental changes. The Bod Pod is sensitive to changes in temperature, humidity, and pressure making it a finicky device (8, 31, 61). Nevertheless, the Bod Pod has been through much scientific rigor making it a popular and accepted laboratory measure of body composition assessment for many different populations. Despite the current positive results, scanning technology for measuring fatness is in its infancy. Many more investigations must take place before the 3D scanner might be regarded as accurate, reliable, and worthy as the Bod Pod.

**Comparison of BMI groupings.**

Accurately measuring obese individuals has been a weakness of most body composition methods. Interestingly, 3D MU was as good at predicting BF as compared to Bod Pod in both normal and overweight subjects as defined by BMI (p = 0.01) using DXA as the criterion (Table 6). In fact, it appears that the 3D body scanner may be more accurate at estimating BF in overweight subjects (Table X) If this proves to be true this could be an obvious advantage over other current technologies. The Bod Pod is a relatively small device with a height limit of ~ 6'6" and a weight limit of ~ 300lb. DXA has a weight limit of 275-350lb depending on the model. In addition, many larger subjects are too wide to fit on the DXA scanning area. Whereas, the 3D body scanner is a

much larger area and could potentially measure almost any person regardless of height, weight or width. This is an area where future research is should focus.

**DoD versus 3D MU.**

The 3D MU correction equation shows a significant improvement over that of the original [TC2] BF estimation equation created by the DoD (34). The DoD equation significantly underestimated BF compared to DXA (2.8%). The DoD equation also had a much wider range (5.4 - 54.5%) compared to DXA (8.2 - 32.8%). BF by the DoD is determined by circumference measurements, which not surprisingly, typically do not accurately predict body fatness (86). Obviously, circumferences are not the most accurate means of determining BF since it is impossible to determine how much muscle or fat is underneath the skin. Typically BF predicted by circumferences has a very high error (20). Studies comparing this method to HW showed a 6.8 to 18% false positive rate for individuals declared as having excess body fat (86). In addition, research suggests circumferences are even less accurate for individuals with very low or very high BF (11). Our population consisted of leaner individuals (16.3% BF) and thus might further explain why the DoD equation did not accurate predict BF in this sample. It appears the 3D MU equation is a better alternative to the currently employed equation. When compared to DXA over the entire sample the mean difference of the DoD was 2.77% with a SEE 3.67 compared to that of 0.2% with a SEE 3.09 using 3D MU equation.

**Limitation and sources of error.**

While there were 97 subjects that completed the study only 85 subjects were used for final statistical analysis or ~88% of total subjects.  Subjects removed from the data set

met two criterion: 1) they were ±3 SD from the mean of the 3D body scanner BF, and 2) they exhibited "influence" if not removed.  Influence was determined by using Cook's *D* which is frequently used to calculate the leverage that specific cases may exert on the predicted value of the regression line (74).  While there were 12 outliers using 3D SCAN as the criterion, if the criterion was switched to DXA there were zero ouliers and if switched to Bod Pod there were 2 outliers (both of which were also outliers with 3D SCAN).  The variability with the 3D body scanner is higher than with other methods and needs to be improved upon in order for 3D body scanning to be a valid method of assessment in the future.  Examining standard protocol for 3D body scanning to make it consistent for each subject could help with limiting false positive readings.  Limiting the number of anomalous readings is of critical importance and an area that must be addressed by the manufacturer in order for this tool to be considered laboratory quality. It should be noted that other technologies, Bod Pod in particular, were not perfect the first time they were applied to body composition assessment (24, 32).  In fact, Bod Pod underwent many technology and software advances in order to become a valid tool for body composition assessment.

One possible explanation for some of the strange results (outliers) is in the determination of body volume. Minor variations in volume will significantly alter density estimation and thus BF. Therefore it is critical that body volume is measured as accurately as possible with as little error as possible. While 3D body scanning body volume was highly correlated to Bod Pod body volume ($r = 0.98$; $p = 0.01$), with similar means (Table 4), there was a slight underestimation of volume. The underestimation of volume would explain the underestimate of BF by the 3D scanner compared to DXA.

Unfortunately, the 3D body scanner fails to give full volumes for the head, hands, and feet. Since scanning technology's main use is to custom fit clothing there is no reason for the device to precisely measure these body parts. In fact, only part of the head, hands, and feet are shown in the scanner output (shown in pictures below).
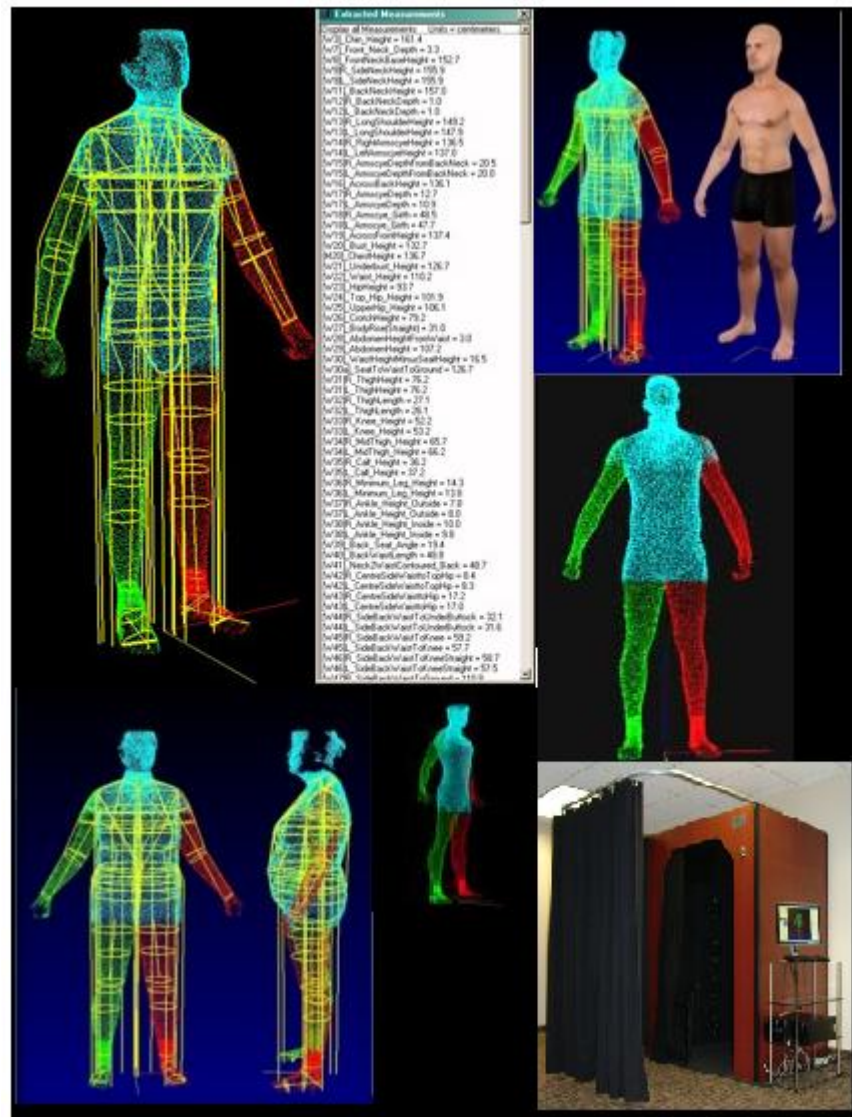
Although the scanner attempts to determine a volume for these segments, it appears to a major limitation in determining total body volume. Volumes of the head, hands, and feet were measured manually (Appendix D) and an attempt was made to add the combination of these volumes to total body volume via the scanner. However, the addition of these volumes increased total body volume to a very high value since the scanner is already partially measuring these body parts. Accurate determination of head, hands, and feet volume is an area that, if improved, might vault the 3D Scanner to the forefront of laboratory body composition assessment techniques. Without an improvement in this area, it is unlikely that the 3D scanner will replace currently employed methods.

One finally source of error in determining body volume is the amount of hair on the head. The body scanner can only measure non-hair covered portions of the head. Individuals with significant amounts of hair will likely have additional underestimation of body volume and thus body fat. Perhaps by wearing a swim cap this can be improved. We failed to account for this and recognize it as a limitation. Future researchers should consider this fact, especially if they work with populations that have considerable head hair.

Although questions about scanner body volume exist, the scanner appears to very reliable. The 3D body scanner reliability testing ($n = 10$; r = 0.922 ;p <0.001), was consistent and similar to DXA and Bod Pod reliability data (8). Reliability is key factor for a technique to reach laboratory status. The fact that the 3D scanner is consistent is important and noteworthy. [TC]<sup>2</sup>'s 3D Body Measurement System uses a white light-

based scanner and proprietary measurement extraction software. The scanner captures

hundreds of thousands of data points of an individual's image and the software

automatically extracts dozens of measurements (48). These measurements include

circumferences and lengths of certain specified regions that can be combined in order to

asses a bulk body volume of the subject. This volume can then be used for the purpose of

body composition assessment. The scanner technology appears to be as reliable as other

laboratory body composition assessment techniques.

The underestimation of BF via the scanner compared to DXA illustrates the need

for a DXA based correction equation. A closer look at Figure 6 shows the

underestimation to be fairly consistent across the population. If the underestimation was

not consistent then the creation of a new prediction equation or correction factor would

have been futile. The 3D MU equation was created in order to correct for this

underestimation and when applied, (Figure 5) the difference between DXA and 3D MU is

almost non-existent (0.2%). A valid prediction equation will not only have similar

means, it will have a high $R^2$ and a low SEE ($< 3.5\%$) when compared to the criterion

(41). Particularly, the equation must have a low SEE. SEE is a measure of prediction

error. The SEE is interpreted in the same way as the standard deviation. Thus, the larger

the spread of scores the larger the deviation or the larger the error. A low SEE will yield a

more accurate predication equation with less variability. Determining the validity of these

measures and assessing the accuracy of a new predication equation versus a criterion is

essential for evaluating new methods of assessment. Lohman has outlined the ability to

accept new equations on the basis of SEE and criterion for new prediction equations (53).

The 3D MU has a SEE of 2.7% and thus meets Lohman's criteria for a prediction equation.

**CONCLUSION**

The current study is the first to investigate the use of 3D body scanning technology for body composition assessment. Although the 3D body scanner shows promise as a method of evaluating BF, more work is needed before it can be considered an acceptable laboratory method of assessment. A 3D MU prediction equation was created that appears to be more accurate for young men than the current DoD equation. However, the 3D MU equation needs additional investigation and validation. Scanning technology must more accurately measure head, hands, and feet before it will be as accurate as other laboratory methods. Future research should focus on different populations and in determining possibly sources of error.

