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The relationship between the body mass index and the subcutaneous adipose tissue

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Abstract

Objectives: The aim of the study was to investigate the relationship between the body mass index and ultrasound-measured subcutaneous adipose tissue (SCAT) thickness, in order to propose an alternative non-invasive and inexpensive method to measure the subcutaneous fat. We also evaluated the liver size and the existence of hepatosteatosis, and investigated whether there was a relationship between liver measurements and body mass index (BMI), and the SCAT measurements.

Methods: Height, weight, arm SCAT, umbilical SCAT, thigh SCAT, umbilical preperitoneal fat (PPF) and craniocaudal liver size of 72 volunteers were measured and liver parenchymal echogenicity was evaluated with ultrasound. Correlations between BMI and the SCAT, the PPF, and liver measurements were evaluated statistically.

Results: BMI was mostly well correlated with umbilical SCAT ($r=0.650$, $p<0.001$). The arm SCAT ($r=0.549$, $p<0.001$) and the thigh SCAT ($r=0.470$, $p\leq0.001$) followed it. The umbilical PPF was only correlated with the umbilical SCAT. There was no relationship between arm, or thigh SCAT values and existence of hepatosteatosis, but existence of hepatosteatosis was related with umbilical SCAT ($p=0.008$), and umbilical PPF ($p=0.009$) values.

Conclusion: As an alternative method to skinfold measurement, SCAT measurement with ultrasound can be used to evaluate body fat status.

Keywords: fat; hepatosteatosis; obesity; weight

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Introduction

Body mass index (BMI) is the most common method used to classify individuals as overweight, obese and thin.[1–3] BMI is used to determine obesity-related disease risks in both adults and children.[4] Skinfold thickness has long been used as the subcutaneous fat measurement method, on the grounds that half of the total body fat is collected in the subcutaneous fat deposits and this is related to the total amount of fat.[5,6] Since the amount of subcutaneous fat is an indicator of total body fat, it has been widely used to determine total body fat.[7,8] The skinfold technique is commonly used because it is noninvasive, relatively easy to administer, and inexpensive.[9]

In this study we aimed to investigate the relationship between the body mass index and ultrasound-measured subcutaneous adipose tissue (SCAT), in order to propose an alternative non-invasive and inexpensive method to measure the subcutaneous fat. We also evaluated the liver size and the existence of hepatosteatosis, and investigated whether there was a relationship between liver measurements and BMI, and the SCAT measurements.

Materials and Methods

Seventy-two volunteers (41 women, 31 men), aged between 20 and 76 were included in this study. Those with physical problems, diabetes, severe liver, kidney and heart diseases, those who were treated with diuretics, those who were treated for cancer, and those who were on a special diet program to gain or lose weight were excluded from the study.

Measurements of the subjects were made in the morning on an empty stomach and without excessive fluid intake (between 8–10 am) and height measurements were made with bare feet. Weight was measured barefoot and wearing light clothing. Length measurement was made with a wall tape measure sensitive to centimeter, and weight measurement was made with a scale sensitive to 0.1 kilograms. In order to avoid errors that may occur in the body compositions to be measured, the subjects were asked to rest for half an hour and avoid exercise before starting the measurement.

Measurements with ultrasound were made with 5–11 MHz linear (for the SCAT measurements) and 1–6 MHz convex (for the deeper measurements) probes (LOGIQ S7 Expert, GE, Medical Systems). SCAT measurements were done while the volunteers were lying supine, and while limbs were extended in anatomic position, from three regions: mid-arm (arm SCAT), umbilical (umbilical SCAT), and mid-thigh (thigh SCAT). Mid-arm was determined as the mid-point between the uppermost point of the glenohumeral joint and antecubital fossa (**Figure 1a**). Mid-thigh was determined as the mid-point between the anterior superior iliac spine and the base of patella (**Figure 1b**). Limb measurements were done on the right side. Umbilical measurements were done on the midline, 5 cm above the umbilicus (**Figure 1c**). The thickness (antero-

