Reliability of Measuring Subcutaneous Fat Tissue Thickness Using Ultrasound in Non-Athletic Young Adults

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ABSTRACT

Background: Obesity is a major health burden worldwide. A method of assessing uncompressed subcutaneous adipose tissue thickness (USATT) using ultrasound is widely used in sports medicine. However, studies on the reliability of the method in non-athletic people are lacking. We aim to determine the reliability of the human observer in measuring the USATT in non-athletic people.

Material and method: Two young non-athletic, volunteers, having normal body mass, one male (24 years, BMI=21.6 kg/m²) and one female (31 years, BMI=20.73 kg/m²) were measured by 15 observers, 3 times, in 3 gender specific sites. There were 7 expert observers and 8 novices. We used a Hosand BX 2000 Ultrasonic Adipometer to measure USATT.

Outcomes: 91% of the measurement’s deviations from the mean were between -4 and 4 mm. Variance of deviation from mean measurements for novices was 5.93 mm, while for experts it was 5.40 mm. Standard error of measurement (SEM) and intraclass correlation coefficient (ICC) for calculated body fat percentage (BF%) (intra-observer SEM=0.78, ICC=0.98; inter-observer SEM=0.45, ICC=0.99) and for all the USATT measurements (intra-observer SEM=0.54, ICC=0.98; inter-observer SEM=0.75, ICC=0.96), showed excellent reliability. The expert observers showed slightly higher ICC and lower SEM values compared to novices.

Conclusion: The intra and inter-observer reliability of the adipometer was very good in measuring the USATT. There was no notable difference between expert and novice observers, thus suggesting that the method can be reliably used by anyone after a brief training, for both research and clinical practice.

Keywords: uncompressed subcutaneous adipose tissue thickness, non-athletic adults, ultrasound, reliability
BACKGROUND

Obesity is a major health burden worldwide. The global prevalence of the overweight and obese is on the rise affecting both developed and developing countries, men and women, adults and children (1). The Global Burden of Disease Study estimated that the proportion of overweight or obese adults in 2013 was 36% in men and 37% in women worldwide (2). There is stringent need to monitor and treat obesity and its comorbidities (3,4). Body composition assessments vary in precision and in the target tissue of interest. For large studies or for nutritional screening and follow-up the most common assessments tools are anthropometric and include measuring weight and stature. These measures are quick, simple and require only limited training. Calculating the body mass index (BMI) is the most used assessment tool however is gives modest data on the body composition (5). Measuring abdominal circumference and skinfold require more training and carry different degrees of error with them. The magnitude of measurement errors is essential in interpreting the results of anthropometric assessments (6). More complex methods such as bioelectrical impedance, dual-energy X-ray absorptiometry, body density, and total body water estimates (7). All the methods have advantages and shortcomings. A new method of assessing uncompressed subcutaneous adipose tissue thickness (USCATT) using ultrasound is widely applied in sports medicine (8-10). However, studies on the reliability of this method in non-athletic people are lacking.

This paper aims to determine the reliability of the human observer in measuring the uncompressed subcutaneous adipose tissue thickness (USCATT) using ultrasound in non-athletic people. Two forms of observer reliability are discussed: the intra-observer (or within observer) reliability – the degree to which measurements taken by the same observer are consistent; the inter-observer (or between observers) reliability – the degree to which measurements taken by different observers are similar.

MATERIAL AND METHODS

Participants:

Two young non-athletic, volunteers, having normal body mass, one male (24 years, BMI=21.6 kg/m²) and one female (31 years, BMI=20.73 kg/m²) were measured by 15 observers, 3 times, in 3 gender specific sites. The observers were fifteen medical students that took ultrasonic measurements at 3 gender specific sites after a brief initial training.

Observers:

Observers were separated in two groups: experts (n=7) and novices (n=8). The experts had previously used the adipometer and had performed at least 500 measurements, while novices had no prior experience with this equipment. All the observers were instructed on how to handle the ultrasonic equipment for taking measurements at the established anatomic sites.

