A Case of Growth Transformation in Unexercised Limb Bones

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Abstract The unexercised limb bones of a male patient with hydrocephalus, who had been bedridden for 16 years, were observed and measured in order to examine growth transformation and growth direction. Although length growth was not markedly disturbed, transverse growth and the thickness of periosteal deposition were delayed. These findings confirmed that stress is necessary for growth of bone thickness. No differences in the circumference and area of the medullary cavity were evident between this subject and the femora of the average adult male, in spite of the delayed thickness growth. Therefore it was considered that lack of exercise disturbs the thickness growth of bone, but does not disturb bone resorption in the medullary cavity.

Key Words Unexercised, Limb bones, Growth of bone, Transformation, Bone resorption

Introduction

Length growth of limb bones differs from growth in thickness. As stated in GRAY's Anatomy (WILLIAMS and WARWICK, 1989) and Principles of Anatomy and Physiology (TORTORA and ANAGNOSTAKOS, 1987), an increase of epiphyseal cartilage contributes to growth in the length and thickness of bone through continuous subperiosteal deposition and endosteal erosion.

Recently an opportunity arose to dissect and study the body of a male patient with hydrocephalus, who had been bedridden for 16 years. The limb bones were pathologically thin, but there was no difference in their length between this patient and the average adult male. Retarded thickness periosteal growth was evident, but there was little retardation of length cartilaginous

growth. The direction of bone growth relative to stress was examined using materials from this patient.

Subject and Observations

The subject was a Japanese male patient with hydrocephalus, who had died aged 16 years and 1 month. He had been bedridden since admission to the National Higashinagano Hospital. The head girth was 754 mm, extremely large in comparison with the average (559.8 mm) for a Japanese aged 16 years (Japanese Standards Association, 1984). The volume of cerebrospinal fluid was 2,800 ml and the weight of brain 1,845 g. During life, the patient had been unable to move his head unaided, and had lain with the left side of the face in contact with the bed. He had been lying in a supine position, with the left shoulder in contact with the bed. Scoliosis and

antero-posterior torsion of the spine were observed. The head of the femur was not well developed, the acetabulum was shallow, and no formation of the acetabular tegmen was detected because of luxatio coxae congenita. The left sides of both knees had been in contact with the bed because of the congenital luxation of the hip joint.

Chondral ossification was observed at the acromial and sternal ends of both clavicles, the distal end of the right radius, the styloid processes of both ulnae, and the proximal ends of both fibulae. The epiphyseal junctions of other long bones appeared to be ossified.

Methods

Measurements taken were those defined by MARTIN and SALLER (1957). The data obtained from the patient were compared with data reported for modern Japanese bones (OHBA, 1950; SUZUKI, 1961; ARAI, 1973; EBINA, 1951; FUKUDA, 1961; MORITA, 1950; NISHIHARA, 1953; TAKANO, 1958a, b), the difference being expressed as percentages relative to the average or relative to the standard deviation.

Cross-sectional images of the femora were obtained using a CT-scanner (HITACHI CTW3-40). Forty-four right femora (from males aged 16–29 years) from the collection of the Department of Anatomy, Jikei University School of Medicine, were used for CT-scan comparison. The cross-sectional area and the circumference at the mid-shaft and the medullary cavity of the femora were calculated from the photographs with the aid of a digitizer (GRAFTEC KD3800).

Results

The measurement data for the upper limb bones are shown in Table 1.

Clavicle

A difference in the maximum length between

right and left was found. The left bone was short (maximum length: 122 mm), and showed strong curvature of the shaft (23.8) in comparison with the right side. The mid-shaft circumferences of both the right and left bones were 33 mm. The arc lengths of the shaft curvature were 112 mm (right) and 106 mm (left).

Scapula

A difference in the coracoid process between right and left was found, the right being larger than the left. The vertical diameter was 7.4 mm (right) and 6.3 mm (left) at the mid-point of the maximum length of the coracoid. The sagittal diameter was 12.7 mm (right) and 9.2 mm (left), and the circumference of the mid-point was 36 mm (right) and 28 mm (left).

Humerus

The proximal epiphyseal line was well defined, and resembled a shallow groove. The crest of the lesser tubercle was not defined, but the crest of the greater tubercle was sharp (Fig. 1a). In particular, the left crest of the greater tubercle protruded and showed medial deviation. The deltoid tuberosity was faintly evident. The radial nerve sulcus was not found. In cross-section, the mid-shaft of the right humerus was columnar in shape, with compression at the antero-medial and posterior surfaces (Fig. 1b); the left mid-shaft showed a columnar shape with compression at the medial and lateral surfaces. The distal parts of both bones showed a deltoid columnar shape (Fig. 1c), their anterior edges were sharp, and the antero-lateral and posterior surfaces were narrow.

