Genetic factors in the tissue composition of human limbs

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ABSTRACT

Monozygotic twins of 4 pairs at 16 years (boy) participated as experimental subjects. The cross-sectional area of tissues such as muscle, fat and bone in forearm, upper arm, leg and thigh were measured by means of ultrasonic method. The maximum isometric strength of flexors and extensors at the three joints of elbow, knee and ankle were measured by means of strain gauge force transducers. The intra-pair difference (ID) in subcutaneous fat were 19–37%, which indicated higher value than those in the bone (8–16%) and the muscle (2–7%). In consideration of ID in the tissue composition for dizygotic twins which previously reported (Ohtsuki, 1976), the interindividual variations in bone may only be ascribed to genetic difference.

Keywords: Cross-Sectifnal area of tissue; Identical twin; Ultrasonic measurement

Human limbs (forearm, upper arm, leg and thigh) are mainly composed of tissues such as bone, fat, blood vessels, nerve and connective tissue. It is previously reported that cross-sectional areas of muscle, fat and bone closely related to the muscle functions such as strength and power and the musculartraining (Fukunaga, 1976). From biological, physiological and also educational points of view, it is important to know the heredity and environment affect affect on the composition and muscle strength. From acomparison of intrapair differences between identical and non-identical twins, in it possible to determine that ohenotypic variability in identical twins is due solely to environmental agents, whereas that in non-identical twins is due to both genetic fluctuations and extragenetic influeces.

The purpose of the present study was to observe the effect of heredity on the tissue composition and the muscle strength in human limbs.

METHOD

Male monozygotic twins of 4pairs at 16yrs participated as experimental subjects. Their zygosity was determined in a manner previously descrived (Inoue, 1962).

The cross-sectional areas of tissues of tissues such as muscle, fat and bone were measured by means of ultrasonic method (SS-120, ECHO-VISION, ALoKA, JAPAN). The frequency of the ultrasonic wave was chosen to be 5 MHZ. The subjects immersed his arm or leg pependicularly along the central axis of a water tank. The scanner, oscillating in a range of 60 degrees circulates around the tank is about 30s and produces an image of a cross-section of the arm, leg and thigh respectively, on the specially designed oscilloscope which is photographed by means of a 35 mm camera. A tipical ultrasonic photograph of the leg and thigh was presented in Fig. 1. The photograph was traced and planimetric values were obtained from the three tissues, which were then converted into actual cross-secsional areas by the calibrated formula.

The maximum isometric strength of flexors and extensors at the three joints of elbow, knee and ankle were measured bymeans of strain gauge force transducers. The subject was seated in a specially designed chair and isometric muscle strength was measured in the elbow joint flexed at 90°, the knee at 110° and the ankle at 90°, respectively. Three trials of maximum effort for about 5-sec duration each were given and the highest value was used for further analysis.

RESULTS

Cross-sectional pictures of leg and thihg of twin A and B were shown in Fig. 1. From these