Anthropometric measurements method and evaluation procedures:

All measurements were made during the morning hours. Height was determined using a stadiometer and body mass was determined using a calibrated digital scale. We calculated body mass index (BMI) as weight/(height in meters)². We used the World Health Organization (WHO) definitions for overweight: a body mass index (BMI) of ≥25 kg/m², and for obesity a BMI of ≥30 kg/m².

Ultrasonic measurement technique and evaluation procedures

The measurements were made in a hydrated state, in standing position. We used a Ho­sand BX 2000 Ultrasonic Adipometer sistem in ‘default’ setting. Measurements were done by applying the device to the skin; while previously, a thin coating of water-soluble gel was applied to the contact surface of the device. The transducer was positioned carefully to avoid compression of the subcutaneous fat. The transducer was held parallel to the direction of the skinfold in order to assure precise depth analyses, as an angulation of interfaces different than 90 degrees, may result in a transmission parallax error (11). During the measurement, the Adipometer was glided slightly back and forth along the skin surface (approximately 5 mm from the measurement site) to provide local averaging of the measurements, over a period of 3 to 5 seconds. Subcutaneous adipose thickness was then calculated using the prediction equations supplied by the man-
manufacturer’s computer algorithm. The measurements were made at the three gender specific anatomic ISAK sites (protocol of the International Society for the Advancement of Kinanthrometry (12)) on the left side of the body: triceps, subscapular, chest in the male and triceps, abdomen, supraspinale (above iliac crest) in the female. The anatomical sites were not set with mark on the skin. Each observer set the site before each measurement.

Ethics

Permission to undertake the study was provided by the Ethics Commission of “Victor Babes” University of Medicine and Pharmacy, Timisoara. The participants and the observers signed a written consent form after discussing the methods and aims of the study with the investigators.

Statistics

Statistical analysis was performed with SPSS (IBM SPSS Statistics V.22). Descriptive statistics provide mean, standard deviation, minimum and maximum for all variables. Reliability assessment was done using intraclass correlation coefficient (ICC, alpha two way mixed, absolute agreement), Cronbach’s alpha and Standard Error of Measurement (SEM=SD*√(1-Cronbach’s α)) were calculated for all and for each uncompressed subcutaneous adipose tissue thickness measurement, at three ISAK sites. ICC and Cronbach’s α values between 0.7-0.9 were considered representative of a good reliability, while a value above 0.9 was considered representative for a very good reliability. The closer the SEM is to 0, the higher is the reliability (13). Linear correlation fit line and 95% Confidence Intervals (CI) lines from regression analysis as well as Pearson’s regression coefficient squared (R2) are given (Figure 1).

OUTCOMES

Descriptive statistics are presented in Table 1, for the male and the female. They both had normal weight according to BMI under 25 kg/m², however the female had more subcutaneous adipose tissue thickness, and higher body fat percentage compared to the male.

Figure 1 depicts the observer’s deviations from the mean in all the adipometer measurements (in mm), from novice observers (A.) and expert observer (B.) for male and female at each anatomical site. Confidence intervals are also presented as upper and lower 95% CI. Most (91%) of the measurement deviations from the mean were between -4 and 4 mm. Mean deviations for novices was -0.35 (SD=2.43); variance=5.93, while for experts it was 0.42 (SD=2.32), and variance=5.40 p=0.007 (paired t test).

Intra and interobserver reliability assessment are presented in Table 2 and 3, SEM, ICC and the 95% CI of calculated body fat percentage and all the subcutaneous adipose thickness measurements, at all the sites, in the male and female (n=270 measurements) are presented in Table 2 and are also detailed for expert (n=144 measurements) and novice observers (n=126 measurements). All values for inter and intra-observer ICC, both in expert and novice observers, were above 0.9, showing excellent reliability. However, the expert observers showed slightly higher ICC and lower SEM values compared to novices.

Table 3 presents intra and inter-observer reliability assessment of calculated BF% and the USATT (n=45 measurements) as ICC and 95% CI. The intra-observer reliability was good (above 0.7) for calculated body fat percentage and for measurements at each site, except for female abdomen. The inter-observer reliability was good for all sites in the male and the female, but poor for the male subscapular and female abdomen sites (ICC < 0.7). The further separation into expert and novice observer for each site is not shown because it implies comparison of only 7 and 8 measurements respectively, thus the split analysis was not considered significant.