Radius

The distal end of the right radius showed chondral ossification. The radial tuberosity was normal. The transverse diameter and the circumference were small.

Table 1. Measurements in mm and indices of upper limbs

Item with MARTIN's number ¹⁾	Hydrocephalus	Recent Japanese			Difference	
	H	N	M ²⁾	SD	100[H-M]/M	[H-M]/SD
Clavicle (right)						
		(TAKANO, 1958a)				
1 Max. length	142	125	139.6	9.8	2	0.2
2a:1 Index of curvature	18.3	125	22.1	2.1	-17	-1.8
4 Vert. diam. of mid-shaft	9	125	10.0	1.4	-10	-0.7
5 Sagit. diam. of mid-shaft	11	125	12.2	1.7	-10	-0.7
4:5 Index of cross-section	81.8	124	83.4	13.0	-2	-0.1
6 Circumf. of mid-shaft	33	125	38.2	4.1	-14	-1.3
6:1 L-T index	23.4	125	27.3	3.1	-14	-1.3
Scapula (right)						
		(TAKANO, 1958b)				
1 Anatomical width	133	124	149.3	9.3	-11	-1.8
2 Anatomical length	80	124	98.2	5.3	-19	-3.4
2:1 W-L index	60.2	125	66.1	3.4	-9	-1.7
6:2 Supraspin. index	50.0	124	42.3	5.2	18	1.5
12 Length of glen. cav.	35	124	35.2	2.5	-1	-0.1
13 Width of glen. cav.	21	124	26.8	2.3	-22	-2.5
13:12 L-W index of glen. cav.	60.0	125	76.2	5.0	-21	-3.2
15 Angle between L-W	79	125	88.2	3.1	-10	-3.0
Humerus (right)						
		(NISHIHARA, 1953)				
1 Max. length	305	70	295.9	16.9	3	0.5
3 Upper epiph. width	43	70	48.3	2.7	-11	-2.0
4 Bicondylar width	48	70	59.0	3.7	-19	-3.0
5 Max. diam. of mid-shaft	16	70	22.4	1.8	-29	-3.6
6 Min. diam. of mid-shaft	11	70	17.7	1.6	-38	-4.2
6:5 Index of cross-sec.	68.8	70	79.6	4.7	-14	-2.3
7 Least circumference	45	70	62.3	4.3	-28	-4.0
7:1 L-T index	14.9	70	21.1	1.6	-29	-3.9
10 Sagit. diam. of head	39	70	44.2	3.0	-12	-1.7
12a Width of troch. & cap.	34	70	40.8	3.2	-17	-2.1
14 Width of olec. fossa	24	70	27.0	1.8	-11	-1.7
16 Cond.-shaft angle	93	70	81.1	3.4	15	3.5
18 Torsion angle	129.7	70	152.7	5.2	-15	-4.4
Ulna (right)						
		(EBINA, 1951)				
1 Max. length	239	64	241.5	10.3	-1	-0.2
6(1) Width of upp. epiph.	22	64	31.5	2.4	-30	-4.0
11 D-V diam. of shaft	11	64	13.2	1.1	-17	-2.0
12 Transv. diam. of shaft	8	64	16.3	1.1	-51	-7.5
11:12 Index of cross-sec.	137.5	64	80.9	7.3	70	7.8
3:2 L-T index	12.3	64	17.5	1.3	-30	-4.0
Radius (left)						
		(EBINA, 1951)				
1 Max. length	228	64	223.7	10.0	2	0.4
2 Physi. length	214	64	207.3	8.8	3	0.8
3 Min. circumference	26	64	40.4	2.8	-36	-5.1
4 Transv. diam. of shaft	12	64	16.5	1.4	-27	-3.2
5 D-V diam. of shaft	7	64	11.7	1.0	-40	-4.7
5:4 Index of cross-sec.	58.3	64	71.0	5.8	-18	-2.2
4(1) Transv. diam. of capit.	18	64	21.1	1.3	-15	-2.4
5(5) Circumference of mid-shaft	29	64	43.4	3.4	-33	-4.2
5(6) Width of lower epiph.	24	64	33.3	2.2	-28	-4.2
3:2 L-T index	12.1	64	19.6	1.4	-38	-5.4

1) English version according to SUZUKI *et al.* (1986)

2) Mean for recent Japanese

Fig. 1. CT cross-section image of the right humerus of a hydrocephalic patient: a. proximal $\frac{1}{4}$ level; b. mid-shaft level; c. distal $\frac{1}{4}$ level.

