Comparison of Limb Cross-section between Ultrasonic and CT Method

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Abstract

The cross-sectional area of muscle, subcutaneous fat, and bone in four male healthy subjeccts were measured by means of CT (computerized tomography) and UT (ultrasonic circular compound system) methods, in order to establish an efficacy of the ultrasonic method as a tool for estimating tissue area of human limbs. Cross-sectional photos of forearm, upper arm, leg, and thigh were taken by means of both CT and UT methods. The boundary line between fat and muscle, or muscle and bone was drawn on a tracing paper which was superimposed correctly on the cross-sectional photos taken by CT and UT methods. The cross-sectional area of tissues were estimated by means of planimetry. In the UT pictures the boundaries of each tissue such as fat, muscle, and bone were observed clearly, and in CT images the clear cross-section of bone and muscle were indicated. In generally almost the same cross-sectional image of forearm was observed by both CT and UT methods. In the whole area 8% higher values by UT method was observed than by CT. This significant difference was derived from the difference in fat area between both methods. At another measured limbs such as upper arm, leg and thigh there were no significant difference of whole area between both methods. Fat area indicated larger differences, which tendency was especially observed on the arm composed of less subcutaneous fat. Percent differences of muscle area between both methods were statistically insignificant and indicated lower difference (about 4%) than those in the other tissues. In the bone area there were statistically insignificant differences between both methods. It is considered that UT method used in the present study is effective system for measuring cross-sectional area of muslce, fat, and bone in human extremities.

Introduction

A number of applications have been implemented to assess the size of tissues in human extremities. In the past it has been proved difficult to determine the cross-sectional area of muscle, fat and bone in the human extremities, due to the lack of innocuous and accurate technique, which methods have included only dissection and anthoropometry.

More recently, computerized X-ray tomography (CT)[1,2,5], as a precise and noninvasive technique, has been used to determine cross-sectional representations of the soft tissue and bone in the human body in both normal and athletic populations. CT scanning clearly defines the soft tissue borders, therefore allowing the measurement of the areas of the different structures. Computerized tomography has also been reported as an accurate method of assessing the size of different muscle bellies.[2] However, there raised some problems in the repeated use of roentgenogram to a healthy body.

Ultrasonic photography also has been used recently as an effective method to estimate different limb components[3]. While ultrasound is a noninvasive technique which can be repeated without tissue damage, it is necessary to confirm the accuracy of method for defining the interface among muscle, fat and bone.

The purpose of the present study was to compare the ultrasonic method with CT-scan, and to establish efficacy of the ultrasonic circular compound scanning method as a tool for measuring the cross-sectional area of muscle, bone and subcutaneous fat of the forearm, upper arm, leg, and thigh.

Method

The subjects were 4 healthy adult males, with a mean age of 28 years, a mean weight of 65 kg, and mean height of 170 cm. Cross-sectional photos of forearm, upper arm, leg, and thigh were taken by means of both ultrasonic (UT) and CT methods (CT).

Ultrasonic apparatus used in the present study was ALOKA SSD 120 ECHOVISION which was

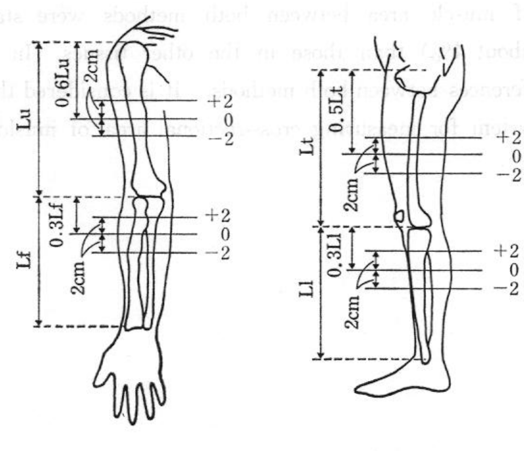

Fig. 1. Measured points of cross-section by CT and UT methods.

connected to automatic circular compound scanning. This ultrasonic system was specially designed only for measuring cross-section of each tissue such as fat, muscle and bone in human limb. By using this automatic scanning the transducer can move around the limb without contact to the limbs. The ultrasonic wave frequency was 5 MHz.