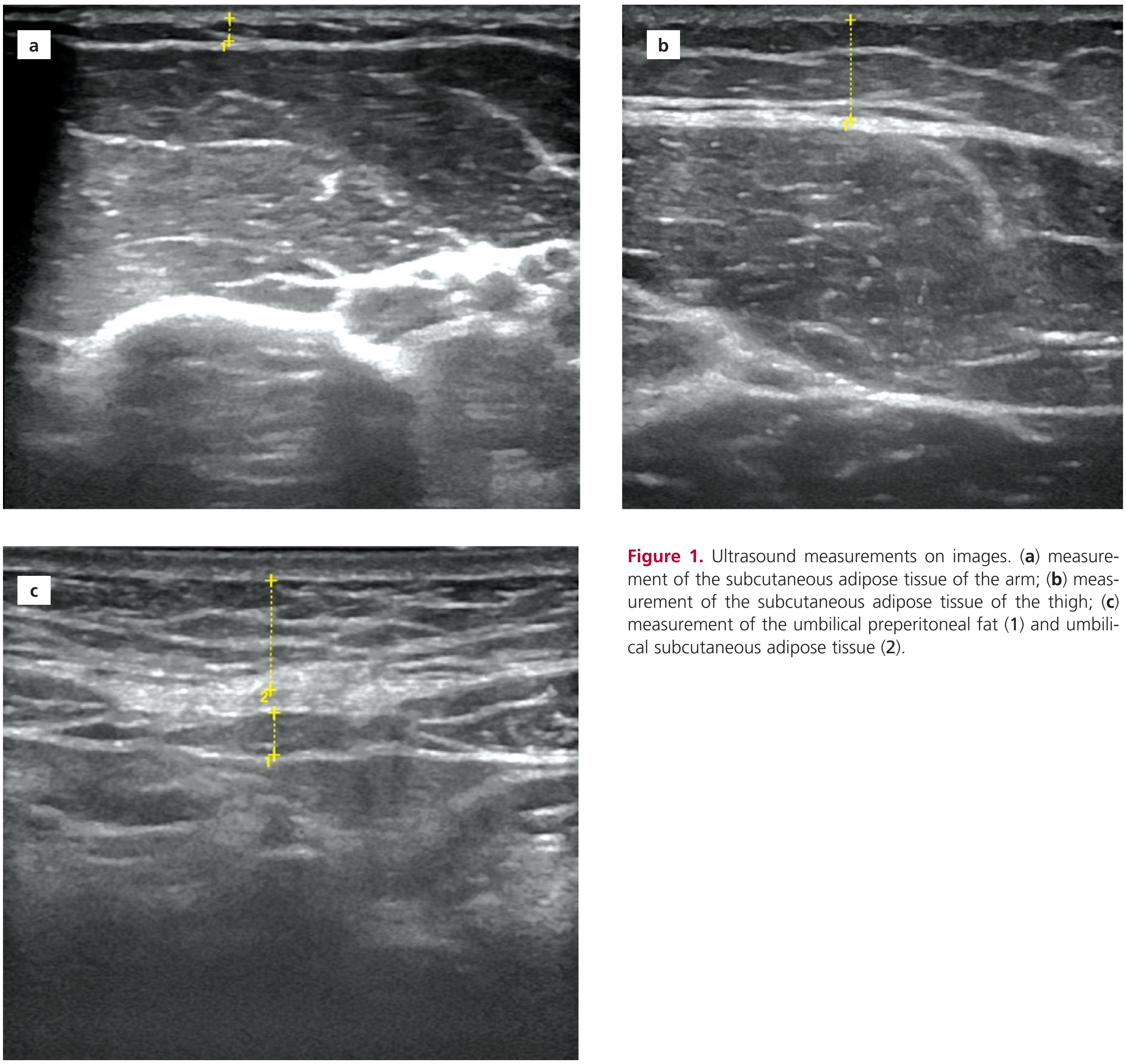

Figure 1. Ultrasound measurements on images. (**a**) measurement of the subcutaneous adipose tissue of the arm; (**b**) measurement of the subcutaneous adipose tissue of the thigh; (**c**) measurement of the umbilical preperitoneal fat (**1**) and umbilical subcutaneous adipose tissue (**2**).

posterior diameter) of the subcutaneous fat tissue (hypodermis) in the transverse view was measured as the arm SCAT anterior to the biceps muscle, the thigh SCAT anterior to the rectus femoris muscle, and the umbilical SCAT anterior to the rectus abdominis muscle. The thickness of the adipose tissue between the deep fascia and the peritoneum was measured as umbilical preperitoneal fat (PPF). In the right upper quadrant of the abdomen, craniocaudal liver size and parenchymal echogenicity, in terms of steatosis, were evaluated with a 1–6 Mhz convex probe, while the patient was in inspiration.