Ulna

The distal ends of both ulnae were not ossified and the styloid process showed chondral ossification. The ulnar tuberosity was ill-defined, in contrast to the radial tuberosity, showed a normal pattern. The supinator crest was observed, and the interosseous border at the distal third of the shaft showed slight lateral protrusion. The crest of attachment of the pronator quadratus was continuous with the interosseous border.

The measurements of the right lower limb bones are shown in Table 2.

Femur

Both femoral heads were less developed than normal, and showed a large degree of torsion (right 4.9 SD, left 2.9 SD), resulting in twisting of the upper part of the shaft (Fig. 2b). The right torsion angle was greater than the left (right 59°, left 38°). These angles were also greater than those of the average Japanese (12.4°). Prominent protrusion of the greater and lesser trochanters was observed, although both were not markedly large (Fig. 2a). The intertrochanteric line was not defined and the intertrochanteric crest was absent. The posterior area between the greater and lesser trochanters was largely concave. The gluteal tuberosity was not elevated, but was prolonged to the linea aspera. The medial and lateral lips of the linea aspera were not definitely defined

at the distal third of the shaft (Fig. 2c). The posterior margin of the linea aspera was sharp. The upper protruding part of the adductor tubercle was not well defined. The width of the articular surface was narrow from the inferior to posterior area of the medial and lateral condyles. The intercondylar fossa was largely concave.

Tibia

The tibiae showed strong torsion, as in the case of the femora. The torsion on the left side was greater than that on the right (right 21°, left 27°), contrary to the bilateral difference noted for the femora. The tibial tuberosity was observed as a forward eminence, but no protrusion was found. In cross-section, the upper part of the shaft showed a deltoidal columnar shape (Fig. 3a). The anterior margin and interosseous border of the lower half of the shaft could not be seen clearly. The medial, lateral and posterior surfaces of the lower half of the shaft were not flat, but convex, giving the lower half of the shaft a columnar shape (Fig. 3b). The soleal line was indefinite at the postero-superior part of the bone. The upper medial part of the shaft as far as the nutrient foramen was concave, and the sulcus was observed. The maleolar sulcus on both sides was absent.