Ultrasonic cross-section of upper extremity was measured with the arm depended vertically in a prone position, and that of the lower extremity was measured in upright position. The subjects were requested not to cause any movement of the arm or the leg for 30 seconds while the ultrasonic transducer circulated around the extremity. The cross-sectional view of tissues was depicted by the pulsed echo on 5 inch Brauntube and TV monitor.

CT scanner of GE-8800 was used to estimate cross-sectional image of tissue with the subject in a supine position.

The boundary line between fat and muscle, or muscle and bone was drawn on a tracing paper which was superimposed correctly on the cross-sectional photos taken by CT and UT methods. The cross-sectional areas of subcutaneous fat, muscle, and bone were estimated by means of planimetry.

Before the estimation of ultrasonic and CT photos the anthoropometric measurements, such as length of radius, humerus, tibia and femur, were made in order to determine the sites for estimating the cross-section of extremities. Figure 1 shows the points for measuring cross-section by CT and

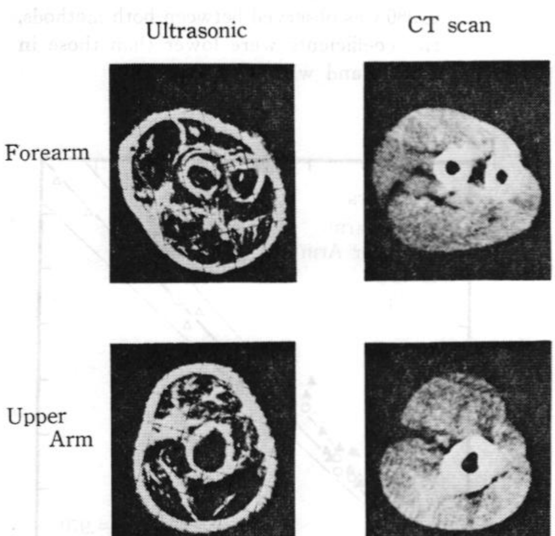

Fig. 2. Cross-sectional view of human forearm and upper arm at 0 of measured point obtained from ultrasonic (UT) and CT scans. In CT photo the layer of subcutaneous fat is observed not so clearly, while in UT photo the boundary of subcutaneous fat and intramuscular tissues such as fascia and intramuscular fat are observed clearly. In generally, almost the same cross-sectional view is observed at both methods.

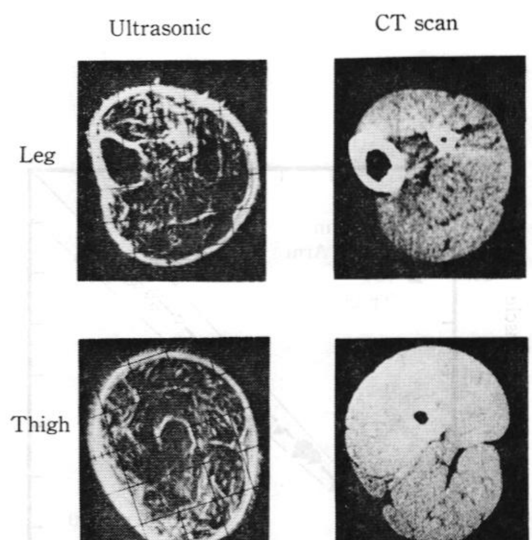

Fig. 3. Cross-sectional view of human leg and thight at 0 measured point obtained from UT and CT. As shown in arm the layer of subcutaneous fat is observed not so clearly in CT photo. In leg and thigh the fascia located between muscle bundles, such as gastrocnemius and others, or vastus lateralis and vastus intermedius, are observed clearly in UT than in CT. While the bounderly between bone and muscle is considered to be observe more clearly in CT than in UT photo.