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APPENDIX A:

EXTEND LITERATURE REVIEW

**EXTENDED LITERATURE REVIEW**

**DEVELOPING A NEW METHOD OF BODY COMPOSITION ASSESSMENT
USING PRINCIPLES OF DESITOMETRY**

**DENSITOMETRY**

The term densitometry generally refers to the process of estimating body

composition from body density. The density of the human body ($D_b$) is equivalent to a

ratio of its mass (m) and volume (V). Cadaver studies have shown lean tissue to be

approximately 1.100 g/ml while fat tissue is ~0.090 g/ml (62). Body mass is estimated

from body weight, which is relatively easy to measure (55). Thus, in order to accurately

measure body density and accurate volume must be obtained. Once both mass and

volume are known equation A can be used (80):

$$\mathbf{D_b = m/\ V.} \tag{A}$$

The density of any material is a function of the proportions and densities of its

components. In the classic two-component (2C) model of body composition, body

weight is divided into fat (F) and fat-free mass (FFM). Thus, the density can be found

using equation B (80):

$$\mathbf{1/\ D_b = F/\ D_F\ + FFM/\ D_{FFM}} \tag{B}$$

The fat-free mass is a heterogeneous compartment that can be further separated

into water (W), protein (P), and mineral (M) (16). Thus, when combined with F a four-

compartment model of body composition can be derived in equation C (16, 80):

$$\mathbf{1/\ D_b = F/\ D_F + W/\ D_W + P/\ D_P + M/\ D_M} \tag{C}$$

The assumptions of $D_F$, P, W, and M are based upon limited data studies using

animal and human cadavers by dissection and chemical analysis.

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**Assumptions.** There are a several assumptions that are used when determining body fat from body density. These assumptions can be used in order to increase or decrease the validity of the tests used in order to determine body density. The assumptions are as follows (16, 54, 56, 86):

1. Separate densities of compartments are additive. Meaning that in a 2C model that body fat plus lean tissue will equal total weight.

2. The densities of the compartments of the body are relatively constant from person to person.

3. The proportions of the constituents other than fat are relatively constant.

4. The person being measured differs from a standard reference body only in amount of body fat or adipose tissue.

It is of note that in the 2C model the density of fat is assumed to be constant at 0.90 g/ml and has been shown to be relatively constant even with site variation (29, 54). While this does hold true, the assumption that 0.90 g/ml for the average density of all body fat would have a relatively small error in the density formula with a possible exception to very lean subjects (54). The two components of FFM, muscle and bone, have densities of 1.066 g/ml and 3.317 g/ml respectively (71).

Differences in FFM are more critical to the assumptions made, variations have been found in several populations which allow for decreased validity of body fat estimation. These populations include and are not limited to (17, 22, 25, 54): Specialized trained groups, elderly, advanced maturation youth, gender, and racial differences. Also, there is an inherent biological variability of FFM, assuming each source of variation is independent of each other, the total error using the law of propagation of errors is

estimated to be 3.9% or -0.0084 g/ml in $D_{FFM}$ in a general population and -0.0060 g/ml or 2.8% in a specific population (86-87).

**Body Density Equations.** Studies using healthy adults have been conducted in order to create equations which can convert density to %BF. These equations can be used by any model which can provide body density. The Brozek equation [%BF = {(4.57/Db)-4.141}x100] and the Siri equation [%BF = {(4.950/Db)-4.50}x100] are the most commonly used conversion equations (16, 86). While the two equations give similar results in healthy subjects they vary in specific populations. The Brozek equation was based upon chemical composition of cadaver analysis and was intended to be used in young, healthy, non-athletic populations (15). The Siri equation was intended to be used in healthy adults and has been found to be more variable in subjects who were young, very lean, very obese, and those with high musculoskeletal development (71, 101). Thus, when applying the two equations the specific population which is used should be of note and accounted for.

**Hydrodensitometry.** Hydrodensitometry can be separated into two approaches of determining body volume: water displacement or underwater weighting. Water displacement involves a person being directly immersed in water then measuring the amount of water displaced in a volumeter by the addition of the body (4). The amount of water displaced is equal to the volume of the subject. An alternative to this method is underwater weighing, commonly referred to as hydrostatic weighing (HW). HW has often been considered the "gold standard" method of body composition assessment techniques (23). HW uses Archimedes's principle to determine total body volume and thus density by measuring the difference between a subject's weight in water and that in

air (12).  A study conducted by Ward et al. showed good re-test reliability in the two methods (r = 0.96 for water displacement and r = 0.99 for HW) and good agreement between method (r = 0.96) with the mean difference in %BF between methods being 0.7% (94).  HW is considered to be the original and most acceptable 2C. In lay terms, since fat is less dense than water, it floats, while lean body tissue (muscle and bone) is denser than water, and thus sinks.

While HW is an acceptable laboratory method, it has several methodological issues, including: subject position, determining residual volume, number of trials, comfort level in water, and head placement (14, 26, 77, 90, 99-100). While density can be estimated with acceptable precision and accuracy in most populations, the assumption of an invariant fat-free composition, commonly used to convert density to composition, may not be valid for some individuals.  The total theoretical error of HW is estimated to be 0.0062 g/ml or ~2% body fat (56).  This error combines the error of FFM (as previously discussed) and the technical error using HW.  It should be noted that this is representative of a specific population and would have higher error in a general population.

**Accuracy of Hydrostatic Weighing.**  Sources of variation in body density are due to three biological sources: fat, water and/or mineral content.  Due to variations in the water and mineral content of FFM the interpretation can lead to errors of 2-4% depending on the population (53).  There are several sources of variation in body density measurement.  Variation in residual lung volume is considered to be the largest (3).  The combined error from residual volume is estimated to be 0.00139 g/ml (99-100). Variations due to bodyweight, underwater weighing and the measurement of water temperature at the time of measurements are much smaller than residual volume and have

a combined error of 0.0006g/ml (100).  Variations in body density of the combined is

about 0.0015-0.0020 g/ml and is considered to be the characteristic trail-to-trail variation

within a given day using most hydrostatic weighing systems.  Within-subjects standard

deviation larger than 0.0020 g/ml reflect larger measurement errors in one or more of the

components of body density and indicate a need to improve the measurement precision

(53).

     **Bod Pod.**  Air displacement plethysmograph uses the relationship between

pressure and volume to derive body volume.  In this method body volume is equal to the

volume of air remaining in the chamber after the subject has been placed into it.

Although  the respiration movement, gas and water vapor exchange, and heat generated

by the body in a closed space can make a significant impact on the accuracy of the

measurement (23).

     The Bod Pod appears to have overcome some of these challenges in order to make

an accurate measurement of body volume.  The Bod Pod is a 2C model that determines

body volume by measuring the amount of air displaced by the body (7, 21, 31).  Body

density can then  be determined when weight is taken and thus BF can be determined

using the Siri equation (86). The Bod Pod is widely used in laboratories due to its ease of

use, speed, and portability.  The Bod Pod tends to accurately measure BF compared to

other laboratory methods (8, 13, 61).  Dempster and Aitkens have described the

procedure and principles in more detail (23).  Briefly, the Bod Pod consists of a single

fiberglass structure with two internal chambers separated by an oscillating diaphragm

which allows for small volume changes in the two chambers.  The volume changes are

exactly equal in magnitude but opposite in sign, these shifts result in complementary

pressure fluctuation in the two chambers. The relationship between pressure and volume is calculated using Poisson's Law:

**Poisson's Law:** $P1/P2 = (V2/V1)^{\gamma}$

Where P1 and V1 represent one paired pressure and volume, P2 and V2 represent a second and $\gamma$ is the ration of the specific heat of the gas at a constant pressure to that at a constant volume (92). When this method is applied to inanimate objects the validity and reliability are excellent (r = 1.0, SEE 0.004 L) (23). When applied to humans and compared with HW on same-day tests the Bod Pod was slightly better than HW with average coefficients of variation of 1.7% for Bod Pod and 2.3% for HW (68). The mean difference between the two methods was only 0.3% (r = 0.96, SEE 1.81%). Mean differences between in BF measured by the BOD POD and DXA have varied. The differences in BF have ranged from the negative (range: -2.0% to -3.0%) in four studies (20, 52, 70, 83) and positive (1.7 %BF) in one of the studies (93) .

**Dual energy radiography**. Duel energy radiography is a method of assessing tissue densities and content of a body by using X-ray rather than gamma-ray radiation to measure whole body and regional compositions (35, 64-65). Under this category of technologies is duel energy X-ray absortometry (DXA) which allows for a 3C model that measures bone mineral density (BMD), lean body mass, and fat mass. DXA has been shown to be an effective, easy, and safe method of assessing body composition across populations (8). Although DXA uses radiation, the dosage is very low (<5 mrem) (9) and therefore many researchers refer to it as the new "practical gold standard" of body composition assessment (3, 4). DXA is precise over repeated measurements on subjects

in lean tissue and BMD.  Coefficients of variations from BMD have been reported to be

0.6% and 1.6% in soft tissues, such as fat and lean, which were similar to that of

established 2C models (45, 63).  DXA is not without assumptions and limitations,

variations in fat distribution, body thickness and fat content of bone marrow are sources

of biological variation (53).  Though these variations can be minimal and with better

technology and software these variation are minimal. Samples in postmenopausal women

have shown an error of 0.0026g/ml or 1.2%BF (45).  Recent studies have shown DXA to

be precise and reproducible in measuring BMD, lean tissue, and fat mass in children (51).

Also, the use of DXA has been expanded to be used in rodent models with excellent

precision, $R^2$=0.98, in measuring of FFM (89).

**Three-dimensional body scanning**.  The 3D body scanner was originally

developed to be used in the fashion industry for improved fitting of clothes. Body

scanners use light to illuminate an objects, or in this case the human body, while a series

of cameras capture reflected light resulting in a detailed digital 3D image.  The scanner

allows for linear, two- dimensional and three-dimensional measurements of the body's

surface.  The body measurements are very precise and are much more accurate than

typical anthropometric measurements determined by tape measures, sliding calipers, and

other devices (33).  More importantly, since the scanner measures total body volume, BF

can easily be predicted by calculating body density. The scanner is thus a 2C model that

might have promise as another method of BF assessment. The scanning procedure is very

fast (5 seconds) and completely non-invasive which allows for mass testing.

No one has yet compared 3D scanner produced body density to DXA or any

other laboratory method.  Previous studies by the United States Department of Defense

(DoD) have looked at using 3D body scanning as a novel, effective method of assessing body composition (33). However, instead of using body volume to calculate density and thus fatness, they used circumferences to predict BF.  This study was not published. Comparing BF of 37 white males attained from DXA and 3D body scanning, linear regression analysis from circumferences revealed moderate and statistical significance (p<0.05) and Pearson correlation coefficients with moderate standard errors ($R^2$=0.74, SEE= 3.3).  Generally, using circumferences as a measure of BF is considered to be a crude measure with much variability (27, 41, 55).