Fibula

The heads of both fibulae showed chondral

Table 2. Measurements in mm and indices of right lower limbs

Item with MARTIN's number ¹⁾	Hydrocephalus		Recent Japanese			Difference	
	H	N	M ²⁾	SD		100[H-M]/M	[H-M]/SD
Pelvis							
		(ARAI, 1973)					
1 Height	151	115	206.0	8.1	-27		-6.8
2 Max. width	192	115	255.5	12.1	-25		-5.2
1:2 W-H index	78.6	115	79.8	3.5	-2		-0.3
3 Outer sagit. diam.	158	115	165.5	10.1	-5		-0.7
9 Height of ilium	103	115	133.6	7.0	-23		-4.4
11 Depth of iliac fossa	5	115	7.9	2.3	-37		-1.3
12 Width of ilium	115	115	150.3	6.8	-23		-5.2
12:10 Iliac index	164.3	115	161.7	8.0	2		0.3
15 Height of ischium	57	115	79.7	3.1	-28		-7.3
17 Length of pubis	69	115	75.8	3.7	-9		-1.8
22 Max. diam. of acetab.	38	115	53.5	2.2	-29		-7.0
24 T.diam. of pelv. inlet.	83	115	119.1	5.8	-30		-6.2
33 Infra-pubic angle	72	115	62.4	7.9	15		1.2
Femur							
		(OHBA, 1950)					
1 Max. length	391	132	412.1	18.6	-5		-1.1
2 Physiological length	384	132	408.1	19.4	-6		-1.2
5 Shaft length	323	132	324.8	17.8	-1		-0.1
6 Sagit. diam. of mid-shaft	18	132	27.6	2.2	-35		-4.4
7 Transv. diam. of mid-shaft	14	132	26.2	2.1	-47		-5.8
6:7 Pliasteric index	128.6	132	105.7	8.4	22		2.7
8:2 L-T index	13.3	132	20.4	1.3	-35		-5.5
8:5 L-T index	15.8	132	25.6	1.6	-38		-6.1
10:9 Platymetric index	105.9	132	82.2	6.8	29		3.5
13 Upper width	56	132	92.8	5.3	-40		-6.9
15 Vert. diam. of neck	21	132	33.3	2.7	-37		-4.6
18 Vert. diam. of head	31	132	46.1	2.8	-33		-5.4
21 Bi-epicondylar width	62	132	79.7	4.0	-22		-4.4
22 Proj. length of lat. cond.	45	132	60.3	3.1	-25		-4.9
22:21 Condylar index	72.6	132	75.7	2.7	-4		-1.1
27 Index of curvature	4.4	132	3.5	1.0	26		0.9
28 Torsion angle	58.7	132	12.4	9.5	373		4.9
29 Neck-shaft angle	133	132	128.4	4.6	4		1.0
30 Condyle-shaft angle	100	132	81.1	1.8	23		10.5
Tibia							
		(SUZUKI, 1961)					
1 Total length	331	80	320.4	14.7	3		0.7
3 Width of upper epiph.	55	80	74.6	3.2	-26		-6.1
6 Width of lower epiph.	35	80	51.3	2.2	-32		-7.4
8 Max. diam. of mid-shaft	13	80	28.7	2.1	-55		-7.5
9 Transv. diam. of mid-shaft	12	80	22.8	1.7	-47		-6.4
9:8 Index of cross-sec.	92.3	80	78.7	6.5	17		2.1
9a:8a Cnemic index	100.0	80	78.3	7.3	28		3.0
10b:1 L-T index	10.9	80	22.7	1.4	-52		-8.4
11 Index of curvature	1.1	80	1.9	0.7	-42		-1.1
12 Retroversion angle	8	80	13.6	4.0	-41		-1.4
14 Torsion angle	21	80	16.7	8.1	26		0.5
Fibula							
		(FUKUDA, 1961)					
1 Max. length	303	80	322.4	15.7	-6		-1.2
2 Max. diam. of mid-shaft	7	80	14.8	1.5	-53		-5.2
3 Min. diam. of mid-shaft	6	80	10.9	1.1	-45		-4.5
4(2) Width of lower epiph.	15	80	19.8	1.6	-24		-3.0
4(a):1 L-T index	5.0	80	11.7	1.3	-57		-5.2

1) English version according to SUZUKI *et al.* (1986)

2) Mean for recent Japanese

Fig. 2. CT cross-section image of the right femur of a hydrocephalic patient: a. lesser trochanter level; b. proximal $\frac{1}{4}$ level; c. distal $\frac{1}{3}$ level.

Fig. 3. CT cross-section image of the right tibia of a hydrocephalic patient: a. proximal $\frac{1}{4}$ level; b. distal $\frac{1}{4}$ level.

ossification, and the anterior margin showed a rounded edge. In cross-section, the shaft did not appear deltoid columnar in shape, but square columnar. No concavity of the medial surface was observed. The shaft was curved antero-medially, rather than postero-laterally.

Discussion

One of the essential factors affecting bone transformation is excessive secretion of growth hormone. However, it appeared that this had not occurred in the present patient because of the significantly shorter length of the long bones compared with the normal average Japanese adult, and the absence of any delay of bone age.

A brief description of the bones in the present patient have already been given by TAKEUCHI *et*

al. (1989). The head of the femur did not articulate with the acetabulum, and the left sides of both knees had been in contact with the bed because of congenital luxation of the hip joint. The thigh from the inguinal area to the knee was partly twisted to the left because of the position of the pelvis during supine lying. Therefore the torsion angle of the femur was large. The right thigh showed internal rotation and the left external rotation because both thighs were twisted to the left. For this reason, the right torsion angle of the femur, which had been subjected to continuous internal rotation, was greater than the left.

Bone transformation was also observed in the upper limbs. The left shoulder had been in contact with the bed due to the large head being

turned toward the left. For this reason, a difference between the right and left clavicles was observed. However there was not much difference between the circumferences at the mid-shaft and the length of the arc of the shaft curvature. Therefore this transformation of the clavicle was due to continuous compression, and not to growth transformation. SCOTT (1957), in describing bone transformation, stated that growing bone is changed by outer stress, whereas mature bone is not changed to a great extent. The observed transformation of the left clavicle was thus due to external stress on the growing bone (SCOTT, 1957).