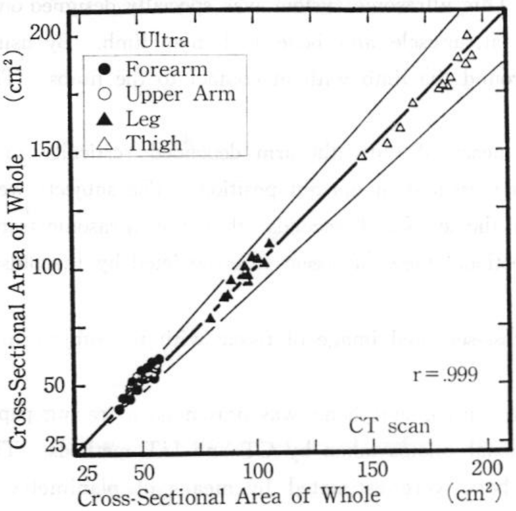

Fig. 4. Relationship of whole cross-sectional area between CT and UT methods. There were significantly higher correlation coefficients of 0. 999 between both methods.

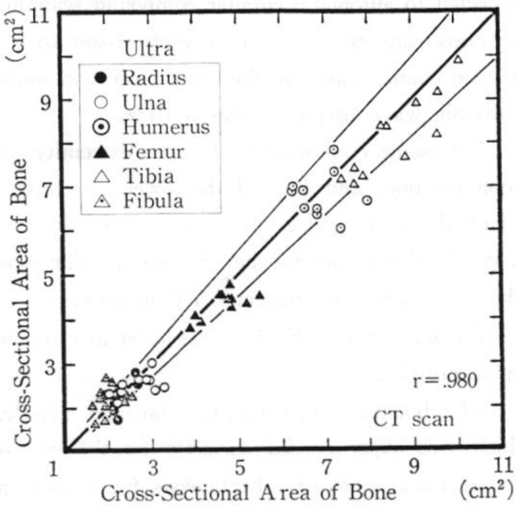

Fig. 5. Relationship of bone cross-sectional area between UT and CT methods. Bone area obtained from UT indicated little lower values than those from CT. While significantly higher correlation coefficients of 0. 980 was observed between both methods, the coefficients were lower than those in muscle and whole area.

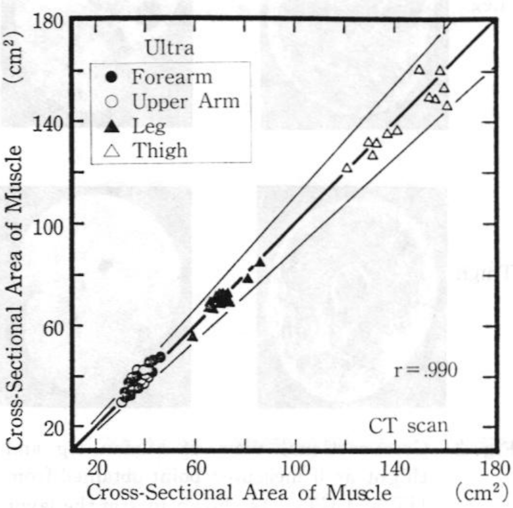

Fig. 6. Relationship of muscle cross-sectional area between CT and UT methods. There were higher correlation coefficients of 0. 990 between both methods.

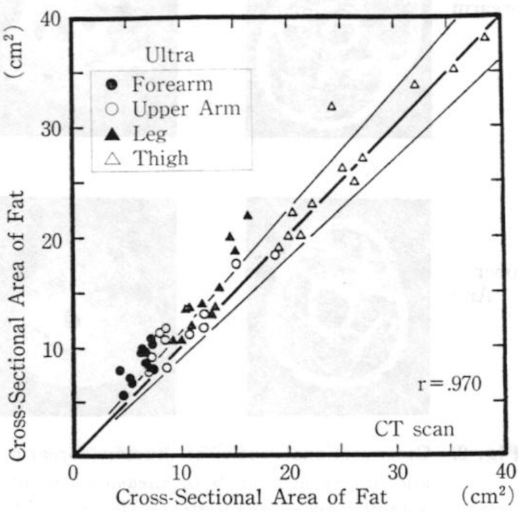

Fig. 7. Relationship of subcutaneous fat area between CT and UT methods. The correlation coefficients between both methods were statistically significant, while the coefficients were lower in fat than those in whole, muslce and bone area. The cross-sectional area obtained from UT indicated a little higher value than those from CT.

