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Relationships between Body Fat Measured by DXA and Subcutaneous Adipose Tissue Thickness Measured by Lipometer in Adults

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Abstract The aim of this study was to examine the relationships between body fat measured by DXA and subcutaneous adipose tissue layers (SAT-layers) measured by LIPOMETER in adult males (n=28) and females (n=53). Body height and mass were measured and BMI was calculated (kg/m2). Measurements of the thicknesses of SAT-layers by LIPOMETER were performed at 15 original body sites. Body composition was measured using DXA. Total body fat % measured by DXA was highly dependent on the SAT-layers in the upper back and inner thigh in males (87.1%, $R^2\times100$) and the lateral chest, biceps, and calf in females (78.5%, $R^2\times100$). There were gender differences in trunk fat mass and right hand and leg fat mass calculation using specific SAT-layers. In conclusion, our results indicate that there are close relationships between SAT-layers and body fat measured by DXA. However, there are big differences between genders. *J Physiol Anthropol 26(4): 513–516, 2007*
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Introduction

Body composition is frequently used as one of several indicators of the overall health of the population. A variety of methods are used to estimate body composition. Inexpensive and non-invasive body composition methods are sought as alternatives to the expensive and cumbersome classical hydrodensitometry (Behnke et al., 1942), dual energy X-ray absorptiometry (DXA, Mazess et al., 1990), computed tomography (Fowler et al., 1991), or air-displacement plethysmography (Ittenbach et al., 2006).

Subcutaneous adipose tissue thickness is frequently measured by skinfold calipers (Jackson et al., 1980), ultrasound (Booth et al., 1966) or near-infrared spectroscopy (Conway et al., 1984). Selection of method to use may be based upon a variety of factors, including (but not limited to) cost, size, portability, technical complexity (whether easy to use), and, finally, reliability and validity of measurements.

The LIPOMETER is an optical device for measuring the thickness of a subcutaneous adipose tissue layer. It offers a non-invasive, quick, precise, and safe way of measuring a fat layer. The LIPOMETER illuminates the interesting layer, measures the backscattered light signals and from these it computes absolute values of subcutaneous adipose tissue layer thickness (Möller et al., 1994). LIPOMETER results have been reasonably well validated previously in adults using total body electrical conductivity (TOBEC, Möller et al., 2000), in children with skinfold thicknesses and bioelectrical impedance analysis (BIA, Jürimäe et al., 2003), in adults using BIA (Jürimäe et al., 2005), and in adults using computer tomography (Möller et al., 1999). At present, more validation studies are needed using DXA as a criterion method (Mazess et al., 1990). Unfortunately, the results of the LIPOMETER are not yet well validated against body fat parameters measured by DXA. We hypothesized that the body fat measured by DXA is highly correlated with SAT-layers because most of the fat tissue is located subcutaneously. Secondly, the thickness of SAT-layers measured on the trunk or limbs is highly related to fat mass on the trunk or limbs measured by DXA. The aim of this study was to examine the relationships between body fat measured by DXA and SAT-layers measured by LIPOMETER in adult males and females.

Methods

The subjects of this study were 28 healthy males and 53 females aged 22–62 years. This study was approved by the

Medical Ethics Committee of the University of Graz (Austria). Body height was measured using a Martin metal anthropometer in cm (±0.5 cm) and body mass with medical scales in kg (±0.05 kg), from which the body mass index (BMI kg/m^2) was calculated.

Measurement for the thickness of SAT-layers by LIPOMETER was performed in mm at 15 original body sites (neck, triceps, biceps, upper back, front chest, lateral chest, upper abdomen, lower abdomen, lower back, hip, front thigh, lateral thigh, rear thigh, inner thigh, calf) on the right side of the body in the standing position (Möller et al., 1994). The coefficients of variation of SAT-layers range between 1.9% for SAT-layer front chest and 12.2% for SAT-layer rear thigh (Möller et al., 2000). The LIPOMETER uses light-emitting diodes, which illuminate the interesting SAT-layer, forming certain geometrical patterns varying in succession. A photodiode measures the corresponding light intensities backscattered in the subcutaneous adipose tissue. These light signals are amplified, digitized, and stored on computer (Möller et al., 1999).