The correlations between BMI and the SCAT, the PPF, and liver measurements were analyzed using SPSS (Statistical Package for Social Sciences) for Windows (Version 22, Chicago, IL, USA). Kolmogorov-Smirnov and Shapiro-Wilk tests were used to check normality. The Student's t-test was used to compare normally distributed pairs, the Wilcoxon signed-rank test was used to compare non-normally distributed pairs, and chi-square test was used to compare categorical variables. Pearson correlation analysis was used to test the relationship between normally distributed variables, and Spearman correlation analysis was used to test the relationship between non-normally distributed variables. For all analyses; $p<0.05$ was considered as statistically significant.

Results

The characteristics of the volunteers and the results of the measurements are summarized in **Table 1**, and the correlations between the measurements are summarized in **Table 2**.

Ultrasound examination showed that 68.1% of the volunteers (49 out of 72) did not have hepatosteatosis, 16.7% (12 out of 72) had grade I hepatosteatosis, 15.3% (11 out of 72) had grade II hepatosteatosis. Hepatomegaly was detected in two of the volunteers (2.8%).

BMI was mostly well correlated with umbilical SCAT ($r=0.650$, $p<0.001$). The arm SCAT (well correlated) ($r=0.549$, $p<0.001$) and the thigh SCAT (fairly correlated) ($r=0.470$, $p\leq0.001$) followed it. The umbilical PPF was only correlated with the umbilical SCAT. There was an excellent correlation between arm SCAT and thigh SCAT, and good correlation between arm SCAT and umbilical SCAT. Interestingly, arm SCAT showed correlation with age even if it was weak. There was no relationship between arm, or thigh SCAT values and existence of hepatosteatosis, but existence of hepatosteatosis was related with umbilical SCAT ($p=0.008$), and umbilical PPF ($p=0.009$) values. Since hepatomegaly was detected in only two volunteers, which was not statistically sufficient to correlate with any measure.

Except for the height, none of the measurements showed any statistically significant gender difference (**Table 3**).

Discussion

Obesity is a metabolic disease which can cause many health problems and related deaths.[10] It is a health problem that increases the risk of coronary artery disease, hypertension, type II diabetes, obstructive pulmonary disease, osteoarthritis and some types of cancer, and significantly reduces life expectancy.[11] BMI is generally the first step and the most ideal method for measuring obesity, but it is considered as a rough guide. Because the fat rates in different people do not correspond to the same level of obesity.

World Health Organization (WHO) interprets BMI for adults as follows: <18.5: underweight, 18.5–24.9: nor-

Table 1
The characteristics of the volunteers and the results of the measurements.

	Mean or median*± SD	Range: min–max or 95% CI†
Age (years)	40.00±13.23	20–76 years
Height (cm)	167.94±10.39	150.00–200.00
Weight (kg)	76.06±14.82	48.00–113.00
BMI	26.96±4.68	16.34–40.27
Arm SCAT (mm)	2.80*±2.44	0.20–15.10
Thigh SCAT (mm)	11.65±5.61	10.33–12.97†
Umbilical SCAT (mm)	18.33±7.39	16.59–20.07†
Umbilical PPF (mm)	4.55*±3.49	0.90–17.40

*Arm SCAT and umbilical PPF were given as median value since they were not distributed normally. †95% CI was given for means of normally distributed parameters. **BMI:** body mass index; **CI:** confidence interval; **PPF:** preperitoneal fat; **SCAT:** subcutaneous adipose tissue; **SD:** standard deviation.

Table 2

Correlations between measurements.