FIGURE 1. Deviations from the mean value of all measurements from novice observers (A.) and expert observer (B.) for male and female at each anatomical site.
DISCUSSION

We are proposing a new assessment method for subcutaneous adipose tissue using ultrasound in non-athletic adults. In fact, trying to extend the use of this method form the sports medicine into the routine clinical practice of an internist or nutritionist evaluating a normal weight or overweight person. Estimating the reliability of this method on people that are not professional athletes is very important in this context. Reliability is the consistency of a measurement. It is assessed in the sciences literature in many ways, however the most frequently used are the intraclass correlation coefficient (ICC) and the standard error of measurement SEM, which can be calculated from the ICC (13). The SEM is an indication of the precision of a measurement.

In our study, most of the observer’s deviations from the mean, in all the adipometer measurements, were between -4 and 4 mm. Deviation variance was slightly lower for experts (5.40) versus novices (5.93), which is to be expected for any measurement. However, intra and interobserver reliability assessment for all measurements and calculated BF% showed excellent reliability in both expert and novice observers, ICC above 0.9, SEM below 1.

In detailed analysis, the intra-observer reliability was good or excellent (ICC above 0.7 or above 0.9 respectively) for calculated body fat percentage and for measurements at each site, except for female abdomen. The inter-observer reliability was good for calculated body fat in the male and the female, but poor for the male subscapular and female abdomen sites. Measurement sites were used according to the ISAK protocol (International Society for the Advancement of Kinanthrometry). However, these anatomical sites have been selected for skinfold measurement and not for ultrasound. In particular, the subscapular and abdomen

<table>
<thead>
<tr>
<th>Variables</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>BMI (kg/m²)</th>
<th>Body fat% - adipometer, 15 observers</th>
<th>Mean Subscapular - adipometer (mm)</th>
<th>Mean Chest - adipometer (mm)</th>
<th>Mean Triceps - adipometer (mm)</th>
<th>Mean Supraspinale - adipometer (mm)</th>
<th>Mean Abdomen - adipometer (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>male</td>
<td>24</td>
<td>69</td>
<td>179</td>
<td>21.56</td>
<td>12.95</td>
<td>5.48</td>
<td>5.67</td>
<td>5.65</td>
<td>10.59</td>
<td>11.98</td>
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<tr>
<td>female</td>
<td>31</td>
<td>62</td>
<td>173</td>
<td>20.73</td>
<td>25.18</td>
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</table>

TABLE 1. Descriptive statistics.

<table>
<thead>
<tr>
<th>SEM</th>
<th>Cronbach’s alpha</th>
<th>ICC</th>
<th>CI 95% Lower Bound</th>
<th>CI 95% Upper Bound</th>
<th>Observer</th>
<th>ICC</th>
<th>CI 95% Lower Bound</th>
<th>CI 95% Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF% Intra-observer</td>
<td>0.779</td>
<td>0.985</td>
<td>0.973</td>
<td>0.992</td>
<td>novice</td>
<td>0.982</td>
<td>0.96</td>
<td>0.993</td>
</tr>
<tr>
<td>all sites Intra-observer</td>
<td>0.543</td>
<td>0.983</td>
<td>0.973</td>
<td>0.958</td>
<td>novice</td>
<td>0.919</td>
<td>0.868</td>
<td>0.935</td>
</tr>
<tr>
<td>BF% Inter-observer</td>
<td>0.450</td>
<td>0.995</td>
<td>0.985</td>
<td>0.999</td>
<td>expert</td>
<td>0.991</td>
<td>0.969</td>
<td>0.999</td>
</tr>
<tr>
<td>all sites Inter-observer</td>
<td>0.757</td>
<td>0.967</td>
<td>0.935</td>
<td>0.984</td>
<td>novice</td>
<td>0.991</td>
<td>0.972</td>
<td>0.999</td>
</tr>
</tbody>
</table>

TABLE 2. Intra and inter-observer reliability assessment of calculated body fat percentage and all the subcutaneous adipose thickness measurements, at all the sites, in the male and female and further detailed in expert and novice observers.

SEM = standard error of measurement; ICC = intra-class correlation coefficient; CI = confidence interval.