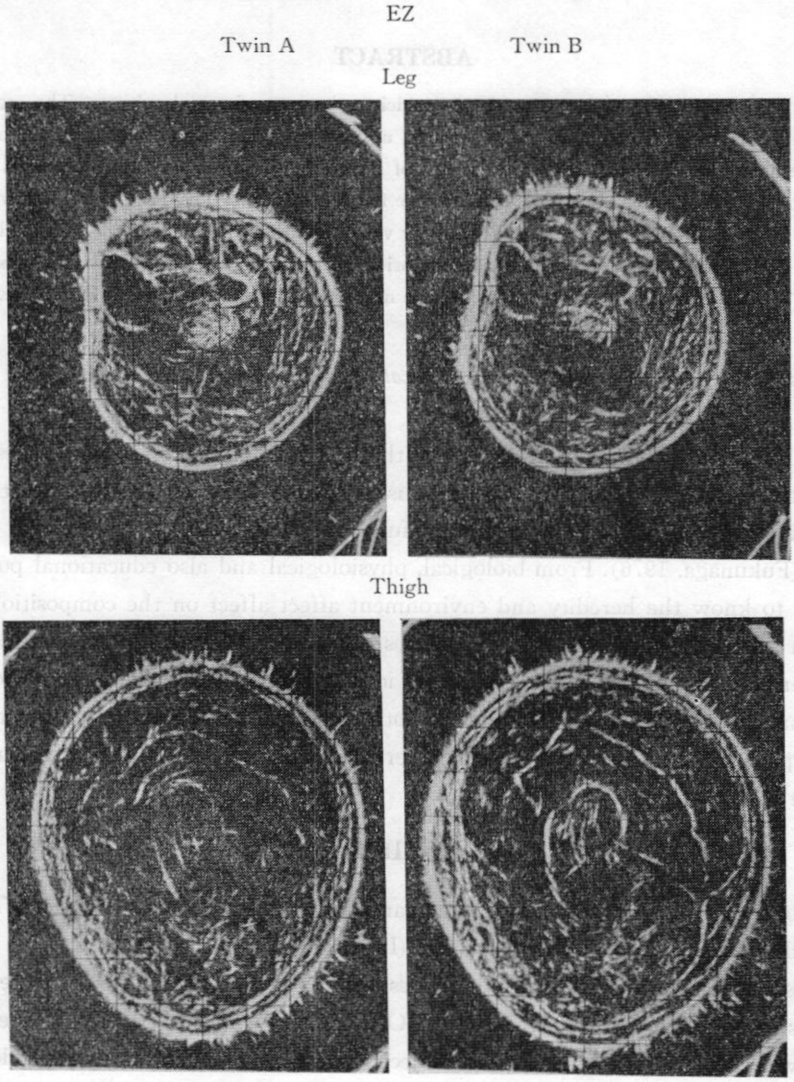

Figure 1 Ultrasonic cross-sectional view of human leg and thigh.

Table 1 Body height, weight and isometric muscle strength of monozygotic twins. (m ± s. d.)

	Twin A	Twin B
Body Height (cm)	171. 5 ± 9. 9	171. 0 ± 9. 1
Body Weight (kg)	63. 6 ± 4. 9	60. 8 ± 7. 8
Muscle strengfh (kg)		
Knee extension	69. 4 ± 4. 5	68. 4 ± 7. 3
flexion	26. 7 ± 0. 6	29. 1 ± 6. 2
Planter flexion	124. 0 ± 15. 4	120. 9 ± 21. 4
Dorsal flexion	24. 7 ± 3. 7	25. 0 ± 1. 5
Elbow extension	21. 7 ± 4. 3	19. 5 ± 3. 2
flexion	18. 5 ± 0. 5	17. 9 ± 2. 0

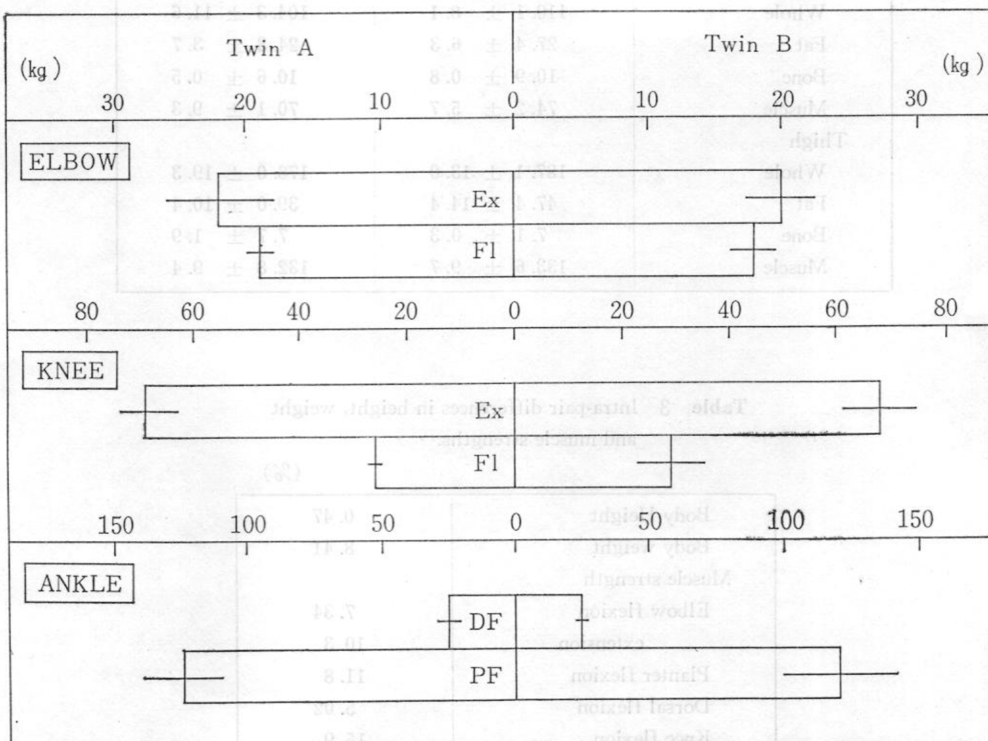

Figure 2 Muscle strength at elbow, knee and ankle joints in monozygotic twins. (m ± s. d.)