Body composition was measured using DXA. Scans of the whole body were performed using a Lunar DPX-IQ scanner (Lunar Corporation, USA). Total body fat %, fat mass and separately trunk fat mass and right arm and leg fat mass were measured. Trunk fat mass measured by DXA was compared with SAT-layers located on the trunk—neck, upper back, lower back, inner chest, hip, front chest, upper abdomen, and lower abdomen. Additionally we selected upper trunk SAT-layers (neck, upper back, front chest, lateral chest) and lower trunk SAT-layers (upper abdomen, lower abdomen, lower back, hip) (Horejsi et al., 2002). Right arm fat mass measured by DXA was compared with SAT-layers in triceps and biceps and right leg fat mass with SAT-layers in rear thigh, calf, lateral thigh, front thigh, and inner thigh.

Statistical analysis was performed with SPSS 11.0 for Windows (Chicago, IL, USA). Means and standard deviations (±SD) were determined. Statistical comparisons between genders were made using independent t-tests. The effect of different single SAT-layers to the body fat % and mass measured by DXA was analyzed using stepwise multiple regression analysis. Significance was set at $p<0.05$.

Table 1 Anthropometry, body composition and 15 sat-layers of the subjects ($\bar{X}\pm$SD)

	Males (n=28)	Females (n=53)	p
Age (yrs)	33.9±16.6	40.2±10.6	<0.01
Height (cm)	182.1±7.1	166.9±5.8	<0.001
Body mass (kg)	82.3±16.0	77.2±16.3	<0.05
BMI (kg/m^2)	24.8±4.6	27.7±5.9	<0.01
DXA body fat %	15.3±7.4	34.0±8.2	<0.001
DXA body fat mass (kg)	13.3±8.8	26.6±10.4	<0.001
LIPOMETER thickness of SAT-layers (mm)			
Neck	4.6±4.3	9.6±5.9	<0.001
Triceps	4.7±2.8	15.1±6.2	<0.001
Biceps	2.1±1.7	9.9±4.9	<0.001
Upper back	3.4±2.8	9.9±5.8	<0.001
Front chest	4.8±4.1	11.1±6.9	<0.001
Lateral chest	4.4±4.1	14.2±9.6	<0.001
Upper abdomen	7.0±6.4	13.4±6.9	<0.001
Lower abdomen	6.2±5.0	11.0±6.6	<0.001
Lower back	6.1±3.4	12.0±5.5	<0.001
Hip	6.0±4.6	13.4±6.6	<0.001
Front thigh	2.6±1.6	8.2±3.2	<0.001
Lateral thigh	2.3±1.3	8.6±3.0	<0.001
Rear thigh	1.9±1.2	6.0±3.0	<0.001
Inner thigh	4.2±3.0	10.1±3.6	<0.001
Calf	1.4±0.9	3.8±1.9	<0.001

Results

Mean anthropometrical and body composition parameters and 15 SAT-layers are presented in Table 1. Females were older than males, males were taller and heavier than females, and BMI was higher in females. Body fat % and mass measured by DXA were higher in females. All measured SAT-layers were higher in females.

Results of the stepwise multiple regression analysis, where the dependent variables were total body fat %, body fat mass, and fat mass of trunk, arm, and leg and the independent variables were SAT-layers measured by LIPOMETER, are presented in Table 2. Upper back and inner thigh SAT-layers in males and lateral chest, biceps, and calf in females explained 87.1% ($R^2\times100$) and 78.5% of the total variance in body fat %, respectively. Total body fat mass was explained to some degree by other SAT-layers—in males by upper back and lateral chest (87.0%) and in females by biceps, lateral chest, and hip (83.8%). Trunk fat mass characterized by 90.2% in upper back and front chest SAT-layers in males and 85.0% in lateral chest and upper back SAT-layers in females using SAT-layers on the trunk. Using selected upper trunk SAT-layers, it was found that trunk fat mass (DXA) was dependent on the upper back and front chest in males (90.2%) and in the lateral chest and neck in females (77.8%). The influence of lower trunk SAT-layers to the trunk fat mass (DXA) was lower—the upper abdomen characterized in males 74.2% and upper abdomen and hip in females 60.5% of the total variance.