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APPENDIX B:

INFORMED CONSENT

# CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY

**INVESTIGATOR'S NAME:  JUSTIN RYDER, BA.**

**PROJECT # 1129817**

**DATE OF PROJECT APPROVAL:  FEBRUARY 25, 2009**

| FOR HS IRB USE ONLY |
| --- |
| **APPROVED** |
| |
| _____ |
| HS IRB Authorized Representative           Date |
| |
| **EXPIRATION DATE:**  _____ |

**STUDY TITLE:** THREE DIMENSIONAL BODY SCANNING AS A NEW TECHNIQUE FOR MEASURING BODY COMPOSITION.

## INTRODUCTION

**This consent may contain words that you do not understand.  Please ask the investigator or the study staff to explain any words or information that you do not clearly understand.**

This is a research study that includes only people who choose to participate.  As a study participant you have the right to know about the procedures that will be used in this research study so that you can make the decision whether or not to participate.  The information presented here is simply an effort to make you better informed so that you may give or withhold your consent to participate in this research study.

Please take your time to make your decision and discuss it with your family and friends.

You are being asked to take part in this study because you are a male between the ages of 18 and 55.

This study requires no funding and will be presented to the subjects free of charge.

In order to participate in this study, it will be necessary to give your written consent.

## WHY IS THIS STUDY BEING DONE?

The purpose of this study is to determine if the 3D body scanner is an effective method of measuring body composition in comparison with known techniques.

This study is a pilot study to be under taken in order to see what the applicability of the 3D body scanner is to body composition.  It is hypothesized that it can be used as a non-invasive tool for measuring body composition.

## HOW MANY PEOPLE WILL TAKE PART IN THE STUDY?

About 200 people will take part in this study at the University of Missouri-Columbia.

## WHAT IS INVOLVED IN THE STUDY?

If you choose to participate in this study, you will complete the following items: 1) one duel x-ray absorbtometry scan (DXA), 2) one Bod Pod evaluation, 3) one skinfold examination, 4) one bio-electrical impendence (BIA) assessment, 5) body pictures, and 6) one 3D body scan 7) Hand and foot volume assessment via water displacement.

If you take part in the study, you will have the following test and procedures:

1) You will have body weight, height, skinfolds, BMI, and waist-to-hip ratio measurements taken.
2) You will have a body composition test measured by the DXA.  This will require you laying flat on a bed as still as possible for about two minutes.  You will be wearing no shoes, no metal, t-shirt and gym shorts.  The DXA uses X-rays to determine your body composition and is considered the gold standard.

3) You will have a body composition test measure by the Bod Pod.  This will require you to sit inside an "egg-shaped" chamber for 5 minutes while breathing normally.  You will be wearing only a swimming suit and swim cap (which will be provided).
4) You will have your picture taken while in your swimming suit.  These pictures will be used to illustrate different body types and body fat percentages for publication.  If used your face will be blurred to protect your identity.
5) You will have skinfolds taken.  These measurements require a caliper device which pinches your skin and subcutaneous fat (fat just below your skin).  This can cause discomfort, redness and bruising.
6) You will have a bio-electrical impedance (BIA) test performed.  This sends an electrical current through your body but you will not feel it.
7) You will have a 3D body scan of your body while wearing non-tight underwear only.  The body scan is a non-invasive procedure which takes about ten seconds.
8) Hand and foot volume will be measured by water displacement using a volumeter. The volumeter will be used in order to ascertain proper foot volume in order to add accuracy to the body scanner measurements.  A persons hand/ foot can be placed in it and the amount of water spill over (displaced) will be measured in order to get an accurate foot volume.
9) You will be asked to sign this consent form before beginning the study.

## HOW LONG WILL I BE IN THE STUDY?

We think you will be in the study for 2 hours in one day.  The investigator and/or your doctor may decide to take you off this study if you become uncomfortable with the several tests you have to perform.

**You can stop participating at any time.  Your decision to withdraw from the study will not affect in any way your medical care and/or benefits.  If you decide to stop participating in the study, you are encouraged to discuss your decision with Mr. Justin Ryder.**

## WHAT ARE THE RISKS OF THE STUDY?

You will be exposed to small amounts of radiation during the DXA scan.  Radiation effects are cumulative.

Reproductive risks: The effects of the DXA scan on the male reproductive system are unknown and could cause harm.  If you have questions about the reproductive issues, please discuss them with your investigator or your doctor.

There is a risk of bruising during the skinfold test. Calipers are used to pinch the skin which can cause discomfort and in some cases bruising.  Some subjects may experience claustrophobia when using the Bod Pod test.

For the reasons stated above the investigator will observe you closely while giving the treatment described and, if you have any worrisome symptoms or symptoms that the investigator or his associates have described to you, notify the investigator immediately.  Mr. Justin Ryder's telephone number is 314-882-6838 or Dr. Steve Ball can be reached at 573-882-2334.  For more information about risks and side effects please e-mail Mr. Justin Ryder at jrrgy5@mizzou.edu or Dr. Steve Ball at ballsd@missouri.edu.

## ARE THERE BENEFITS TO TAKING PART IN THE STUDY?

If you agree to take part in this study, there may or may not be direct medical benefit to you. You may expect to benefit from taking part in this research to the extent that you are contributing to medical knowledge.  We hope the information learned from this study will benefit the methodology of calculating body composition in the future. Also it will enable participants to learn about their body composition.

There is no guarantee that taking part in this research will result in any improvement in current methods of measuring body composition.

## WHAT OTHER OPTIONS ARE THERE?

An alternative is to not participate in this research study.

Please discuss these and other options with Mr. Justin Ryder and/or Dr. Steve Ball.

## WHAT ABOUT CONFIDENTIALITY?

Information produced by this study will be stored in the investigator's file and identified by a code number only.  The code key connecting your name to specific information

about you will be kept in a separate, secure location.  Information contained in your records may not be given to anyone unaffiliated with the study in a form that could identify you without your written consent, except as required by law.  If the investigator conducting this study is not your primary, or regular doctor, Mr. Justin Ryder must obtain your permission before contacting your regular doctor for information about your past medical history or to inform them that you are in this trial.

It is possible that your medical and/or research record, including sensitive information and/or identifying information, may be inspected and/or copied by the study sponsor (and/or its agent), the Food and Drug Administration (FDA), federal or state government agencies, or hospital accrediting agencies, in the course of carrying out their duties.  If your record is inspected or copied by the study sponsor (and/or its agents), or by any of these agencies, the University of Missouri-Columbia will use reasonable efforts to protect your privacy and the confidentiality of your medical information.

The results of this study may be published in a medical book or journal or used for teaching purposes.  However, your name or other identifying information will not be used in any publication or teaching materials without your specific permission.

In addition, if photographs, audiotapes or videotapes were taken during the study that could identify you, then you must give special written permission for their use.  In that case, you will be given the opportunity to view or listen, as applicable, to the photographs, audiotapes or videotapes before you give your permission for their use if you so request.

## WHAT ARE THE COSTS?

There is no cost to you for any of the body composition assessments.  However, you will be paying for the normal cost your swimsuit, gym shorts and t-shirt.  If you already have these items then you have no cost associated for this study.

## WILL I BE PAID FOR PARTICIPATING IN THE STUDY?

You will receive no payment for taking part in this study.

## WHAT IF I AM INJURED?

It is not the policy of the University of Missouri to compensate human subjects in the event the research results in injury.  The University of Missouri, in fulfilling its public

responsibility, has provided medical, professional and general liability insurance coverage for any injury in the event such injury is caused by the negligence of the University of Missouri, its faculty and staff.  The University of Missouri also will provide, within the limitations of the laws of the State of Missouri, facilities and medical attention to subjects who suffer injuries while participating in the research projects of the University of Missouri.  In the event you have suffered injury as the result of participation in this research program, you are to contact the Risk Management Officer, telephone number (573) 882-1181, at the Health Sciences Center, who can review the matter and provide further information.  This statement is not to be construed as an admission of liability.

## WHAT ARE MY RIGHTS AS A PARTICIPANT?

**Participation in this study is voluntary.  You do not have to participate in this study.  Your present or future care will not be affected should you choose not to participate.**  If you decide to participate, you can change your mind and drop out of the study at any time without affecting your present or future care in the University of Missouri.  Leaving the study will not result in any penalty or loss of benefits to which you are entitled.  In addition, the investigator of this study may decide to end your participation in this study at any time after Mr. Justin Ryder or Dr. Steve Ball has explained the reasons.

You will be informed of any significant new findings discovered during the course of this study that might influence your health, welfare, or willingness to continue participation in this study.

## WHOM DO I CALL IF I HAVE QUESTIONS OR PROBLEMS?

If you have any questions regarding your rights as a participant in this research and/or concerns about the study, or if you feel under any pressure to enroll or to continue to participate in this study, you may contact the University of Missouri Health Sciences Institutional Review Board (which is a group of people who review the research studies to protect participants' rights) at (573) 882-3181.

You may ask more questions about the study at any time.  For questions about the study or research related injury, please contact Mr. Justin Ryder via e-mail at jrrgy5@mizzou.edu or Dr. Ball at ballsd@missouri.edu.

A copy of this consent form will be given to you to keep.

# SIGNATURE

I confirm that the purpose of the research, the study procedures, the possible risks and discomforts as well as potential benefits that I may experience have been explained to me. Alternatives to my participation in the study also have been discussed. I have read this consent form and my questions have been answered. My signature below indicates my willingness to participate in this study.

_____          _____

_____

Subject/Patient*                                                                                Date

_____          _____

_____

Legal Guardian/Advocate/Witness (if required)**                                        Date

_____          _____

_____

Additional Signature (if required) (identify relationship to subject)***      Date

*A minor's signature on this line indicates his/her assent to participate in this study. A minor's signature is not required if he/she is under 7 years old. Use the "Legal Guardian/Advocate/Witness" line for the parent's signature, and you may use the "Additional Signature" line for the second parent's signature, if required.

**The presence and signature of an impartial witness is required during the entire informed consent discussion if the patient or patient's legally authorized representative is unable to read.

***The "Additional Signature" line may be used for the second parent's signature, if required. This line may also be used for any other signature which is required as per federal, state, local, sponsor and/or any other entity requirements.

"If required" means that the signature line is signed only if it is required as per federal, state, local, sponsor and/or any other entity requirements.