Ex : Extension
Fl : Flexion
DF : Dorsal flexion
PF : Planter flexion

Table 2 Cross-sectional areas of whole section, fat, bone snd muscle in the human limbs.

Cross-sectional area (cm^2)

	Twin A	Twin B
Forearm		
Whole	47.9 ± 3.1	44.8 ± 5.5
Fat	11.9 ± 2.7	10.1 ± 2.4
Bone	3.9 ± 0.3	4.0 ± 0.7
Muscle	32.5 ± 1.9	31.3 ± 3.6
Upper arm		
Whole	51.0 ± 7.2	46.6 ± 4.6
Fat	15.7 ± 5.9	12.5 ± 4.4
Bone	3.6 ± 0.2	3.9 ± 0.5
Muscle	31.9 ± 3.6	30.2 ± 2.6
Leg		
Whole	110.1 ± 8.1	104.3 ± 11.6
Fat	27.4 ± 6.3	24.3 ± 3.7
Bone	10.9 ± 0.8	10.6 ± 0.5
Muscle	74.2 ± 5.7	70.1 ± 9.3
Thigh		
Whole	187.1 ± 13.0	178.0 ± 19.3
Fat	47.4 ± 14.4	39.0 ± 10.4
Bone	7.1 ± 0.3	7.7 ± 1.9
Muscle	133.6 ± 9.7	132.8 ± 9.4

Table 3 Intra-pair differences in height, weight and muscle strengths.

(%)

Body Height	0.47
Body weight	8.41
Muscle strength	
Elbow flexion	7.34
extension	10.3
Planter flexion	11.8
Dorsal flexion	5.02
Knee flexion	15.9
extension	5.02

Intra-pair difference (ID)

$$= \frac{|\text{Twin A} - \text{Twin B}|}{\frac{\text{Twin A} + \text{Twin B}}{2}} \times 100$$

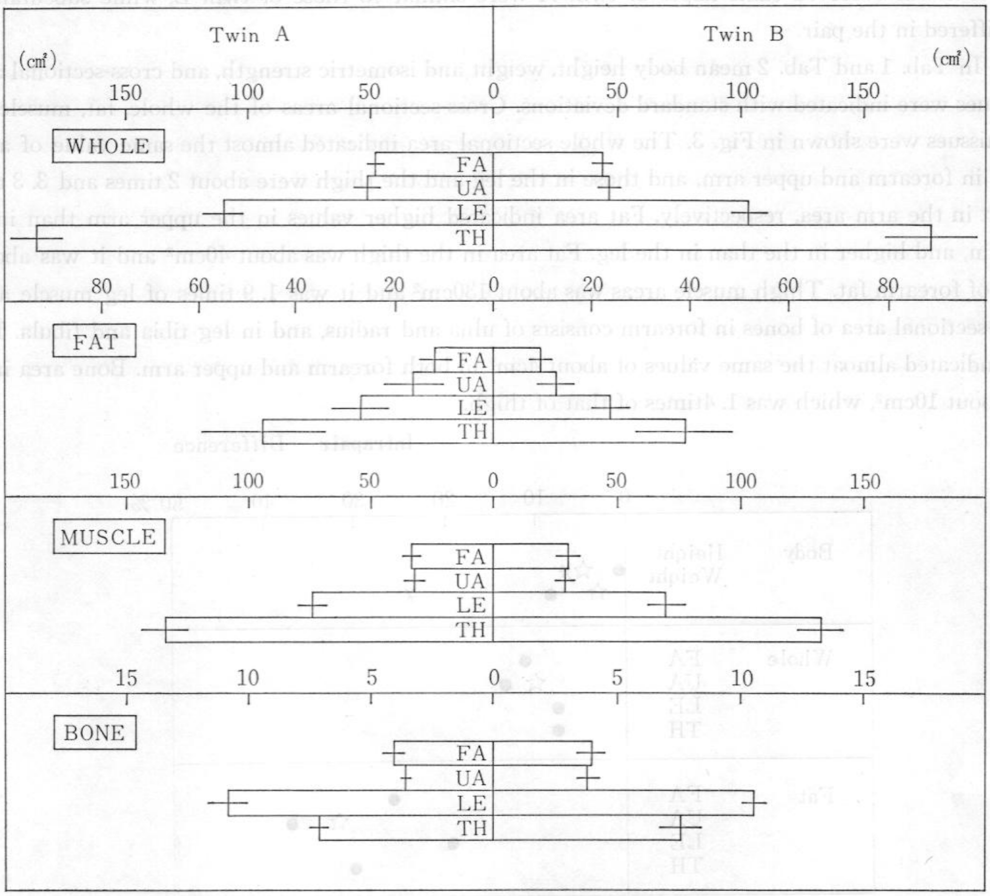

Figure 3 Cross-sectional areas of the whole section, fat, muscle and bone.

