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Validity of Bottle Buoyancy Technique to Determine Body Volume

Michael Firth
Southern Illinois University Carbondale, mfirth@siu.edu

I have completed all the revisions and I am submitting it. Thanks!

VALIDITY OF BOTTLE BUOYANCY TECHNIQUE TO DETERMINE BODY VOLUME

by

Michael Firth

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A Research Paper

Submitted in Partial Fulfillment of the Requirements for the

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RESEARCH APPROVAL

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Approved by:

Dr. Daniel Becque - Chair

Dr. Michael Olson

Graduate School

Southern Illinois University Carbondale

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Introduction

In the past there have been multiple techniques utilized to determine total body volume. Many of these measurements include the use of hydrostatic weighing as a valid determinate of body volume. This type of method applies Archimedes' principle of water displacement where body volume is computed as the difference between body mass measured in air and while submerged in water. There are some other techniques, including whole body air displacement plethysmography, that make use of an apparatus that is set up to measure body volume and are complex and expensive. While these techniques and apparatuses are useful in determining body volume, many of them are not available to groups of individuals, like sport teams and small fitness gyms, due to their complexity and high cost.

Katch, Hortobagyi, and Denahan (1989) introduced a method which involved the use of only a 2 gallon plastic bottle and a graduated cylinder, being the first to introduce the bottle buoyancy technique. This new method also used Archimedes' principle as many other hydrostatic weighing techniques, but in turn was much more cost efficient and simpler to administer. Although this method was created over twenty years ago it has received very little acknowledgement. Gulick and Geigle (2003) tested the validity of this method using a different sized container while still obtaining valid and reliable results. There have been a limited number of other studies that have utilized the bottle buoyancy technique as one method of testing the body composition of collegiate athletes and shown its validity compared to other hydrostatic weighing techniques (Carey & Serfass, 1999; McNeal, Poole, & Sands 1999).

The purpose of this investigation was to investigate the validity of the bottle buoyancy technique within a large, yet relatively still body of water, such as a swimming pool. If accurate compared to the valid hydrostatic weighing technique then the bottle buoyancy method presents a simple and inexpensive method that could be used in a variety of locations eliminating the use of a laboratory setting for the determination of body volume.

Method

Subjects

Eighteen individuals from an undergraduate collegiate swim team participated in this study. The recruitment process and data collection procedures were approved by the SIUC Human Subjects Committee. The following were the physical characteristics for the subjects: males (n=10), age = 19.3 ±1.19 years, height = 180.2 ±6.39 cm, body mass = 74.53 ±5.83 kg; females (n=8), age = 19.6 ±1.11 years, height = 168.5 ±7.37 cm, body mass = 67.13 ±5.87 kg. Before the testing began, the subjects were instructed on the procedures for each technique, and then reminded again the days of the testing. Written consent was obtained before testing.

Procedure

There were two different methods used to measure body volume. The hydrostatic weighing technique was performed in a 1.19 x 0.73 x 1.19 meter tank containing 940 L of water with the participant sitting in a weighted PVC pipe chair with warm water (~32℃) up to their neck. The chair was attached to a Chatillion scale of which the baseline mass was recorded. The participant began by sitting with their head out of the water. The participants completed a full expiration of the air from their lungs and then bent forward putting their head underwater. While their head was underwater, the participant's mass was recorded to the nearest 0.01 kg. The participant's head was underwater for 5-10 seconds until a stable reading of the scale was observed. A minimum of six trials were conducted to determine mass underwater of the participants. The participant's comfort level determined the rest period in between each trial. The last five trials were averaged for each participant to estimate mass underwater.

The body volume of each participant was determined using the following equation:

Volume = {[Ma - (Mw - Tare)] / Dw} - RLV

Where Ma = mass in air (kg)

Mw = mass under water (kg)

Dw = temperature correction for water density at time of weighing

RLV = residual lung volume (Liters)

The subject's RLV was determined by measuring their vital capacity with a spirometer. The vital capacity in Liters was used to estimate RLV.