### SIGNATURE OF STUDY REPRESENTATIVE

I have explained the purpose of the research, the study procedures, identifying those that are investigational, the possible risks and discomforts as well as potential benefits and have answered questions regarding the study to the best of my ability.

_____          _____

_____

Study Representative****                                                      Date

****Study Representative is a person authorized to obtain consent.  Per the policies of the University of Missouri Health Care, for any 'significant risk/treatment' study, the Study Representative must be a physician who is either the Principal or Co-Investigator.  If the study is deemed either 'significant risk/non-treatment' or 'minimal risk,' the Study Representative may be a non-physician study investigator.

APPENDIX C:

DATA COLLECTION SHEET

# JUSTIN RYDER THESIS STUDY

**SUBJECTS NUMBER:**_____

**BIRTH DATE:**_____

**AGE:**_____(YR)

**WEIGHT:**_____(LB)

**HEIGHT:**_____(IN)

| (cm) | TRIAL 1 | TRIAL 2 | TRIAL 3 | MEAN |
|------|---------|---------|---------|------|
| **WAIST:** | _____ | _____ | _____ | _____ |
| **HIP:** | _____ | _____ | _____ | _____ |

---

## BIA

**Z =**            **Ph =**                **R =**                **Xc=**

---

**DXA %BF RESULT =**

---

## SKINFOLDS

| | TRIAL 1 | TRIAL 2 | TRIAL 3 | MEAN |
|------|---------|---------|---------|------|
| **CHEST:** | _____ | _____ | _____ | _____ |
| **SUBSCAPULAR:** | _____ | _____ | _____ | _____ |
| **MIDAXILLARY:** | _____ | _____ | _____ | _____ |
| **TRICEP:** | _____ | _____ | _____ | _____ |
| **ABDOMEN:** | _____ | _____ | _____ | _____ |
| **SUPRAILIAC:** | _____ | _____ | _____ | _____ |
| **THIGH:** | _____ | _____ | _____ | _____ |

**FOOT VOLUME**

**RIGHT =**

**LEFT=**

**HAND VOLUME**

**RIGHT =**

**LEFT =**

**HEAD MEASURES**

**HEAD CIRCUMFRENCE=**

**HEAD LENGTH =**

**HAND MEASURES**

**FIRGURE OF 8 RIGHT =**

**FIGURE OF 8 LEFT =**

---

**3D BODY SCANNER**

**BULK VOLUME=**

**WAIST=**

**HIP=**

**ABDOMEN=**

**DoD FITNESS EQUATION =**

---

APPENDIX D:

ADDITIONAL STATISTICAL RESULTS

**Manually measured volumes of head, hand, and feet.**

|  | Mean + SD | Range |
|---|---|---|
| Head (L) | 4.32 ± 0.49 | 2.11 - 6.74 |
| Right Hand (L) | 0.42 ± 0.11 | 0.26 - 0.76 |
| Left Hand (L) | 0.42 ± 0.11 | 0.22 - 0.74 |
| Right Foot (L) | 0.96 ± 0.14 | 0.68 - 1.49 |
| Left Foot (L) | 0.95 ± 0.13 | 0.68 - 1.50 |

Correlation of all variable to DXA

| n = 85 | Age | Height (M) | Weight scale(kg) |
|---|---|---|---|
| Age | 1 | 0.109 | .258** |
| Height (M) | | 1 | .462** |
| Weight scale(kg) | | | 1 |
| Weight Bod Pod (lb) | | | |
| Waist by hand (cm) | | | |
| Hip by hand (cm) | | | |
| BMI | | | |
| WHR | | | |
| SiriSCAN | | | |
| Bod Pod BF Siri | | | |
| DoD equation | | | |
| Hip by Scanner (cm) | | | |
| Waist by Scanner (cm) | | | |
| Abdomen by Scanner (cm) | | | |
| DXA | | | |

* $p < 0.05$     ** $p < 0.01$

Correlation of all variable to DXA

| n = 85 | Age | Height (M) | Weight scale(kg) |
|---|---|---|---|
| Age | 1 | 0.109 | .258** |
| Height (M) | | 1 | .462** |
| Weight scale(kg) | | | 1 |
| Weight Bod Pod (lb) | | | |
| Waist by hand (cm) | | | |
| Hip by hand (cm) | | | |
| BMI | | | |
| WHR | | | |
| SiriSCAN | | | |
| Bod Pod BF Siri | | | |
| DoD equation | | | |
| Hip by Scanner (cm) | | | |
| Waist by Scanner (cm) | | | |
| Abdomen by Scanner (cm) | | | |
| DXA | | | |

* $p < 0.05$  ** $p < 0.01$

| n = 85 | Weight Bod Pod (lb) | Waist by hand (cm) | Hip by hand (cm) |
| --- | --- | --- | --- |
| Age | .243* | .310** | 0.164 |
| Height (M) | .467** | 0.177 | .243* |
| Weight scale(kg) | 1.000** | .813** | .868** |
| Weight Bod Pod (lb) | 1 | .807** | .870** |
| Waist by hand (cm) | | 1 | .731** |
| Hip by hand (cm) | | | 1 |
| BMI | | | |
| WHR | | | |
| SiriSCAN | | | |
| Bod Pod BF Siri | | | |
| DoD equation | | | |
| Hip by Scanner (cm) | | | |
| Waist by Scanner (cm) | | | |
| Abdomen by Scanner (cm) | | | |
| DXA | | | |

* $p < 0.05$    ** $p < 0.01$

| n = 85 | BMI | WHR | SiriSCAN | Bod Pod BF Siri |
|---|---|---|---|---|
| Age | .231* | .313** | 0.038 | .297** |
| Height (M) | -0.149 | 0.062 | -0.131 | 0.020 |
| Weight scale(kg) | .806** | .387** | 0.042 | .600** |
| Weight Bod Pod (lb) | .799** | .368** | 0.040 | .596** |
| Waist by hand (cm) | .798** | .775** | 0.104 | .690** |
| Hip by hand (cm) | .795** | 0.141 | 0.130 | .660** |
| BMI | 1 | .412** | 0.138 | .673** |
| WHR | | 1 | 0.034 | .371** |
| SiriSCAN | | | 1 | 0.160 |
| Bod Pod BF Siri | | | | 1 |
| DoD equation | | | | |
| Hip by Scanner (cm) | | | | |
| Waist by Scanner (cm) | | | | |
| Abdomen by Scanner (cm) | | | | |
| DXA | | | | |

* p < 0.05     ** p <0.01

| n = 85 | DoD equation | Hip by Scanner (cm) | Waist by Scanner (cm) |
|---|---|---|---|
| Age | .226* | .212* | .302** |
| Height (M) | 0.079 | .210* | .195* |
| Weight scale(kg) | .623** | .897** | .851** |
| Weight Bod Pod (lb) | .624** | .893** | .852** |
| Waist by hand (cm) | .723** | .788** | .854** |
| Hip by hand (cm) | .558** | .894** | .798** |
| BMI | .663** | .859** | .830** |
| WHR | .510** | .320** | .497** |
| SiriSCAN | 0.167 | 0.145 | 0.120 |
| Bod Pod BF Siri | .623** | .683** | .748** |
| DoD equation | 1 | .628** | .802** |
| Hip by Scanner (cm) | | 1 | .848** |
| Waist by Scanner (cm) | | | 1 |
| Abdomen by Scanner (cm) | | | |
| DXA | | | |

* p < 0.05     ** p <0.01

| n = 85 | Abdomen by Scanner (cm) | DXA |
|---|---|---|
| Age | .394** | .271** |
| Height (M) | .249* | -0.043 |
| Weight scale(kg) | .791** | .514** |
| Weight Bod Pod (lb) | .791** | .517** |
| Waist by hand (cm) | .737** | .556** |
| Hip by hand (cm) | .777** | .597** |
| BMI | .724** | .617** |
| WHR | .348** | .233* |
| SiriSCAN | 0.119 | .237* |
| Bod Pod BF Siri | .719** | .856** |
| DoD equation | .680** | .629** |
| Hip by Scanner (cm) | .815** | .656** |
| Waist by Scanner (cm) | .856** | .751** |
| Abdomen by Scanner (cm) | 1 | .742** |
| DXA | | 1 |

* p < 0.05    ** p <0.01

APPENDIX E:

RAW DATA

| Subject | Age | Height(in) | Weight(lb) | BodPodWeight (lb) | Bodpod BF | Bulk vol scan | DXA BF | R hand vol |
|---|---|---|---|---|---|---|---|---|
| 1.00 | 22.00 | 70.75 | 193.00 | 191.90 | 7.10 | 2.77 | 9.80 | 450.00 |
| 2.00 | 22.00 | 70.25 | 194.00 | 192.90 | 10.60 | 2.80 | 14.30 | 450.00 |
| 3.00 | 22.00 | 72.25 | 187.50 | 185.90 | 12.60 | 2.80 | 18.80 | 400.00 |
| 4.00 | 23.00 | 68.75 | 156.00 | | | 2.23 | 8.10 | 390.00 |
| 5.00 | 22.00 | 74.25 | 197.00 | 196.10 | 16.90 | 2.93 | 21.10 | 455.00 |
| 6.00 | 22.00 | 67.25 | 181.00 | 179.40 | 10.50 | 2.68 | 14.60 | 350.00 |
| 7.00 | 20.00 | 72.25 | 236.00 | 235.40 | 23.40 | 3.46 | 21.20 | 405.00 |
| 8.00 | 22.00 | 72.00 | 167.50 | 166.20 | 9.60 | 2.48 | 11.30 | 315.00 |
| 9.00 | 21.00 | 71.25 | 166.00 | 165.40 | 7.30 | 2.41 | 10.50 | 385.00 |
| 10.00 | 21.00 | 68.50 | 182.50 | 181.50 | 19.50 | 2.69 | 21.80 | 445.00 |
| 11.00 | 22.00 | 69.50 | 279.50 | 279.10 | 37.30 | 4.20 | 31.90 | 535.00 |
| 12.00 | 21.00 | 68.00 | 179.00 | 178.80 | 16.80 | 2.71 | 21.40 | 420.00 |
| 13.00 | 19.00 | 70.00 | 161.00 | 160.30 | 1.40 | 2.32 | 8.20 | 430.00 |
| 14.00 | 21.00 | 72.00 | 197.00 | 196.00 | 11.60 | 2.89 | 16.50 | 410.00 |
| 15.00 | 21.00 | 70.75 | 173.50 | 171.30 | 21.20 | 2.58 | 21.50 | 355.00 |
| 16.00 | 18.00 | 67.00 | 123.50 | 122.70 | 1.30 | 1.78 | 16.60 | 310.00 |
| 17.00 | 21.00 | 76.00 | 234.00 | 232.60 | 18.30 | 3.50 | 21.40 | 550.00 |
| 18.00 | 22.00 | 72.50 | 194.00 | 192.30 | 12.90 | 2.88 | 21.80 | 430.00 |
| 19.00 | 23.00 | 68.50 | 182.00 | 180.80 | 19.10 | 2.67 | 19.70 | 400.00 |
| 20.00 | 20.00 | 70.25 | 141.00 | 142.80 | 5.50 | 2.89 | 12.60 | 360.00 |
| 21.00 | 21.00 | 69.25 | 195.00 | 194.00 | 17.70 | 2.04 | 21.10 | 460.00 |
| 22.00 | 23.00 | 66.75 | 168.50 | 165.80 | 17.50 | 2.44 | 18.30 | 355.00 |
| 23.00 | 20.00 | 72.00 | 183.50 | 180.00 | 19.10 | 2.65 | 17.60 | 375.00 |
| 24.00 | 23.00 | 69.00 | 159.00 | 157.20 | 8.90 | 2.28 | 19.10 | 400.00 |
| 25.00 | 20.00 | 73.00 | 149.00 | 148.40 | 9.80 | 2.17 | 13.70 | 405.00 |
| 26.00 | 22.00 | 71.00 | 162.00 | 160.80 | 8.50 | 2.35 | 18.30 | 475.00 |
| 27.00 | 19.00 | 64.50 | 152.00 | 152.10 | 14.10 | 2.32 | 15.10 | 325.00 |
| 28.00 | 21.00 | 77.00 | 265.00 | 263.60 | 14.40 | 3.88 | 14.90 | 630.00 |
| 29.00 | 22.00 | 71.00 | 189.00 | 187.60 | 14.50 | 2.79 | 15.40 | 400.00 |
| 30.00 | 21.00 | 71.50 | 154.00 | 153.60 | 8.10 | 2.25 | 12.70 | 430.00 |
| 31.00 | 19.00 | 68.00 | 164.00 | 162.10 | 18.60 | 2.85 | 16.20 | 520.00 |
| 32.00 | 22.00 | 71.00 | 195.00 | 192.70 | 16.00 | 2.35 | 16.90 | 470.00 |
| 33.00 | 21.00 | 68.50 | 174.00 | 173.50 | 11.40 | 2.59 | 15.30 | 505.00 |
| 34.00 | 21.00 | 71.75 | 179.00 | 178.10 | 11.50 | 2.69 | 12.20 | 550.00 |
| 35.00 | 25.00 | 73.50 | 155.00 | | | 2.26 | 9.60 | 435.00 |
| 36.00 | 21.00 | 69.50 | 198.00 | 197.40 | 21.90 | 3.00 | 26.10 | 420.00 |
| 37.00 | 20.00 | 66.50 | 190.00 | 189.30 | 9.40 | 2.77 | 14.70 | 410.00 |
| 38.00 | 20.00 | 73.50 | 181.00 | 180.30 | 12.40 | 2.66 | 15.10 | 510.00 |
| 39.00 | 20.00 | 68.00 | 164.00 | 163.70 | 12.60 | 2.42 | 14.80 | 400.00 |
| 40.00 | 20.00 | 68.50 | 165.00 | 164.20 | 8.40 | 2.44 | 13.70 | 385.00 |
| 41.00 | 21.00 | 71.00 | 167.00 | 165.80 | 10.00 | 2.39 | 13.10 | 435.00 |
| 42.00 | 21.00 | 69.00 | 167.00 | 166.50 | 12.20 | 2.46 | 13.90 | 370.00 |
| 43.00 | 21.00 | 70.00 | 180.00 | 178.90 | 11.10 | 2.62 | 15.50 | 525.00 |
| 44.00 | 21.00 | 76.50 | 195.00 | 194.50 | 4.20 | 2.87 | 12.90 | 525.00 |
| 45.00 | 19.00 | 74.00 | 193.00 | 191.80 | 8.30 | 2.81 | 14.00 | 535.00 |
| 46.00 | 21.00 | 67.50 | 173.00 | 172.60 | 10.20 | 2.81 | 15.80 | 410.00 |
| 47.00 | 23.00 | 69.50 | 178.00 | 176.90 | 12.80 | 2.58 | 15.60 | 470.00 |
| 48.00 | 21.00 | 55.50 | 129.50 | 128.70 | 5.50 | 2.68 | 15.50 | 280.00 |

| Subject | Age | Height(in) | Weight(lb) | BodPodWeight (lb) | Bodpod BF | Bulk vol scan | DXA BF | R hand vol |
|---|---|---|---|---|---|---|---|---|
| 49.00 | 19.00 | 72.50 | 176.00 | 175.50 | 1.80 | 1.89 | 9.30 | 395.00 |
| 50.00 | 19.00 | 72.50 | 162.00 | 160.90 | 6.90 | 2.56 | 15.70 | 405.00 |
| 51.00 | 24.00 | 71.75 | 173.50 | 172.50 | 11.60 | 2.36 | 19.30 | 445.00 |
| 52.00 | 25.00 | 69.50 | 179.50 | 177.20 | 10.00 | 2.57 | 13.70 | 395.00 |
| 53.00 | 20.00 | 72.50 | 178.00 | 177.20 | 11.70 | 2.60 | 12.60 | 415.00 |
| 54.00 | 21.00 | 69.80 | 163.40 | 162.80 | 5.60 | 2.65 | 10.50 | 365.00 |
| 55.00 | 19.00 | 73.25 | 259.00 | 258.20 | 22.70 | 2.39 | 22.90 | 560.00 |
| 56.00 | 21.00 | 71.00 | 172.50 | 171.90 | 9.20 | 3.89 | 12.90 | 425.00 |
| 57.00 | 21.00 | 67.75 | 160.50 | 157.20 | 6.00 | 2.53 | 13.40 | 500.00 |
| 58.00 | 18.00 | 68.50 | 158.00 | 159.70 | 3.20 | 2.32 | 11.80 | 375.00 |
| 59.00 | 21.00 | 68.00 | 165.00 | 164.30 | 5.80 | 2.31 | 11.80 | 385.00 |
| 60.00 | 20.00 | 69.00 | 154.00 | 153.30 | 14.60 | 2.43 | 15.60 | 320.00 |
| 62.00 | 21.00 | 69.75 | 150.50 | 149.80 | 8.10 | 2.20 | 13.70 | 360.00 |
| 63.00 | 19.00 | 69.50 | 153.00 | 152.50 | 6.00 | 2.23 | 10.40 | 375.00 |
| 64.00 | 21.00 | 70.50 | 168.00 | 167.00 | 13.00 | 2.46 | 16.00 | 425.00 |
| 65.00 | 26.00 | 74.50 | 221.00 | 220.40 | 7.90 | 3.32 | 16.20 | 485.00 |
| 66.00 | 19.00 | 71.00 | 171.50 | 170.80 | 3.70 | 2.44 | 12.00 | 450.00 |
| 67.00 | 25.00 | 66.50 | 167.50 | 166.60 | 25.90 | 2.46 | 25.00 | 300.00 |
| 68.00 | 24.00 | 69.50 | 155.00 | 154.30 | 8.00 | 2.30 | 16.40 | 305.00 |
| 69.00 | 22.00 | 70.75 | 230.00 | 228.90 | 29.20 | 3.51 | 29.40 | 370.00 |
| 70.00 | 21.00 | 72.25 | 146.00 | 145.60 | 7.80 | 2.18 | 13.50 | 260.00 |
| 71.00 | 20.00 | 71.00 | 176.00 | 175.40 | 11.10 | 2.57 | 14.20 | 265.00 |
| 72.00 | 20.00 | 68.50 | 147.50 | 145.30 | 5.60 | 2.14 | 12.60 | 255.00 |
| 73.00 | 23.00 | 69.50 | 214.50 | 212.30 | 37.60 | 3.22 | 32.80 | 320.00 |
| 74.00 | 22.00 | 72.00 | 152.00 | 150.20 | 13.70 | 2.23 | 13.90 | 365.00 |
| 75.00 | 21.00 | 69.50 | 162.00 | 161.00 | 8.40 | 2.34 | 11.30 | 310.00 |
| 76.00 | 19.00 | 71.00 | 177.00 | 176.20 | 10.50 | 2.64 | 16.40 | 410.00 |
| 77.00 | 30.00 | 67.25 | 197.50 | 196.90 | 19.80 | 2.97 |  | 450.00 |
| 78.00 | 27.00 | 74.75 | 202.00 | 201.50 | 12.10 | 2.96 | 15.40 | 470.00 |
| 79.00 | 24.00 | 67.75 | 168.50 | 167.90 | 27.30 | 2.48 | 25.30 | 330.00 |
| 80.00 | 25.00 | 67.00 | 162.50 | 162.00 | 12.70 | 2.33 | 12.40 | 355.00 |
| 81.00 | 24.00 | 71.50 | 222.00 | 221.00 | 22.50 | 3.33 | 21.80 | 510.00 |
| 82.00 | 23.00 | 73.00 | 180.00 | 179.50 | 2.20 | 2.65 | 12.20 | 440.00 |
| 83.00 | 21.00 | 73.50 | 197.50 | 196.70 | 13.00 | 2.93 | 18.10 | 410.00 |
| 84.00 | 21.00 | 64.50 | 148.00 | 147.60 | 1.50 | 2.23 | 18.60 | 295.00 |
| 85.00 | 22.00 | 71.00 | 158.00 | 157.10 | 4.90 | 2.37 | 17.60 | 395.00 |
| 86.00 | 22.00 | 66.50 | 156.00 | 155.00 | 9.00 | 2.25 | 13.20 | 375.00 |
| 87.00 | 28.00 | 72.25 | 203.00 | 202.00 | 21.80 | 3.05 | 21.80 | 385.00 |
| 88.00 | 22.00 | 70.00 | 186.50 | 185.70 | 9.70 | 2.76 | 16.00 | 455.00 |
| 89.00 | 20.00 | 68.50 | 176.00 | 175.20 | 21.10 | 2.60 | 18.80 | 345.00 |
| 90.00 | 27.00 | 75.25 | 157.00 | 157.00 | 10.80 | 2.39 | 14.60 | 360.00 |
| 91.00 | 22.00 | 69.25 | 162.00 | 161.10 | 9.00 | 2.39 | 17.50 | 375.00 |
| 92.00 | 23.00 | 72.00 | 165.50 | 165.00 | 5.80 | 2.40 | 11.70 | 395.00 |
| 93.00 | 30.00 | 73.00 | 191.00 | 190.00 | 13.40 | 2.84 | 18.70 | 360.00 |
| 94.00 | 20.00 | 72.00 | 157.50 | 157.00 | 4.00 | 2.30 | 11.70 | 320.00 |
| 95.00 | 22.00 | 69.75 | 173.00 | 172.00 | 14.70 | 2.54 | 16.80 | 405.00 |
| 96.00 | 21.00 | 72.75 | 182.00 | 180.10 | 3.90 | 2.65 | 12.60 | 405.00 |
| 97.00 | 24.00 | 70.50 | 220.00 |  |  | 3.24 | 16.80 | 325.00 |