FA : Forearm
UA : Upper arm
LE : Leg
TH : Thigh

Table 4 Intra-pair differences in tissue composition.

(%)

	Forearm	Upper arm	Leg	Thigh
Whole	11. 3	13. 5	7. 55	7. 34
Fat	26. 1	36. 9	18. 9	29. 5
Bone	7. 83	12. 0	7. 99	16. 7
Muscle	7. 31	6. 35	6. 47	1. 55

pictures it was observed thats hapes of twin A were similar to those of twin B, while subcutaneous fats differed in the pair.

In Tab. 1 and Tab. 2 mean body height, weight and isometric strength, and cross-sectional areas of tissues were indicated with standard deviations. Cross-sectional areas of the whole, fat, muscle and bone tissues were shown in Fig. 3. The whole sectional area indicated almost the same value of about 50cm² in forearm and upper arm, and those in the leg and the thigh were about 2 times and 3. 3 times of that in the arm area, respectively. Fat area indicated higher values in the upper arm than in the forearm, and higher in the than in the leg. Fat area in the thigh was about 40cm² and it was about 4 times of forearm fat. Thigh muscle areas was about 130cm² and it was 1. 9 times of leg muscle area. Cross-sectional area of bones in forearm consists of ulna and radius, and in leg tibia and fibula. Bone area indicated almoat the same values of about 4cm² in both forearm and upper arm. Bone area in leg was about 10cm², which was 1. 4times of that of thigh.

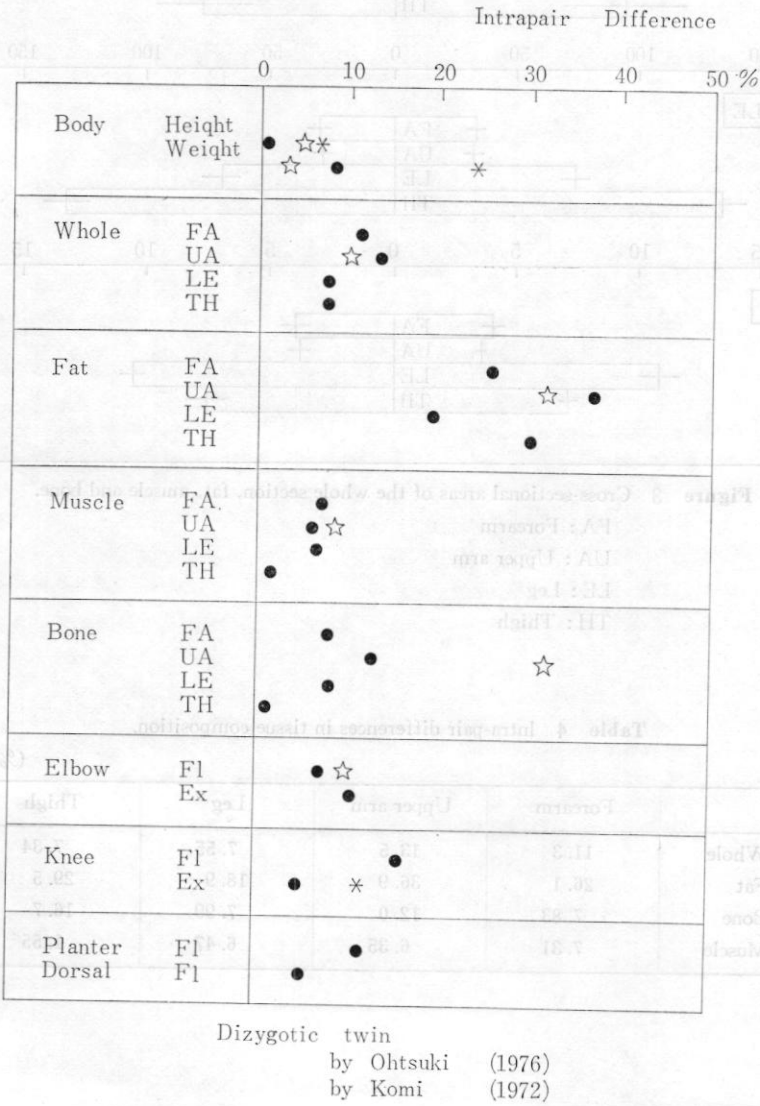

Figure 4 Intra-pair differences in monozygotic twins.