		Arm SCAT	Thigh SCAT	Umbilical SCAT	Umbilical PPF
Age	r-value	0.296			
	p-value	0.012*	0.423	0.078	0.545
Height	r-value	-0.397	-0.451		
	p-value	<0.001	<0.001	0.627	0.653
Weight	r-value	0.252		0.554	0.430
	p-value	0.033*	0.287	<0.001	<0.001
BMI	r-value	0.549	0.470	0.650	0.420
	p-value	0.001	<0.001	<0.001	<0.001
Arm SCAT	r-value		0.724	0.555	
	p-value		<0.001	<0.001	0.070
Thigh SCAT	r-value	0.724		0.383	
	p-value	<0.001		<0.001	0.310
Umbilical SCAT	r-value	0.555	0.383		0.334
	p-value	<0.001	<0.001		0.004*
Umbilical PPF	r-value			0.334	
	p-value	0.070	0.310	0.004*	

*p<0.05. **BMI:** body mass index; **PPF:** preperitoneal fat; **SCAT:** subcutaneous adipose tissue.

mal weight, 25.0–29.9: pre-obesity, and ≥30.0: obesity. BMI is calculated based on the formula: weight (kg) / [height (m)]^2. BMI, which is one of the most basic methods in determining obesity, is also the first method used by WHO to determine obesity. However, BMI does not take into account the weight of the increased muscle tissue, the body's water retention and the distribution of adipose tissue. Individuals with similar BMI may have different abdominal fat tissue. Therefore, waist circumference and waist-hip ratio measurements have been seen as an alter-

Table 3

Gender differences.

	Gender	Mean or median*	P-value
Height (cm)	W	161.85	0.003†
	M	176.00	
Weight (kg)	W	70.42	0.301
	M	83.53	
BMI	W	26.95	0.347
	M	26.97	
Arm SCAT (cm)	W	3.50*	0.495
	M	2.00*	
Thigh SCAT	W	14.85	0.251
	M	7.41	
Umbilical SCAT (cm)	W	18.46	0.424
	M	18.17	
Umbilical PPF (cm)	W	3.70*	0.447
	M	6.70*	

*Arm SCAT and umbilical PPF were given as median since they were not distributed normally. †p<0.05. **BMI:** body mass index; **M:** man; **PPF:** preperitoneal fat; **SCAT:** subcutaneous adipose tissue; **W:** woman native to BMI, with measurements regularly used in both clinical and research settings.

Anthropometric methods are generally preferred when screening for obesity on populations. The most obvious advantages of anthropometric methods are that they are portable, inexpensive and useful in field studies. BMI, which relates weight to height, is the most widely used and also the simplest measure of body size, and is often used to estimate the prevalence of obesity in a population.[12] However, it has been subjected to many criticisms that it does not reveal the fat ratio, and BMI value of the individuals in the body with excess muscle mass or water retention is high. For these reasons, alternative methods are sought for BMI. At this point, circumference measurements are preferred because they give direct information about the individual's fatness status.

Skin fold thickness measurement, dual-energy X-ray absorptiometry scans, and assessment of the SCAT with computed tomography are commonly used methods to evaluate the fat distribution of the body.[9,13] SCAT and visceral adipose tissue measurements with ultrasound have also been used in recent years to evaluate body fat distribution.[14,15]

It has been reported in the literature that there is a relationship between waist circumference and fatty liver.[16] In our study, no correlation was found between any SCAT measurements and hepatosteatosis, not even with umbilical SCAT. This is probably because hepatosteatosis is associated with visceral adipose tissue, not SCAT. But still, we found that the umbilical SCAT was the most correlated SCAT with BMI. In clinical practice, abdominal fat is the most widely accepted in the assessment of obesity.[17]

Some researchers compared the skinfold measurements with ultrasound-measured SCAT values, and dual energy X-ray with CT-measured and ultrasound-measured SCAT values, and found that the measurements were correlated.[13,18] We also found good correlation between BMI values and all three SCAT measurements. In the light of this information, we suggest that SCAT measurements with ultrasound is an inexpensive, safe and easily applicable method for the evaluation of body fat composition.

Conclusion

As an alternative method to skinfold measurement, SCAT measurement with ultrasound can be used to evaluate body fat status.

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

BIT: Project development, data analysis, drafting the article; MB: data collection, data analysis, drafting the article, revising it critically for important intellectual content; FG: data collection, data analysis, drafting the article; ŞCH: data collection, data analysis, drafting the article. All authors approved the final of the version to be published, agree to be accountable for all aspects of the work if questions arise related to its accuracy or integrity.

Ethics Approval

The study was approved by Ethical Committee of Ankara Yildirim Beyazit University (No:2019-33). Informed consent was obtained from all the volunteers and carried out in accordance with the Helsinki declaration of principles.

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