| Subject | L hand vol | R foot vol | L foot vol | Head Length | Head Circ | Head vol | Waist hand | hip hand | WHR | BMI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | 443.00 | 1065.00 | 1043.00 | 19.20 | 57.10 | 4446.35 | 86.00 | 100.50 | 0.86 | 27.17 |
| 2.00 | 460.00 | 925.00 | 930.00 | 19.60 | 57.70 | 4527.70 | 86.00 | 102.00 | 0.84 | 27.70 |
| 3.00 | 400.00 | 860.00 | 930.00 | 20.40 | 60.50 | 5037.26 | 84.00 | 101.50 | 0.83 | 25.31 |
| 4.00 | 395.00 | 1085.00 | 1055.00 | 20.80 | 56.00 | 4012.93 | 77.30 | 97.40 | 0.79 | 23.25 |
| 5.00 | 475.00 | 1250.00 | 1175.00 | 20.40 | 59.60 | 4842.14 | 85.80 | 104.40 | 0.82 | 25.18 |
| 6.00 | 350.00 | 900.00 | 865.00 | 20.40 | 59.60 | 4842.14 | 85.20 | 101.70 | 0.84 | 28.20 |
| 7.00 | 410.00 | 1015.00 | 1020.00 | 19.70 | 58.00 | 4580.55 | 98.50 | 113.70 | 0.87 | 31.85 |
| 8.00 | 370.00 | 880.00 | 830.00 | 19.20 | 57.10 | 4446.35 | 86.70 | 92.40 | 0.94 | 22.76 |
| 9.00 | 375.00 | 995.00 | 1025.00 | 19.30 | 54.50 | 3870.49 | 77.70 | 97.80 | 0.79 | 23.04 |
| 10.00 | 435.00 | 995.00 | 965.00 | 19.00 | 57.00 | 4449.04 | 93.00 | 101.70 | 0.91 | 27.40 |
| 11.00 | 535.00 | 1155.00 | 1190.00 | 20.40 | 61.40 | 5232.38 | 122.30 | 120.80 | 1.01 | 40.77 |
| 12.00 | 430.00 | 990.00 | 940.00 | 18.60 | 56.30 | 4346.02 | 86.30 | 104.40 | 0.83 | 27.27 |
| 13.00 | 460.00 | 915.00 | 910.00 | 19.30 | 58.10 | 4650.97 | 76.60 | 90.20 | 0.85 | 23.15 |
| 14.00 | 410.00 | 965.00 | 945.00 | 19.90 | 57.70 | 4491.14 | 82.50 | 106.40 | 0.78 | 26.77 |
| 15.00 | 380.00 | 1000.00 | 990.00 | 19.60 | 57.70 | 4527.70 | 84.40 | 102.20 | 0.83 | 24.42 |
| 16.00 | 315.00 | 805.00 | 810.00 | 19.60 | 56.00 | 4159.14 | 64.40 | 89.60 | 0.72 | 19.38 |
| 17.00 | 560.00 | 1210.00 | 1170.00 | 19.00 | 57.00 | 4449.04 | 94.50 | 108.30 | 0.87 | 28.54 |
| 18.00 | 415.00 | 975.00 | 930.00 | 20.40 | 58.70 | 4647.02 | 63.80 | 107.00 | 0.60 | 26.00 |
| 19.00 | 395.00 | 890.00 | 880.00 | 19.30 | 57.80 | 4585.93 | 84.60 | 103.20 | 0.82 | 27.33 |
| 20.00 | 390.00 | 910.00 | 855.00 | 19.50 | 54.60 | 3867.80 | 70.00 | 92.00 | 0.76 | 20.13 |
| 21.00 | 465.00 | 1040.00 | 1010.00 | 19.30 | 56.30 | 4260.73 | 88.00 | 104.80 | 0.84 | 28.65 |
| 22.00 | 340.00 | 830.00 | 855.00 | 19.60 | 56.20 | 4202.50 | 82.00 | 97.00 | 0.85 | 26.64 |
| 23.00 | 375.00 | 1055.00 | 1030.00 | 20.40 | 58.30 | 4560.30 | 86.00 | 94.50 | 0.91 | 24.94 |
| 24.00 | 400.00 | 870.00 | 850.00 | 19.50 | 60.10 | 5060.20 | 78.00 | 94.90 | 0.82 | 23.53 |
| 25.00 | 385.00 | 945.00 | 955.00 | 19.40 | 55.50 | 4075.10 | 68.40 | 87.50 | 0.78 | 19.70 |
| 26.00 | 430.00 | 1070.00 | 1070.00 | 19.00 | 56.20 | 4275.60 | 76.10 | 95.50 | 0.80 | 22.64 |
| 27.00 | 310.00 | 850.00 | 830.00 | 19.80 | 56.70 | 4286.53 | 77.10 | 97.10 | 0.79 | 25.74 |
| 28.00 | 585.00 | 1485.00 | 1500.00 | 20.20 | 58.00 | 4519.63 | 91.50 | 118.00 | 0.78 | 31.49 |
| 29.00 | 415.00 | 1015.00 | 1000.00 | 19.50 | 57.70 | 4539.88 | 94.50 | 102.00 | 0.93 | 26.42 |
| 30.00 | 405.00 | 950.00 | 885.00 | 19.10 | 56.30 | 4285.10 | 73.50 | 93.10 | 0.79 | 21.22 |
| 31.00 | 465.00 | 1075.00 | 1070.00 | 20.50 | 57.50 | 4374.68 | 84.50 | 95.00 | 0.89 | 24.99 |
| 32.00 | 485.00 | 1025.00 | 925.00 | 19.50 | 56.00 | 4171.32 | 88.00 | 104.00 | 0.85 | 27.25 |
| 33.00 | 490.00 | 1080.00 | 995.00 | 19.00 | 58.00 | 4665.84 | 87.00 | 101.00 | 0.86 | 26.13 |
| 34.00 | 580.00 | 1210.00 | 1180.00 | 20.50 | 59.00 | 4699.88 | 78.50 | 102.00 | 0.77 | 24.50 |
| 35.00 | 455.00 | 925.00 | 875.00 | 19.50 | 56.00 | 4171.32 | 71.00 | 89.00 | 0.80 | 20.21 |
| 36.00 | 425.00 | 1095.00 | 1055.00 | 18.60 | 55.00 | 4064.18 | 90.80 | 105.30 | 0.86 | 28.88 |
| 37.00 | 425.00 | 900.00 | 955.00 | 18.80 | 56.20 | 4299.97 | 85.80 | 97.60 | 0.88 | 30.27 |
| 38.00 | 510.00 | 1105.00 | 1105.00 | 19.40 | 47.30 | 2297.34 | 78.80 | 98.40 | 0.80 | 23.61 |
| 39.00 | 400.00 | 1090.00 | 1090.00 | 19.70 | 54.50 | 3821.75 | 77.70 | 94.40 | 0.82 | 24.99 |
| 40.00 | 385.00 | 825.00 | 825.00 | 19.30 | 46.40 | 2114.41 | 79.60 | 97.00 | 0.82 | 24.77 |
| 41.00 | 405.00 | 940.00 | 960.00 | 20.00 | 56.80 | 4283.84 | 82.10 | 96.20 | 0.85 | 23.34 |
| 42.00 | 345.00 | 970.00 | 895.00 | 20.60 | 58.00 | 4470.90 | 80.20 | 98.30 | 0.82 | 24.71 |
| 43.00 | 475.00 | 1200.00 | 1110.00 | 20.30 | 58.50 | 4615.85 | 81.00 | 101.00 | 0.80 | 25.88 |
| 44.00 | 535.00 | 1065.00 | 1045.00 | 23.50 | 59.80 | 4507.80 | 83.50 | 101.00 | 0.83 | 23.48 |
| 45.00 | 550.00 | 1200.00 | 1200.00 | 20.30 | 59.00 | 4724.25 | 81.50 | 103.00 | 0.79 | 24.83 |
| 46.00 | 410.00 | 885.00 | 925.00 | 18.50 | 56.50 | 4401.56 | 86.00 | 101.50 | 0.85 | 26.75 |
| 47.00 | 425.00 | 930.00 | 925.00 | 20.00 | 58.00 | 4544.00 | 82.00 | 96.00 | 0.85 | 25.96 |
| 48.00 | 280.00 | 675.00 | 675.00 | 18.60 | 55.30 | 4129.22 | 71.40 | 89.10 | 0.80 | 29.62 |