Right arm fat mass was dependent on both measured right hand SAT-layers—triceps and biceps in males (73.8%) and in females (71.5%). Right leg fat mass was dependent on inner thigh SAT-layers (49.2%) in males, while this relationship was not significant in females.

Discussion

Our results indicate that total body fat % measured by DXA was highly dependent on the SAT-layers in the upper back and inner thigh in males and the lateral chest, biceps, and calf in females. There were gender differences in trunk fat mass and right hand and leg fat mass calculation using specific SAT-

Table 2 Results of the stepwise multiple regression analysis where the dependent variables were body fat %, body fat mass, trunk fat mass, right arm fat mass, and right leg fat mass, and the independent variables LIPOMETER sat-layers

	Gender	Independent variable	Multiple R	R^2	F	SEE	*p*
Total body fat %	M	upper back inner thigh	0.933	0.871	84.3	2.76	<0.000
	F	lateral chest biceps calf	0.886	0.785	59.6	3.93	<0.000
Total body fat mass	M	upper back lateral chest	0.933	0.870	83.8	3019.6	<0.000
	F	biceps lateral chest hip	0.915	0.838	84.5	4347.4	<0.000
Trunk fat mass (trunk SAT-layers)	M	upper back front chest	0.950	0.902	115.2	1562.9	<0.000
	F	lateral chest upper back	0.922	0.850	141.3	2125.9	<0.000
Trunk fat mass (upper trunk SAT-layers)	M	Upper back front chest	0.950	0.902	115.2	1562.9	<0.000
	F	lateral chest neck	0.882	0.778	87.4	2585.9	<0.000
Trunk fat mass (lower trunk SAT-layers)	M	upper abdomen	0.861	0.742	74.6	2490.0	<0.000
	F	upper abdomen hip	0.778	0.605	38.3	3445.8	<0.000
Right arm fat mass	M	triceps biceps	0.859	0.738	35.3	267.5	<0.000
	F	triceps biceps	0.845	0.715	62.7	396.7	<0.000
Right leg fat mass	M	inner thigh	0.701	0.492	25.2	865.7	<0.000

layers.

Different SAT-layers characterized total body fat % in males and females (see Table 2). In males, the upper back and inner thigh and in females the lateral chest, biceps, and calf were selected (87.1% and 78.5% $R^2\times100$ of the total variance respectively). It was very surprising that the measured abdominal SAT-layers were not included in the models in both genders. When body fat mass was used as an independent variable than new SAT-layers were selected. Our previous research in a relatively small group of Estonians using DXA indicated that the neck and hip in males and the calf and hip in females were the most important predictors of total body fat % (Jürimäe et al., 2005). The results probably depend on the fact that SAT-layers on the limbs (especially on the hand) were measured on fewer points than on the trunk. The literature recommendations concerning where to measure subcutaneous adipose tissue are also very varied. In near-infrared spectroscopy only the biceps has been used (Conway et al., 1984). In skinfold thickness caliper measurement, first of all the triceps or subscapular has been recommended (Wang et al., 2000). Interestingly, the thickest SAT-layers in our study such as the lower abdomen or lower back in males and the triceps and lateral chest in females were not included in the models (see Table 2). It can be concluded that it is difficult to explain why one particular site would have a superior composition and yield the least body fat % estimates compared to other sites. There are probably great age, gender, group specific, etc. differences. In our sample, the females were older than the males, which may also influence the results. In addition, females have more fat than males. All this has influenced the results of body fat measurement.

In conclusion, our results indicate that there are close relationships between SAT-layers and body fat measured by DXA. However, there are also big differences between genders.

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