RLV = Vital Capacity *0.22 (for all males)

RLV = Vital Capacity *0.24 (for all females)

The bottle buoyancy technique was performed in the shallow end of the student recreation center pool (22.86 meters x 50 meters, ranging from 1.0 meter to 3.66 meters in depth) containing at least 1.72 million Liters of water at a depth of approximately 1.5 meters. The empty 5 gallon plastic Nalgene bottle was weighed to the nearest 0.1 kg to give a baseline mass. An initial amount of water was added to the bottle before the first trial of each participant. The participants were told to hold onto the bottle, with the cap attached, with both arms wrapped around it against their body. They then completed a full expiration of the air in their lungs and submerged their whole body under the water while holding their breath. The goal was for the participant to achieve a position in the water that makes them neither float to the surface nor sink to the bottom. If the participant sank toward the bottom of the pool the experimenter poured out a slight amount of the water in the bottle. If the participant floated to the surface of the water the experimenter added slightly more water to the bottle. Once the participant maintained a position of neutral buoyancy for two trials in a row the bottle and the water contained in it was weighed on the scale and mass was recorded. A correction factor of 0.20251 kg was determined as the amount of mass needed to sink the plastic bottle itself to compensate for the buoyancy of the bottle itself. This mass was in turn added to the body volume formula as the water weight.

The body volume for the bottle buoyancy technique was determined with the following equation:

Volume = [Ma - ((Mw + bottle buoyancy) * Dw)] / Dw - RLV

Statistics

A repeated measures analysis of variance was used to determine differences between the mean body volumes (SuperAnova, Abacus Concepts, Berkley, CA.). The validity of the study was examined using a spreadsheet (Hopkins, 2000).

Results

The means and standard deviations for the body volume, body density, and percent body fat are presented in Table 1. The mean body volume difference for the group was 532 mL or 0.78%. This small difference between under water weighing (UWW) and the bottle buoyancy method was significant $F(1,17) = 5.237$, $p = .0352$. The relationship between UWW and the bottle buoyancy method is shown in Figure 1. The slope of the line was 1.065, 90% CI [1.003, 1.127]. The intercept of the line was -3.895, 90% CI [-8.131, 0.340]. The Pearson correlation was .99, 90% CI [.98, 1.00]. The typical error of the estimate was 0.92 Liters, 90% CI [0.72, 1.31]. The standardized typical error of the estimate was 14%, 90% CI [11, 19] of the mean body volume. The standardized typical error of the estimate for percent body fat was 31%, 90% CI [24, 44] of the mean percentage body fat.

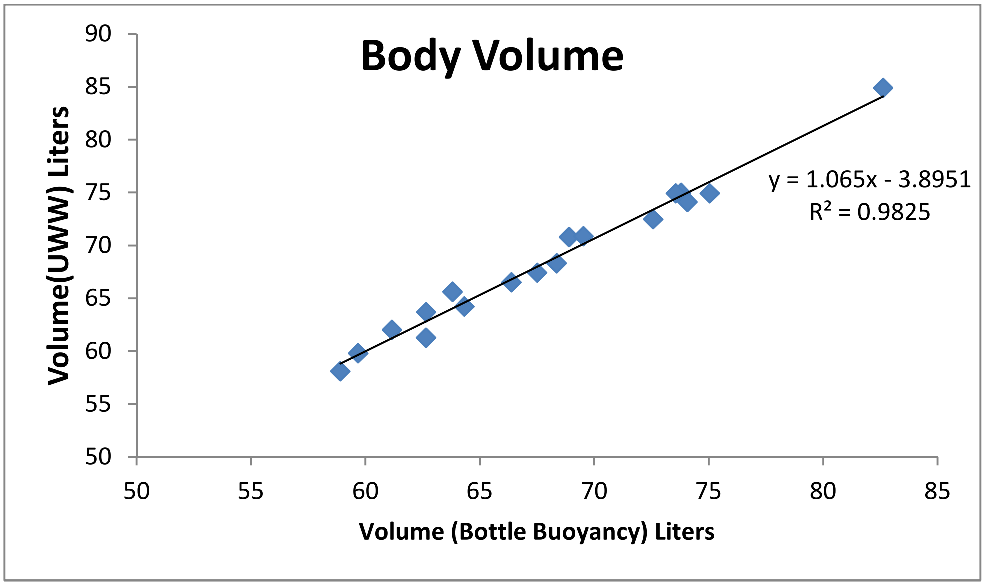

Figure 1. Regression of body volume (UWW) and body volume (bottle buoyancy).