| Subject | L hand vol | R foot vol | L foot vol | Head Length | Head Circ | Head vol | Waist hand | hip hand | WHR | BMI |
|---------|-----------|-----------|-----------|-------------|-----------|----------|-----------|----------|-----|-----|
| 49.00 | 415.00 | 905.00 | 900.00 | 19.00 | 54.80 | 3972.08 | 73.00 | 93.40 | 0.78 | 23.59 |
| 50.00 | 375.00 | 1015.00 | 950.00 | 19.50 | 56.80 | 4344.76 | 73.60 | 94.20 | 0.78 | 21.71 |
| 51.00 | 425.00 | 975.00 | 1005.00 | 21.70 | 59.80 | 4727.11 | 80.00 | 97.10 | 0.82 | 23.74 |
| 52.00 | 390.00 | 930.00 | 910.00 | 21.40 | 58.40 | 4460.14 | 79.60 | 99.00 | 0.80 | 26.18 |
| 53.00 | 420.00 | 1000.00 | 945.00 | 19.10 | 56.00 | 4220.06 | 77.70 | 96.30 | 0.81 | 23.86 |
| 54.00 | 365.00 | 900.00 | 875.00 | 19.40 | 54.50 | 3858.30 | 73.60 | 92.50 | 0.80 | 23.63 |
| 55.00 | 515.00 | 1280.00 | 1280.00 | 19.60 | 56.10 | 4180.82 | 99.60 | 116.00 | 0.86 | 34.01 |
| 56.00 | 430.00 | 1130.00 | 1100.00 | 18.70 | 54.70 | 3986.95 | 76.50 | 93.60 | 0.82 | 24.11 |
| 57.00 | 480.00 | 925.00 | 905.00 | 19.10 | 55.20 | 4046.62 | | | | 24.64 |
| 58.00 | 370.00 | 810.00 | 815.00 | 19.60 | 55.70 | 4094.10 | 74.50 | 94.50 | 0.79 | 23.72 |
| 59.00 | 400.00 | 910.00 | 960.00 | 19.50 | 55.50 | 4062.92 | 82.00 | 94.60 | 0.87 | 25.14 |
| 60.00 | 310.00 | 790.00 | 790.00 | 19.60 | 57.50 | 4484.34 | 81.00 | 97.00 | 0.84 | 22.79 |
| 62.00 | 365.00 | 850.00 | 810.00 | 19.40 | 56.00 | 4183.50 | 63.10 | 88.80 | 0.71 | 21.80 |
| 63.00 | 350.00 | 800.00 | 765.00 | 19.60 | 56.60 | 4289.22 | 77.50 | 91.10 | 0.85 | 22.32 |
| 64.00 | 405.00 | 1005.00 | 990.00 | 19.40 | 55.90 | 4161.82 | 76.60 | 97.00 | 0.79 | 23.81 |
| 65.00 | 490.00 | 1155.00 | 1150.00 | 19.33 | 55.66 | 4118.32 | 90.40 | 104.40 | 0.87 | 28.05 |
| 66.00 | 450.00 | 950.00 | 955.00 | 19.33 | 55.66 | 4118.32 | 80.70 | 94.40 | 0.85 | 23.97 |
| 67.00 | 285.00 | 780.00 | 810.00 | 19.33 | 55.66 | 4118.32 | | | | 26.69 |
| 68.00 | 290.00 | 775.00 | 775.00 | 19.33 | 55.66 | 4118.32 | 78.60 | 93.20 | 0.84 | 22.61 |
| 69.00 | 370.00 | 870.00 | 875.00 | 19.33 | 55.66 | 4118.32 | | | | 32.37 |
| 70.00 | 270.00 | 710.00 | 690.00 | 19.33 | 55.66 | 4118.32 | 74.20 | 84.30 | 0.88 | 19.71 |
| 71.00 | 255.00 | 805.00 | 800.00 | 19.33 | 55.66 | 4118.32 | 86.40 | 95.50 | 0.90 | 24.60 |
| 72.00 | 215.00 | 720.00 | 715.00 | 22.00 | 57.90 | 4278.64 | 74.20 | 91.80 | 0.81 | 22.15 |
| 73.00 | 290.00 | 840.00 | 815.00 | 22.00 | 56.80 | 4040.16 | 98.40 | 108.60 | 0.91 | 31.29 |
| 74.00 | 325.00 | 850.00 | 850.00 | 19.10 | 55.20 | 4046.62 | 75.50 | 94.40 | 0.80 | 20.66 |
| 75.00 | 305.00 | 875.00 | 980.00 | 19.90 | 56.60 | 4252.66 | 79.40 | 93.40 | 0.85 | 23.63 |
| 76.00 | 380.00 | 1010.00 | 965.00 | 20.00 | 57.40 | 4413.92 | 81.40 | 91.40 | 0.89 | 24.74 |
| 77.00 | 425.00 | 905.00 | 895.00 | 19.60 | 57.80 | 4549.38 | 91.80 | 101.80 | 0.90 | 30.77 |
| 78.00 | 465.00 | 1100.00 | 1060.00 | 21.00 | 68.70 | 6741.92 | 87.40 | 95.40 | 0.92 | 25.47 |
| 79.00 | 335.00 | 975.00 | 925.00 | 18.80 | 56.80 | 4430.05 | 82.90 | 100.80 | 0.82 | 25.86 |
| 80.00 | 360.00 | 870.00 | 815.00 | 18.90 | 55.70 | 4179.38 | 77.00 | 92.80 | 0.83 | 25.50 |
| 81.00 | 500.00 | 1050.00 | 1100.00 | 19.20 | 57.90 | 4619.79 | 97.40 | 112.00 | 0.87 | 30.60 |
| 82.00 | 430.00 | 930.00 | 930.00 | 20.30 | 57.50 | 4399.05 | 82.30 | 93.30 | 0.88 | 23.80 |
| 83.00 | 400.00 | 865.00 | 815.00 | 20.00 | 56.40 | 4197.12 | 82.10 | 92.10 | 0.89 | 25.76 |
| 84.00 | 275.00 | 740.00 | 760.00 | 19.10 | 55.10 | 4024.94 | 79.50 | 92.80 | 0.86 | 25.06 |
| 85.00 | 375.00 | 960.00 | 1005.00 | 20.40 | 55.70 | 3996.62 | 70.00 | 91.50 | 0.77 | 22.08 |
| 86.00 | 365.00 | 865.00 | 875.00 | 19.60 | 54.80 | 3898.98 | 75.10 | 92.60 | 0.81 | 24.85 |
| 87.00 | 400.00 | 900.00 | 880.00 | 20.40 | 57.60 | 4408.54 | 93.20 | 99.30 | 0.94 | 27.40 |
| 88.00 | 445.00 | 870.00 | 850.00 | 20.10 | 56.10 | 4119.90 | 82.60 | 99.10 | 0.83 | 26.82 |
| 89.00 | 340.00 | 920.00 | 920.00 | 19.10 | 56.80 | 4393.50 | 84.10 | 97.70 | 0.86 | 26.43 |
| 90.00 | 360.00 | 860.00 | 870.00 | 19.50 | 55.80 | 4127.96 | 79.60 | 91.40 | 0.87 | 19.53 |
| 91.00 | 370.00 | 910.00 | 880.00 | 20.20 | 58.30 | 4584.67 | 78.40 | 93.10 | 0.84 | 23.80 |
| 92.00 | 400.00 | 935.00 | 915.00 | 20.00 | 60.30 | 5042.64 | 76.40 | 94.80 | 0.81 | 22.49 |
| 93.00 | 350.00 | 950.00 | 910.00 | 19.40 | 56.50 | 4291.90 | 89.10 | 99.10 | 0.90 | 25.25 |
| 94.00 | 310.00 | 775.00 | 765.00 | 20.10 | 57.50 | 4423.42 | 78.10 | 90.10 | 0.87 | 21.41 |
| 95.00 | 410.00 | 950.00 | 910.00 | 20.50 | 56.90 | 4244.60 | 92.10 | 95.50 | 0.96 | 25.05 |
| 96.00 | 415.00 | 1065.00 | 1040.00 | 19.00 | 55.80 | 4188.88 | 84.60 | 95.70 | 0.88 | 24.23 |
| 97.00 | 320.00 | 800.00 | 800.00 | 20.20 | 58.60 | 4649.71 | 95.50 | 102.20 | 0.93 | 31.19 |

| Subject | Scan Density | BOD POD density | BOD POD vol | DoD equation BF | scan vol (L) |
|---|---|---|---|---|---|
| 1.00 | 1.12 | 1.08 | 80.37 | 12.57 | 78.57 |
| 2.00 | 1.11 | 1.08 | 81.39 | 14.28 | 79.22 |
| 3.00 | 1.08 | 1.07 | 78.81 | 16.39 | 79.21 |
| 4.00 | 1.12 | | | 7.46 | 63.27 |
| 5.00 | 1.08 | 1.06 | 83.91 | 16.75 | 82.89 |
| 6.00 | 1.08 | 1.08 | 75.70 | | 75.93 |
| 7.00 | 1.09 | 1.05 | 102.08 | 20.70 | 98.08 |
| 8.00 | 1.08 | 1.08 | 70.00 | 8.37 | 70.22 |
| 9.00 | 1.10 | 1.08 | 71.18 | 7.19 | 68.38 |
| 10.00 | 1.09 | 1.05 | 78.11 | 17.32 | 76.15 |
| 11.00 | 1.07 | 1.02 | 124.60 | 54.45 | 119.07 |
| 12.00 | 1.06 | 1.06 | 76.51 | 16.81 | 76.67 |
| 13.00 | 1.11 | 1.10 | 66.34 | 14.76 | 65.68 |
| 14.00 | 1.09 | 1.07 | 82.93 | 11.07 | 81.86 |
| 15.00 | 1.08 | 1.05 | 73.93 | 14.98 | 72.95 |
| 16.00 | 1.12 | 1.10 | 50.73 | 6.16 | 50.31 |
| 17.00 | 1.07 | 1.06 | 99.82 | 19.19 | 99.25 |
| 18.00 | 1.08 | 1.07 | 81.60 | 12.83 | 81.41 |
| 19.00 | 1.09 | 1.06 | 77.73 | 15.02 | 75.63 |
| 20.00 | 0.78 | 1.09 | 59.59 | 18.68 | 81.80 |
| 21.00 | 1.54 | 1.06 | 83.17 | 4.95 | 57.74 |
| 22.00 | 1.11 | 1.06 | 71.02 | 16.81 | 69.21 |
| 23.00 | 1.11 | 1.06 | 77.39 | 10.92 | 75.18 |
| 24.00 | 1.12 | 1.08 | 66.08 | 9.50 | 64.44 |
| 25.00 | 1.10 | 1.08 | 62.56 | 8.11 | 61.38 |
| 26.00 | 1.11 | 1.08 | 67.53 | 10.87 | 66.54 |
| 27.00 | 1.05 | 1.07 | 64.66 | 15.08 | 65.69 |
| 28.00 | 1.10 | 1.07 | 112.16 | 14.57 | 109.94 |
| 29.00 | 1.09 | 1.07 | 79.83 | 14.78 | 78.87 |
| 30.00 | 1.10 | 1.08 | 64.45 | 10.03 | 63.77 |
| 31.00 | 0.92 | 1.06 | 69.56 | 16.93 | 80.59 |
| 32.00 | 1.33 | 1.06 | 82.15 | 14.07 | 66.57 |
| 33.00 | 1.08 | 1.07 | 73.34 | 12.83 | 73.32 |
| 34.00 | 1.07 | 1.07 | 75.29 | 10.70 | 76.28 |
| 35.00 | 1.10 | | | 4.85 | 63.99 |
| 36.00 | 1.06 | 1.05 | 85.36 | 22.89 | 84.97 |
| 37.00 | 1.10 | 1.08 | 79.73 | 9.98 | 78.39 |
| 38.00 | 1.09 | 1.07 | 76.36 | 13.62 | 75.20 |
| 39.00 | 1.09 | 1.07 | 69.40 | 12.71 | 68.42 |
| 40.00 | 1.08 | 1.08 | 68.96 | 11.75 | 69.13 |
| 41.00 | 1.12 | 1.08 | 69.89 | 10.41 | 67.67 |
| 42.00 | 1.09 | 1.07 | 70.52 | 9.40 | 69.53 |
| 43.00 | 1.10 | 1.07 | 75.63 | 10.84 | 74.33 |
| 44.00 | 1.09 | 1.09 | 80.94 | 11.96 | 81.18 |
| 45.00 | 1.10 | 1.08 | 80.55 | 11.26 | 79.70 |
| 46.00 | 0.99 | 1.08 | 72.76 | 14.88 | 79.70 |
| 47.00 | 1.11 | 1.07 | 74.99 | 11.47 | 72.92 |
| 48.00 | 0.78 | 1.09 | 72.76 | 7.99 | 75.75 |