Table 1. Means and standard deviations of whole cross-sectional areas obtained from both methods. Numers in parenthesis represent standard error.

whole area

	site	CT(cm²)		UT(cm²)		(CT-UT)/CT	CT-UT
		m	SD	m	SD	(%)	(cm²)
Forearm	+2	50.5	5.1 (2.6)	53.2	7.2 (3.6)	−5.3	−2.7
	0	48.9	6.4 (3.2)	52.4	6.6 (3.3)	−8.4	−4.0*
	−2	45.9	5.4 (2.7)	47.7	7.3 (3.6)	−3.7	−1.8
Upper arm	+2	55.2	4.9 (2.5)	55.7	6.1 (3.0)	−0.6	−0.4
	0	52.1	4.8 (2.4)	54.6	6.8 (3.4)	−4.6	−2.5
	−2	49.2	5.0 (2.5)	52.1	7.2 (3.6)	−5.5	−2.9
Leg	+2	90.5	7.5 (3.8)	91.8	10.2 (5.1)	−1.4	−1.4
	0	96.3	7.4 (3.7)	97.5	7.3 (3.7)	−1.3	−1.2
	−2	96.9	8.6 (4.3)	99.0	9.9 (4.9)	−2.1	−2.1
Thigh	+2	182.7	12.9 (6.5)	182.9	17.9 (8.9)	−0.0	−0.3
	0	179.5	15.4 (7.7)	172.8	15.0 (7.5)	3.8	6.7
	−2	169.3	16.4 (8.2)	167.6	13.8 (6.9)	0.9	1.8

SE: ( )

Table 2. Means and standard deviations of subcutaneous fat area obtained from both methods. Simboles of * and ** represent significant level of 5 % and 1 %, respectively.

Fat area

	site	CT(cm²)		UT(cm²)		(CT-UT)/CT	CT-UT
		m	SD	m	SD	(%)	(cm²)
Forearm	+2	6.7	1.0 (0.5)	8.9	2.1 (1.0)	−32.3	−2.2
	0	5.6	1.2 (0.6)	8.7	1.2 (0.6)	−57.9	−3.1**
	−2	6.1	1.0 (0.5)	7.9	1.7 (0.8)	−31.7	−1.9*
Upper arm	+2	13.2	4.2 (2.1)	12.8	4.3 (2.1)	3.5	0.4
	0	10.4	3.4 (1.7)	12.5	3.9 (1.9)	−21.4	−2.1**
	−2	9.8	3.7 (1.8)	12.2	3.8 (1.9)	−25.4	−2.3**
Leg	+2	12.7	3.0 (1.5)	15.6	4.8 (2.4)	−21.2	−2.9
	0	12.1	1.9 (0.9)	15.1	3.7 (1.8)	−23.9	−2.9
	−2	12.3	2.5 (1.3)	14.1	3.5 (1.7)	−15.2	−1.9
Thigh	+2	27.9	7.4 (3.7)	29.5	7.0 (3.5)	− 7.1	−1.6
	0	28.2	7.2 (3.6)	25.4	7.4 (3.7)	8.4	2.7
	−2	24.1	5.7 (2.8)	25.7	6.3 (3.1)	− 6.5	−1.6

SE: ( )

UT methods. The measured sites were at three different points each extremity, such as at 30% distal of radius shaft (0), at 2 cm distal (−2) and at proximal (+2) from 0 point in forearm, respectively, at 60% distal of humerus shaft (0), at −2 and at +2 points in upper arm, at 30% distal of tibia shaft, at −2 and at +2, in leg, and in the thigh it was taken at mid femur (0), at −2 and at +2 points.