Table 1. Comparative means and standard deviations of Body Volume, Body Density, and % Body Fat determined by the UWW and bottle buoyancy methods.

Variable	Mean	SD
Males (n=10)		
Volume Chair (Liters)*	71.5	5.6
Volume Bottle (Liters)	70.6	4.9
Density Chair (kg/L)	1.0574	0.0130
Density Bottle (kg/L)	1.0659	0.0163
% Body Fat Chair	16.7	4.1
% Body Fat Bottle	14.5	6.5
Females (n=8)		
Volume Chair (Liters)	65.1	5.9
Volume Bottle (Liters)	64.9	5.6
Density Chair (kg/L)	1.0402	0.0063
Density Bottle (kg/L)	1.0427	0.0104
% Body Fat Chair	25.9	2.8
% Body Fat Bottle	24.8	4.7

Combined (n=18)		
Volume Chair (Liters)	68.6	6.8
Volume Bottle (Liters)	68.1	6.3
Density Chair (kg/L)	1.0518	0.0135
Density Bottle (kg/L)	1.0484	0.0137
% Body Fat Chair	20.8	6.0
% Body Fat Bottle	22.2	6.2

*Chair : Underwater Weighing

Discussion

The results of the present study demonstrate that the bottle buoyancy procedure is a valid method for the determination of body volume as the correlation of the two techniques approached 1.0. The overall difference in body volume for men and women combined was 532 mL when comparing the scale/chair technique with the bottle technique. Although this results in a small difference, it results in a large 14% typical error in body volume. The typical error is magnified to 31% when these body volumes are used to calculate percent body fat.

Other techniques for determining body composition, like the dual-energy x-ray absorptiometry, are not very cost effective and the time needed to run these other tests is not efficient for multiple subjects at a time. If multiple bottles are available for use, the bottle buoyancy procedure can be utilized to test many subjects over a reasonable amount of time. With each test taking between 10-15 minutes a whole team of ~ 20 participants could be tested in less than an hour if five bottles were available. There is also very little set up time needed to prepare for the bottle buoyancy procedure, and little if any training is needed for the testers in order to perform the test on others. With all these variables taken into account, the bottle buoyancy technique can be a highly useful technique in order to periodically determine the body volume of an athlete over the course of a season or career, or an individual attempting to alter their body composition over a period of time.

The body density and percent body fat calculations are not as accurate as the body volume determination and that may be due to the fact that over 60% of the subjects were not able to complete both tests within 3 days of each other as originally planned. The last day for testing had to be cancelled due to inclement weather and the earliest time available to test again was over a week later due to spring break. This could be a factor in the higher body density and percent body fat determinations in the chair/scale procedure since that technique was performed after the bottle buoyancy technique.

The RLV for this study was determined using the subjects vital lung capacity, but it could also be estimated with little loss in accuracy in body density computation by other factors when testing for vital lung capacity is not available (Wilmore, 1980).

Conclusion

The results of this study provide supporting evidence that the bottle buoyancy technique is equal to the UWW in the determination of body volume. This simple and cheap technique can be used instead of UWW when a pool with a depth of at least four feet, a scale, and a large bottle are available for use. With the use of multiple bottles, multiple individuals can be tested at one time, and this will decrease the overall time needed to test a group or team. This quick and portable technique can be a useful technique for the coach of an athletic team or an athletic trainer to track the athlete's or client's body composition over a certain period of time.

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VITA

Graduate School
Southern Illinois University

Michael J. Firth

mfirth@siu.edu

Illinois Wesleyan University
Bachelor of Science, Chemistry, April 2012

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Major Professor: Dr. Daniel Becque