| Subject | Scan Density | BOD POD density | BOD POD vol | DoD equation BF | scan vol (L) |
|---|---|---|---|---|---|
| 49.00 | 1.50 | 1.10 | 72.70 | 7.28 | 53.42 |
| 50.00 | 1.01 | 1.08 | 67.39 | 9.07 | 72.60 |
| 51.00 | 1.18 | 1.07 | 72.99 | 11.55 | 66.85 |
| 52.00 | 1.12 | 1.08 | 74.70 | 11.10 | 72.65 |
| 53.00 | 1.10 | 1.07 | 74.98 | 8.41 | 73.56 |
| 54.00 | 0.99 | 1.09 | 68.00 | 5.35 | 75.02 |
| 55.00 | 1.74 | 1.05 | 111.86 | 22.54 | 67.63 |
| 56.00 | 0.71 | 1.08 | 72.33 | 9.30 | 110.29 |
| 57.00 | 1.02 | 1.09 | 65.66 | 11.84 | 71.75 |
| 58.00 | 1.09 | 1.09 | 66.34 | 6.43 | 65.78 |
| 59.00 | 1.15 | 1.09 | 68.62 | 9.36 | 65.48 |
| 60.00 | 1.02 | 1.07 | 65.29 | 13.33 | 68.70 |
| 62.00 | 1.10 | 1.08 | 62.91 | 7.27 | 62.18 |
| 63.00 | 1.10 | 1.09 | 63.70 | 8.10 | 63.24 |
| 64.00 | 1.10 | 1.07 | 70.86 | 10.36 | 69.59 |
| 65.00 | 1.07 | 1.08 | 92.48 | 18.89 | 94.05 |
| 66.00 | 1.13 | 1.09 | 71.01 | 10.36 | 69.17 |
| 67.00 | 1.09 | 1.04 | 72.66 | 16.17 | 69.61 |
| 68.00 | 1.08 | 1.08 | 64.74 | 14.50 | 65.08 |
| 69.00 | 1.05 | 1.03 | 100.51 | 17.95 | 99.33 |
| 70.00 | 1.07 | 1.08 | 61.09 | 33.26 | 61.79 |
| 71.00 | 1.10 | 1.07 | 74.15 | 9.14 | 72.91 |
| 72.00 | 1.11 | 1.09 | 60.69 | 8.03 | 60.58 |
| 73.00 | 1.07 | 1.02 | 94.87 | 21.48 | 91.24 |
| 74.00 | 1.09 | 1.07 | 63.79 | 7.96 | 63.23 |
| 75.00 | 1.11 | 1.08 | 67.62 | 10.69 | 66.12 |
| 76.00 | 1.08 | 1.08 | 74.35 | 14.43 | 74.76 |
| 77.00 | 1.07 | 1.05 | 84.74 | 18.06 | 84.17 |
| 78.00 | 1.10 | 1.07 | 85.34 | 17.21 | 83.70 |
| 79.00 | 1.09 | 1.04 | 73.44 | 14.73 | 70.21 |
| 80.00 | 1.12 | 1.07 | 68.67 | 11.07 | 65.92 |
| 81.00 | 1.07 | 1.05 | 95.65 | 25.18 | 94.22 |
| 82.00 | 1.09 | 1.10 | 74.36 | 15.66 | 75.07 |
| 83.00 | 1.08 | 1.07 | 83.46 | 13.40 | 82.98 |
| 84.00 | 1.07 | 1.10 | 61.09 | 17.29 | 63.03 |
| 85.00 | 1.07 | 1.09 | 65.50 | 8.43 | 67.05 |
| 86.00 | 1.11 | 1.08 | 65.22 | 10.65 | 63.81 |
| 87.00 | 1.07 | 1.05 | 87.35 | 19.43 | 86.50 |
| 88.00 | 1.09 | 1.08 | 78.21 | 12.93 | 78.04 |
| 89.00 | 1.09 | 1.05 | 75.61 | 16.42 | 73.66 |
| 90.00 | 1.06 | 1.07 | 66.31 | 8.60 | 67.58 |
| 91.00 | 1.09 | 1.08 | 67.72 | 10.68 | 67.72 |
| 92.00 | 1.11 | 1.09 | 68.92 | 7.25 | 67.99 |
| 93.00 | 1.08 | 1.07 | 80.70 | 15.11 | 80.54 |
| 94.00 | 1.10 | 1.09 | 65.33 | 9.70 | 65.24 |
| 95.00 | 1.09 | 1.07 | 73.26 | 13.03 | 71.90 |
| 96.00 | 1.10 | 1.09 | 74.95 | 12.07 | 74.92 |
| 97.00 | 1.09 | | | 17.79 | 91.64 |

| Subject | Ab Scan (cm) | Waist Scan (cm) | Hip Scan (cm) |
|---|---|---|---|
| 1.00 | 75.62 | 76.93 | 100.71 |
| 2.00 | 80.72 | 72.57 | 94.07 |
| 3.00 | 78.59 | 79.50 | 99.36 |
| 4.00 | 78.17 | 77.61 | 97.05 |
| 5.00 | 85.30 | 82.61 | 96.77 |
| 6.00 | 80.21 | 80.07 | 92.08 |
| 7.00 | 79.79 | 77.10 | 95.66 |
| 8.00 | 76.82 | 76.58 | 93.12 |
| 9.00 | 80.06 | 77.83 | 98.20 |
| 10.00 | 82.62 | 82.07 | 96.77 |
| 11.00 | 88.25 | 72.71 | 91.05 |
| 12.00 | 83.10 | 80.82 | 98.57 |
| 13.00 | 84.99 | 83.58 | 100.67 |
| 14.00 | 94.02 | 77.89 | 101.23 |
| 15.00 | 92.93 | 80.76 | 97.58 |
| 16.00 | 86.09 | 75.37 | 100.45 |
| 17.00 | 85.89 | 83.73 | 103.45 |
| 18.00 | 84.70 | 83.84 | 98.35 |
| 19.00 | 83.11 | 81.67 | 105.46 |
| 20.00 | 83.12 | 83.09 | 100.55 |
| 21.00 | 83.82 | 80.91 | 96.55 |
| 22.00 | 87.06 | 85.38 | 106.23 |
| 23.00 | 94.64 | 80.88 | 97.14 |
| 24.00 | 84.41 | 83.33 | 99.15 |
| 25.00 | 84.55 | 84.07 | 102.46 |
| 26.00 | 82.08 | 81.51 | 99.74 |
| 27.00 | 82.57 | 81.73 | 99.94 |
| 28.00 | 86.15 | 82.81 | 99.56 |
| 29.00 | 85.80 | 83.68 | 99.63 |
| 30.00 | 83.38 | 81.77 | 104.10 |
| 31.00 | 89.37 | 87.04 | 106.04 |
| 32.00 | 84.36 | 84.50 | 99.51 |
| 33.00 | 93.90 | 88.59 | 103.29 |
| 34.00 | 83.14 | 82.99 | 101.27 |
| 35.00 | 90.83 | 89.57 | 105.48 |
| 36.00 | 90.97 | 86.07 | 103.31 |
| 37.00 | 87.59 | 82.74 | 103.36 |
| 38.00 | 89.70 | 88.48 | 103.25 |
| 39.00 | 82.61 | 83.21 | 100.77 |
| 40.00 | 83.26 | 82.74 | 99.41 |
| 41.00 | 90.17 | 89.70 | 102.77 |
| 42.00 | 86.23 | 86.68 | 102.39 |
| 43.00 | 85.03 | 83.42 | 103.15 |
| 44.00 | 86.33 | 85.15 | 99.12 |
| 45.00 | 94.55 | 91.58 | 107.49 |
| 46.00 | 88.29 | 86.45 | 104.67 |
| 47.00 | 89.19 | 88.39 | 106.91 |
| 48.00 | 89.01 | 88.16 | 100.75 |

| Subject | Ab Scan (cm) | Waist Scan (cm) | Hip Scan (cm) |
|---|---|---|---|
| 49.00 | 86.38 | 84.02 | 101.64 |
| 50.00 | 90.77 | 91.15 | 107.97 |
| 51.00 | 80.40 | 78.99 | 100.23 |
| 52.00 | 102.20 | 87.84 | 105.82 |
| 53.00 | 90.56 | 89.18 | 101.92 |
| 54.00 | 98.76 | 87.78 | 101.91 |
| 55.00 | 117.43 | 95.07 | 121.04 |
| 56.00 | 89.04 | 86.51 | 104.52 |
| 57.00 | 78.97 | 78.66 | 92.89 |
| 58.00 | 91.43 | 91.02 | 102.37 |
| 59.00 | 88.84 | 85.83 | 103.18 |
| 60.00 | 90.99 | 89.42 | 104.41 |
| 62.00 | 105.95 | 85.71 | 110.54 |
| 63.00 | 87.54 | 86.60 | 99.29 |
| 64.00 | 104.63 | 91.44 | 105.34 |
| 65.00 | 84.74 | 84.52 | 101.60 |
| 66.00 | 101.01 | 87.29 | 102.59 |
| 67.00 | 103.13 | 91.14 | 104.57 |
| 68.00 | 86.85 | 87.39 | 106.60 |
| 69.00 | 103.56 | 95.17 | 106.47 |
| 70.00 | 97.04 | 87.64 | 99.81 |
| 71.00 | 94.15 | 92.98 | 108.29 |
| 72.00 | 90.35 | 90.58 | 104.89 |
| 73.00 | 88.58 | 85.32 | 102.66 |
| 74.00 | 100.59 | 93.84 | 104.48 |
| 75.00 | 97.54 | 93.41 | 112.83 |
| 76.00 | 107.03 | 99.16 | 117.14 |
| 77.00 | 105.76 | 93.60 | 107.44 |
| 78.00 | 99.18 | 95.94 | 108.80 |
| 79.00 | 107.40 | 103.51 | 109.76 |
| 80.00 | 98.25 | 97.46 | 100.90 |
| 81.00 | 105.19 | 101.15 | 116.87 |
| 82.00 | 113.02 | 105.29 | 113.65 |
| 83.00 | 106.71 | 104.99 | 109.58 |
| 84.00 | 112.66 | 100.88 | 115.03 |
| 85.00 | 79.72 | 80.51 | 91.30 |
| 86.00 | 127.95 | 126.43 | 129.61 |