Results and Discussion

The cross-sectional view obtained from CT and UT methods are shown in Figs. 2, and 3. In the UT pictures the boundaries of each tissue such as fat, muscle, and bone were observed clearly, and in the CT images the clear cross-section of bone and muscle were indicated. However, the layer of

Table 3. Means and standard deviations of bone areas obtained from both methods.

Bone

		site	CT(cm^2) m	CT(cm^2) SD	UT(cm^2) m	UT(cm^2) SD	$\frac{CT-UT}{CT}$ (%)	CT-UT (cm^2)
Forearm	Radius	+2	2.3	0.2 (0.1)	2.4	0.2 (0.1)	− 4.7	−0.1
		0	2.3	0.3 (0.1)	2.2	0.1 (0.05)	1.6	0.1
		−2	2.2	0.1 (0.05)	2.0	0.2 (0.1)	9.7	0.2
	Ulna	+2	3.0	0.2 (0.1)	2.6	0.3 (0.15)	15.2	−0.4
		0	2.5	0.4 (0.2)	2.5	0.1 (0.05)	− 0.3	0.0
		−2	2.2	0.2 (0.1)	2.3	0.2 (0.1)	− 4.9	−0.1
Upper arm	Humerus	+2	4.9	0.6 (0.3)	4.3	0.3 (0.15)	10.8	0.6
		0	4.6	0.4 (0.2)	4.5	0.4 (0.2)	6.6	0.0
		−2	4.5	0.4 (0.2)	4.2	0.3 (0.15)	6.9	0.3
Leg	Tibia	+2	9.3	0.8 (0.4)	8.9	0.8 (0.4)	4.4	0.4
		0	8.7	0.8 (0.4)	8.1	0.8 (0.4)	6.4	0.6
		−2	7.8	0.5 (0.2)	7.4	0.6 (0.3)	6.0	0.5
	Fibra	+2	1.9	0.2 (0.1)	2.1	0.4 (0.2)	−10.3	−0.2
		0	2.0	0.3 (0.15)	2.3	0.2 (0.1)	−15.7	−0.3*
		−2	2.1	0.3 (0.15)	2.2	0.4 (0.2)	− 7.4	−0.1
Thigh	Femor	+2	7.0	0.4 (0.2)	6.6	0.8 (0.4)	4.9	0.4
		0	7.0	0.8 (0.4)	6.8	0.4 (0.2)	0.9	0.1
		−2	6.7	0.5 (0.25)	6.5	0.5 (0.25)	2.8	0.2

SE: ( )

Table 4. Means and standard deviations of muscle area obtained from both methods.

Muscle

	site	CT(cm²)		UT(cm²)		CT-UT / CT	CT-UT
		m	SD	m	SD	(%)	(cm²)
Forearm	+2	38.3	4.1 (2.1)	39.4	5.2 (2.6)	−2.8	−1.1
	0	37.7	6.4 (3.2)	39.2	5.7 (2.8)	−4.5	−1.5
	−2	35.2	4.6 (2.3)	35.6	6.4 (3.2)	−0.8	−0.4
Upper arm	+2	37.0	3.8 (1.9)	39.4	4.7 (2.3)	−6.4	−2.4
	0	36.6	4.0 (2.0)	37.4	4.1 (2.1)	−2.5	−0.8
	−2	36.3	4.7 (2.3)	35.6	5.0 (2.5)	1.8	0.7
Leg	+2	68.7	6.6 (3.3)	66.5	8.6 (4.3)	3.4	2.2
	0	72.7	6.8 (3.4)	72.4	4.9 (2.5)	0.2	0.3
	−2	72.3	9.5 (4.8)				
Thigh	+2	148.1	14.0 (7.0)	142.3	13.8 (6.9)	3.8	5.9
	0	146.3	14.2 (7.1)	139.9	12.2 (6.1)	4.3	6.4
	−2	138.2	16.2 (8.1)	141.1	17.9 (8.5)	−2.0	−2.8

SE: ( )

Table 5. Means and standard deviations of cross-sectional area of extensor muscle.