The maximum isometric strengths of flexors and extensors at elbow, knee and ankle joints were indi 2. Strength in the present study (measured strength) were obtained at the wrist for elbow joint, at the ankle for knee, and at the ball of foot for planter flexion and at the instep for dorsal flexion. In elbow and knee joints the strengths for flexion showed smaller values that for extension. In ankle joint, the strength for planter flexion indicated 4. 8 times of that for dorsal flexion.

The intra-pair differences (ID) in the cross-sectional areas of tissues and the isometric strength were shown in Fig. 4. Fat indicated the highest values of ID among three tissues, and it was tended to be larger in the upper arm than in the forearm, and higher in the than in the leg. ID of the bone in the upper arm and the thigh was higher than those fo forearm and leg, respectively. Muscle indicated almost the same values of 6-7% in the forearm, the upper arm and the leg, whereas in the thigh it was 1. 5%, which was closer to the ID in body height. ID in the isometric maximum strength indicated higher values in flexion (planter flexion) than in extension (dorsal flexion) at knee and ankle joint, whereas at elbow joint the strength was almost the same in both flexion and extension.

DISCUSSION

In order to discuss the genetic or environmental factors from the intra-pair difference of tissue composition in monozygotic twin, it is nessesary to get the enough accuracy or reproducebility of the method for measuring the composition of tissues. The accuracy and reproducebility of ultrasonic method for measuring crost-sectional area of tissues in human limbs was reported previously. Ikai and Fukunaga (1970) reported that the differences of tissue area were 3-6% between ultrasonic method and direct method by which cadavars specimen (arm and leg) was cut cross directly, and the reproducebility was about 3-8% for each tissue area. In 1982, Fukunaga and Tsunoda repordte that the cross-section of tissues by ultrasonic method indicated about 7% higher value those by roentogen CT scanning method. From these previous studies it may be considered that the ultrasonic method is useful for measuring cross-sectional area of tissue in human limbs.

In the present study ID of fat indicated higher valueof 19-37% compared to other tissue composition. Ohtsuki and Klissouras (1976) measured the cross-sectional area of tissues in upper arm for monozygotic twins and reported that ID was 6% for the whole section and muscle, 17% fat and 7% for bone. ID of muscle for the upper arm in the present study indicated almost same values as Ohtsukiś. Other tissues like fat and bone showd higher ID in the present study than in Ohtsukiś. The highest value of ID obtsined for fat in the present study was good agreement with Ohtsukiś result.

In order to clarity genetic factor, it is of nessecity to compare the differeces of ID between monozygotic and dizygotic twin. In the previoudy (Ohtsuki and Klissouras, 1976) ID of tissue area in dizygotic twin was 9. 8% for the whole part, 7. 8% for muscle, 32. 0% for fat and 31. 3% for bone (Fig. 4). Comparing these dasa for monozygotic and dizygotic twins it is considered that interindividual variations in bone can only ascribed to genetic difference.

ID of 5-15% for isometric maximum strength in the presənt study was good agreement of othe previous studies, which was 11. 6% for elbow flexors (Ohtsuki, 1976) and 13% for knee extensors (Komi, 1973).

REFERENCES

1. Fukunaga, T. Die absolute Muskelkraft und das Muskelkrafttraining. Sportarzt und Sportmedizin 27 (1), 255-265, 1976.

2. Fukunaga, T and N. Tsunoda. Comparison between ultrasonic and CT method for measuring cross-sectional area of tissues in human. JSUM Proceedings 1982.

3. Ikai, M. and T. Fukunaga. Comparison between ultrasonic and direct methods to measure the cross-sectional area of tissue. Med. Ultrason. 8(1), 77–79, 1970.

4. Inoue, E. Zygosity-diagnosis of Japanese twins by Essen-Mollerś formula (I). In Fujita, T. (ed); Studies on twins III (in japanese), Nihon Gakujutsu Shinkokai 1962.

5. Komi, P., V. Klissouras, and E. Karvinen. Genetic variation in neuromuscular performance. Int. Z. Angew. Physiol., 31, 289–304, 1973.

6. Ohtsuki, T. and V. Klissouras Genetic basis of individual differences in tissue composition. Acta Genet. Med. Gemellol (Roma) 25, 157–163, 1976.