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Head Out of Water Weighing: A Valid Method to Measure Body Fat Storage?

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HEAD ABOVE WATER WEIGHING: A VALID METHOD TO MEASURE BODY FAT STORAGE?
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ABSTRACT
Hydrostatic weighing using underwater weighing with full lung expiration has been established as a valid method to assess body composition; however, many people do not prefer to submerge their heads in water due to various reasons. Keeping the head above water as a method for hydrostatic weighing at full lung capacity has been tested but has not been accepted as an alternative method. Purpose: The main purpose of this study is to determine if hydrostatic weighing with the head above water at residual volume could provide valid estimates of total body fat. Methods: Fifty-eight subjects (F=29, M=29) participated in performing four different methods of underwater weighing: complete immersion with full lung expiration (UWW_{TLC}), complete immersion with total lung capacity (UWW_{TLC}), partial immersion with the head above water at full lung expiration (HAW_{TLC}), and partial immersion with the head above water at total lung capacity (HAW_{TLC}). Bland-Altman Plots were created and regression analyses were used to test for proportional bias across the range of means. Results: There was no significant difference between HAW_{TLC} and UWW_{TLC} for both males and females. However, a Bland-Altman plot indicated the range of error between these methods was >5% body fat for both genders. There was a significant difference between HAW_{RV} versus HAW_{TLC} in both males (t = 4.616, df = 28, p<0.001) and females (t = -14.661, df = 28, p<0.001). Conclusion: These results indicate that although the mean difference between HAW_{RV} and UWW_{TLC} was not significantly different, the large range of error at 95% confidence levels suggests it might not be suitable as a substitute.

INTRODUCTION
Hydrostatic weighing has been considered the “gold standard” in the assessment of body composition for more than 50 years. The initial work by Behnke et al. (1942) measured weight in water with the head totally immersed with full expiration (only residual volume) and with full immersion (total lung capacity). The results of their study was underwater weighing with full expiration can be used to predict body fat in adults with a simple regression equation.

In the 1990s, some modifications were made to this standard method by suggesting a “head above water” weighing at total lung capacity could be an alternative for those with fear of water and those who could not bend forward to fully exhale the air from their lungs. Donnelly et al. (1988) provided a regression equation that has been reported in textbooks for use with healthy adults. This linear regression equation provided an adjustment (y-intercept), which allowed for expected differences in water weight when the head was positioned above the water.

The need to determine total lung capacity in the water during the actual weighing creates some potential problems for subjects who have restrictive lung disorders (cannot inhale maximally), or with large lung volumes and high body fat that create a “negative” value for water weight. The method proposed for this study, head above water with full expiration of air in the lungs, provides another alternative for those wishing to be measured for body composition using densitometry. The main purpose of this study is to determine if hydrostatic weighing with the head above water at residual volume could provide valid estimates of total body fat.

METHODS
Twenty-nine males and 29 females were selected for the analyses. Age, stature (cm) and dry land mass (kg) were recorded for each subject. Vital capacity and residual volume (in liters) were determined using standard techniques.

Four different methods of hydrostatic weighing were performed in the following order to obtain water weight:

Method 1: Total immersion, maximal expiration (UWW_{TLC})
Method 2: Total immersion, maximal inhalation (UWW_{TLC})
Method 3: Partial immersion, maximal expiration (HAW_{TLC})
Method 4: Partial immersion, maximal inhalation (HAW_{TLC})

DATA ANALYSIS
The mean group differences of water weights between UWW_{TLC} and HAW_{TLC} were applied to the calculation of body volume for the HAW_{TLC} method. These body volume measures were then used to calculate body density (kg/L), and using the Siri equation to estimate body fat percentage. Descriptive statistics were used to identify means, standard deviations (SD), and ranges for each method used in this study.

Mean differences and standard deviations were calculated for each comparison and the 95 percent confidence intervals were calculated using 1.96 * standard deviation added to (upper) or subtracting from (lower) the mean. Bland-Altman Plots were then created to illustrate agreement between two methods reporting the mean difference and 95% level of confidence limits. Regression analyses were used to test for significance across the range of subject data to detect proportional bias.

RESULTS
For males, mean age, stature, and mass were 24.5 ± 4.7 yrs, 171.1 ± 8.1 cm, and 67.7 ± 7.6 kg, respectively. For females, mean age, stature, and mass were 22.0 ± 5.5 yrs, 177.5 ± 14.8 cm, and 74.0 ± 7.1 kg, respectively. Table 1 shows the body fat percentage for each method.

Table 1. Body Fat Percentage: Mean, SD, and Range

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean (%)</th>
<th>SD (%)</th>
<th>Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UWW_{TLC} (Males)</td>
<td>17.24</td>
<td>7.02</td>
<td>4.41 – 32.18</td>
</tr>
<tr>
<td>HAW_{TLC} (Males)</td>
<td>17.59</td>
<td>7.47</td>
<td>2.55 – 34.36</td>
</tr>
<tr>
<td>UWW_{TLC} (Females)</td>
<td>24.47</td>
<td>5.66</td>
<td>13.38 – 34.98</td>
</tr>
<tr>
<td>HAW_{TLC} (Females)</td>
<td>24.59</td>
<td>5.51</td>
<td>14.84 – 34.94</td>
</tr>
<tr>
<td>HAW_{RV} (Males)</td>
<td>14.60</td>
<td>7.59</td>
<td>1.28 – 31.12</td>
</tr>
<tr>
<td>HAW_{RV} (Females)</td>
<td>17.15</td>
<td>5.76</td>
<td>6.69 – 32.77</td>
</tr>
</tbody>
</table>

CONCLUSION
Although the body fat percentage between UWW_{TLC} and HAW_{TLC} was not significant, applying the 95% confidence interval results in a large error (>5%) in the estimate of body fat percentage. Therefore this method is not accepted as a replacement for the standard underwater weighing technique.