Extensor muscle

	site	CT(cm²)		UT(cm²)		CT-UT	CT-UT / CT
		m	SD	m	SD	(cm²)	(%)
Forearm	+2	12.7	2.3 (1.6)	18.4	3.0 (1.5)	−5.7*	−47.1
	0	14.3	3.3 (1.7)	17.3	2.7 (1.3)	−3.0*	−23.4
	−2	15.8	2.2 (1.1)	14.9	3.1 (1.6)	0.9	6.1
Upper arm	+2	23.3	2.8 (1.4)	22.7	3.5 (1.8)	0.5	2.1
	0	20.7	3.0 (1.5)	20.3	3.1 (1.6)	0.4	1.2
	−2	17.0	2.9 (1.5)	16.4	3.4 (1.7)	0.6	3.1
Leg	+2	16.4	1.3 (0.7)	15.9	2.7 (1.3)	0.5	3.7
	0	17.5	2.8 (1.4)	18.1	2.3 (1.1)	−0.6	−3.6
	−2	17.4	2.1 (1.0)	18.3	2.4 (1.2)	−0.8	−4.8
Thigh	+2	88.7	8.3 (4.4)	88.4	10.9 (5.5)	0.3	0.4
	0	87.3	8.4 (4.2)	82.4	8.5 (4.3)	4.9	5.5
	−2	83.1	9.2 (4.6)	87.9	7.4 (3.7)	−4.9	−6.5

Table 6. Means and standard deviations of cross-sectional area of flexor muscles.

Flexor muscle

	site	CT(cm^2) m	CT(cm^2) SD	UT(cm^2) m	UT(cm^2) SD	CT-UT (cm^2)	$\frac{CT-UT}{CT}$ (%)
Forearm	+2	22.5	4.0 (2.0)	21.0	2.9 (1.5)	1.5	5.4
	0	23.3	3.4 (1.7)	21.8	3.1 (1.6)	1.5	5.9
	−2	22.5	2.5 (1.2)	20.8	3.4 (1.7)	1.8	7.7
Upper arm	+2	13.7	2.4 (1.2)	16.7	1.8 (0.9)	−2.9*	−23.0
	0	15.9	1.2 (0.6)	17.1	2.3 (1.2)	−1.2	− 7.3
	−2	17.6	1.8 (0.9)	19.0	3.0 (1.5)	−1.4	− 7.8
Leg	+2	52.3	5.4 (2.7)	49.3	4.9 (2.5)	3.1	5.7
	0	54.9	4.2 (2.1)	54.3	2.7 (1.3)	0.6	0.9
	−2	54.9	7.5 (3.7)	55.8	5.6 (2.8)	−0.9	− 2.1
Thigh	+2	59.5	7.7 (3.9)	59.6	7.9 (3.9)	−0.1	− 0.3
	0	58.9	8.0 (4.0)	56.4	6.0 (3.0)	2.6	3.7
	−2	55.2	7.4 (3.7)	53.6	6.5 (3.3)	1.6	2.5

SE : ( )

Table 7. Differences of each tissue area between both methods. Numbers represent means and standard errors which were calculated from all values measured from three different measured positions of 0, +2 −2, in each 4 subject.

	% of Difference $\left(\frac{CT-UI}{CT}\times 100\right)$				
	Forearm	Upper Arm	Leg	Thigh	Total
Whole	− 3.4(1.89)	− 3.7(1.32)	− 1.6(1.06)	1.5(0.73)	− 1.8(0.71)
Fat	−40.6(7.09)	−14.1(4.87)	−20.1(3.90)	−4.4(3.12)	−18.0(3.31)
Lean	− 0.8(1.56)	− 2.1(1.72)	1.3(1.33)	2.2(0.74)	0.2(0.71)
Bone	Radius 2.2(3.89) Ulna 3.4(3.87)	6.2(1.98)	Tibia 5.7(1.48) Fibura −11.0(4.86)	2.8(3.39)	1.6(1.52)
Muscle	− 2.9(1.80)	− 2.3(2.13)	0.9(1.32)	0.6(1.19)	− 0.9(0.84)

CT : CT scan method Ul : Ultrasonic method Mean (SE) subcutaneous fat in CT pictre was not observed so clearly. Hudash, B. (in 1985)[2] reported that CT scanner was a practical tool for cross-sectional measurement of the human total thigh components in vivo. Bone, fat and total thigh size were accurately depicted. He reported also that more accurate image was obtained in subjects with more body fat. In the present study, at the sites with less subcutaneous fat such as forearm and leg, the CT image has given less possibility for indication of the subcutaneous layer of fat. In the UT photo the subcutaneous fat was also more easily observed in fatty limb such as thigh and upper arm than in lean forearm and leg.