<table>
<thead>
<tr>
<th>ICC</th>
<th>CI 95% Lower Bound</th>
<th>CI 95% Upper Bound</th>
<th>ICC</th>
<th>CI 95% Lower Bound</th>
<th>CI 95% Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>male BF%</td>
<td>0.960</td>
<td>0.249</td>
<td>0.889</td>
<td>male BF%</td>
<td>0.945</td>
</tr>
<tr>
<td>male triceps</td>
<td>0.721</td>
<td>0.287</td>
<td>0.822</td>
<td>male triceps</td>
<td>0.980</td>
</tr>
<tr>
<td>male subscapular</td>
<td>0.761</td>
<td>0.451</td>
<td>0.91</td>
<td>male subscapular</td>
<td>0.571</td>
</tr>
<tr>
<td>male chest</td>
<td>0.846</td>
<td>0.642</td>
<td>0.943</td>
<td>male chest</td>
<td>0.679</td>
</tr>
<tr>
<td>female BF%</td>
<td>0.856</td>
<td>0.440</td>
<td>0.91</td>
<td>female BF%</td>
<td>0.832</td>
</tr>
<tr>
<td>female triceps</td>
<td>0.926</td>
<td>0.825</td>
<td>0.973</td>
<td>female triceps</td>
<td>0.952</td>
</tr>
<tr>
<td>female abdomen</td>
<td>0.550</td>
<td>0.101</td>
<td>0.839</td>
<td>female abdomen</td>
<td>0.535</td>
</tr>
<tr>
<td>female supraspinale</td>
<td>0.734</td>
<td>0.387</td>
<td>0.901</td>
<td>female supraspinale</td>
<td>0.831</td>
</tr>
</tbody>
</table>

TABLE 3. Intra and inter-observer reliability assessment of calculated body fat percentage and the subcutaneous adipose thickness measurements, at each site, in the male and female separately.

ICC = intra-class correlation coefficient; CI = confidence interval.
sites can cause identification problems of subcutaneous borders as shown by Muller et al (14,15). In their studies on athletes, the ISAK sites on the limbs showed simple ultrasound structures, however, at the trunk sites, there were anatomical identification problems. Camper’s fascia, at the abdomen caused large measurement deviations between observers (15). At the subcapular site, the presence of two visible bands in the ultrasound image instead of just one muscle-fascia boundary also led to image interpretation confusions (15). The authors proposed that in defining ultrasound sites we should not use only landmarks on the surface, but also ‘landmarks’ contained in the ultrasound image. In addition, for optimising and standardising this ultrasound measurement approach a systematic research for determining the best sites for USATT measurement are needed (14). Ideal sites for ultrasound measurement of subcutaneous adipose thickness should have simple structures; the thickness of the layer should not change appreciably in the vicinity, and their predictive value for total body fat should be high (15).

We used the computer algorithm of the Hosand BX 2000 Ultrasonic Adipometer to control the output of the subcutaneous adipose tissue segmentation process in order to eliminate human variability in interpreting the images of embedded fibrous tissues. Nonetheless, analysis and interpretation of complex biological structures may not be replaced in all cases by computer algorithms. Conversely, the computer algorithm could provide accurate and easy use for any observer in the field, with just a brief training.

The advantages of the ultrasound technique for assessing adipose tissues thickness are:

- it is a non-invasive, non-radiating technique;
- tissue thickness limits can range from 1 to 300 mm;
- quick evaluation process; subject involvement is minimal;
- it can be applied in a medical office or in a field setting;
- the costs are low when compared with other methods for assessing body composition (body impedance, DEXA, CT, MRI).

CONCLUSION

The intra and inter-observer reliability of the adipometer was very good in measuring the uncompressed subcutaneous adipose tissue thickness. Expert and novice observers differed only negligibly in their reliability, thus suggesting that the method can be reliably used by anyone after a brief training. This ultrasound method for assessing subcutaneous adipose tissue thickness in non-athletic young adults supports is applicable with high accuracy and reliability, both for research and clinical purposes. This method may come to rival the widely used skinfold, bioimpedance, and other methods with their well-known weaknesses.

Conflict of interests: none declared.

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