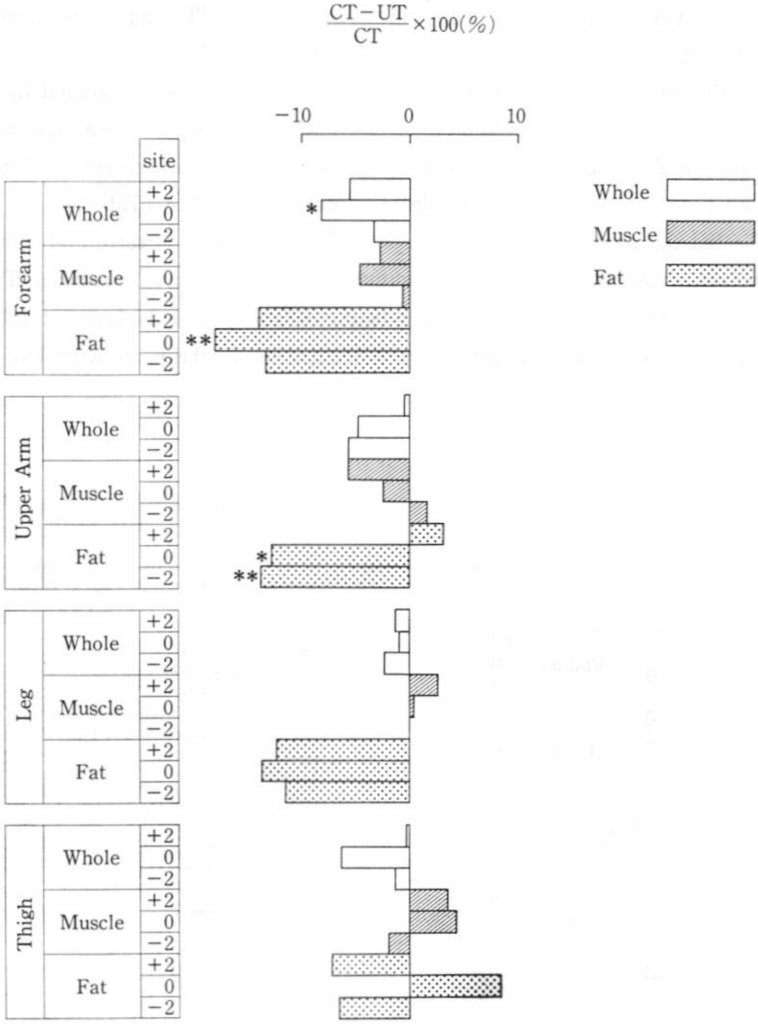

Fig. 8. Differencies of tissue areas between CT and UT methods. Poles represent mean values from 4 subjects. Numbers in site colum represent measured points for estimating cross-cection of tissues in arm, leg and thigh. The measured points were described in the text. Simboles * and ** represent statistically significant level of 5% and 1%, respectively. At thigh and leg there were statistically insignificant differences of cross-sectionel area of every tissues. At forearm and upper arm, however, statistically higher values were observed by UT method.

Similar values were observed for whole areas of forearm, upper arm, leg and thigh in both CT and UT methods. High correlation coefficient (0. 970) between both methods was observed for whole areas (Fig. 4).

It was observed that the thicker bones such as tibia, femur and humerus indicated smalller area in UT than in CT, while the slender bones such as fibula, radius and ulna showed larger area in UT than in CT, while the slender bones such as fibula, radius and ulna showed larger area than in CT. In the total, higher correlation coefficient of 0. 980 between CT and UT methods was observed for bone area (Fig. 5).

Muscle area indicated almost same values with both CT and UT scan. The correlation coefficient of muscle area between both methods was 0. 990 ($p<0.001$) (Fig. 6).

For a comparative purpose the values of cross-sectional areas of tissues obtaind by CT and UT are indicated in Tab. 1−5. As to the whole area no significant differences were observed between both methods at each measured site except at 0 position of the forearm. In general a little higher values (less than about 5%) was observed in the whole area with UT method (Tab. 1).

Fat area indicated the significant higher values with UT in both forearm and upper arm. In the leg or thigh, however, there were no significant differences between both methods. The differences in fat areas between both methods may be due to indistinguishableness of the layer of subcutaneous fat in CT image. Especially, the larger differences were recognized in the parts with less subcutaneous fat

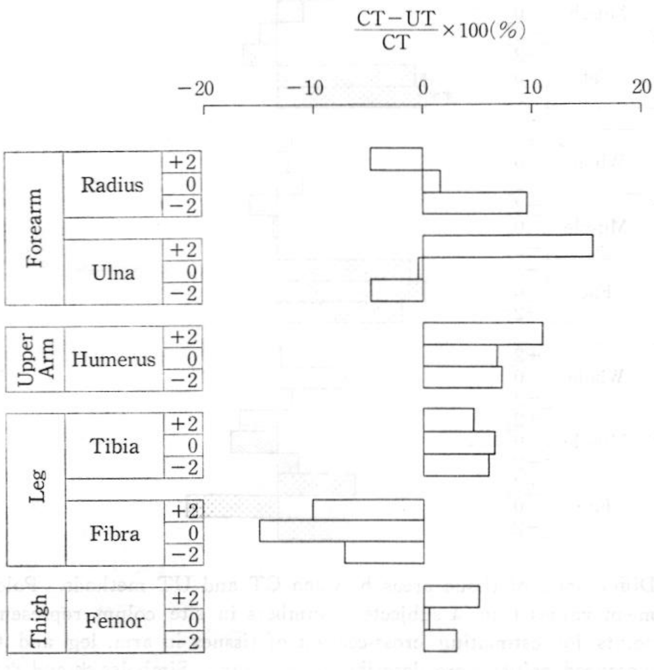

Fig. 9. Differencies of bone area between CT and UT methods. Poles and figures represents same as in Fig. 7. There were insignificant differences of bone area between CT and UT.

area of forearm. From CT photo of the arm with less fat area it was unable to define accurately the layer of subcutaneous fat. The significantly large difference in whole area of a forearm (4. 0 cm^2) between both methods was caused by the large difference in the fat area (3. 1 cm^2).

The differences in bone area between both methods were less than 0. 6 cm^2, which was statistically insignificant.

Comparison of UT with CT for the muscle area is provided in Tab. 4. Absolute differences were -2.4 cm^2 (upper arm) to 6. 4 cm^2 (thigh). The percent differences in muscle area scattered from -6.4% to 4. 3%. However, there were statistically insignificant differences between both methods in every measured points.

The muscle area is anatomically divided into flexor and extensor muscle groups. The cross-sectional areas of both muscle groups are indicated in Tables 5 and 6. While higher values in extensor muscles by UT method were observed at forearm position, no statistical significant differences between both methods were observed at upper arm, leg, and thigh. Flexor muscle area indicated no statistical significant differences between both methods at every limbs except for upper arm.

Percent differences obtained between both methods in the whole, muscle and fat areas are presented in Fig. 8, and in bone area in Fig. 9. In the whole area the highest different was observed by -8% at forearm. This significant difference in the forearm area was derived from the higher fat area by UT than CT.

In a case of muscle area there were no significant differences between both methods. Percent differences of muscle area between both methods were lower (-5% to 4%) than those in the other tissues such as fat and bone. Fat area indicated larger differences. This tendency was especially observed at the arm which was composed of less subcutaneous fat.

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