A large difference between the right and left scapulae was also found. The right coracoid process was larger than the left, because the left upper limb had not moved much due to the left shoulder having been in contact with the bed,

although the right upper limb had been moved relatively more than the left. Healthy bones are larger than atrophied bones (HAMADA *et al.*, 1967, 1968). The difference in thickness between the right and left coracoid processes, to which the short head of the biceps brachii, the coracobrachialis and the pectoralis minor muscles are attached, was due to the difference in the quantity of mechanical stress during the growth period. One report has described a difference in bone transformation between the right and the left (ISHIDA and SUZUKI, 1985) due to disuse atrophy of the limbs after childhood poliomyelitis. There have been a few studies on the influence of childhood paralytic disease on skeletal growth (HUMPHRY, 1862; HOWELL, 1917; TOWER, 1937). These studies showed that growth of bone length and breadth was suppressed in atrophic long bones, and that the

Fig. 4. Upper limb bones of a male patient with hydrocephalus (a) and a normal female aged 20 (b): 1. right radius; 2. right ulna; 3. right humerus.

Fig. 5. Right femur of a male patient with hydrocephalus (a) and a normal female aged 20 (b).

transverse growth of long bones was more markedly disturbed than the axial growth.

The same tendency was observed in the present case. In Figs. 4, 5, 6, the right radius, ulna, humerus, femur, fibula and tibia of the patient are shown in comparison with the right bones of a normal adult female aged 20 years. The length-thickness indices for all the long bones were much smaller in the patient compared with the female control, whose bones were smaller in size than the average normal value for recent Japanese males.

In Table 3, the length of each long limb bone, the circumference of the mid-shaft, the sagittal and the transverse diameter, and indices are compared with those of the normal average Japanese adult as reported in the studies cited in the Methods. Each of the diameters and L-T index at the mid-shaft was small in comparison with the average. In the upper limb, the humerus and radius were slightly longer than average, but the length of the ulna was almost the same (Fig. 7). Thus no delay in length growth was observed. However the size of the epiphyseal bone was

Fig. 6. Lower limb bones of a male patient with hydrocephalus (a) and a normal female aged 20 (b): 1. right fibula; 2. right tibia.

small (range: $-2SD$ to $-3SD$), and the thickness of the epiphyseal bone was much smaller ($-4SD$). The length-thickness index was also small ($-4SD$), and the lower limbs had almost the same tendency (Fig. 8). The head of the femur showed arrested development because of congenita luxatio coxae. Bone transformation such as strong torsion of the femur due to the abnormal position of the patient was observed. For these reasons, the delay in the growth of the lower limb bones was much more obvious than in the upper limbs. However, definite delay in growth

of the lower limb bones was observed, compared with the upper limbs, because of the congenita luxatio coxae and arrested development of the femoral head. Reports stating that the growth in thickness of the limb bones was delayed were the result of comparing the atrophied side and the healthy side (ISHIDA and SUZUKI, 1985; OMORI and ISHIDA, 1948, 1950).

In experiments using animals, MAASS (1901) set the hind leg of rabbit in a cast, and SHIMIZU (1941) amputated the forelimb of rat at the right elbow, leaving the proximal part on the body.

Table 3. Comparison of long bones between hydrocephalic male (H) and recent Japanese males (J)

		Length	Circum- ference	Sagit. diam.	Transv. diam.	Index of cross-section	Length-thickness index
Humerus	-H	305	46	16	11	68.8	14.9
	-J	295.9	66.2	22.4	17.7	79.6	21.1
Radius	-H	228	29	7	10	70.0	13.6
	-J	223.7	43.4	12.2	15.6	78.3	21.1
Ulna	-H	211	26	11	8	137.5	12.3
	-J	210.7	36.6	13.2	16.3	80.9	17.5
Femur	-H	323	51	18	14	128.8	15.8
	-J	324.8	83.6	27.6	26.2	105.7	25.6
Tibia	-H	335	41	13	12	92.3	10.9
	-J	325.3	79.0	28.7	22.8	78.7	22.7
Fibula	-H	303	23	7	6	85.7	5.0
	-J	322.4	43.4	14.8	10.9	73.4	11.7

Fig. 7. Deviation graph of upper limb bones. M: mean for recent Japanese.

These experiments also revealed that the growth in thickness of the limb bones was delayed.

The growth in the length of the upper and lower limb bones was not delayed in our patient, but there observed delayed growth in thickness. This tendency agrees with that in the previous studies (HUMPHRY, 1862; HOWELL, 1917; TOWER, 1937). However, difference between

upper and lower limb bones in delayed growth as observed in our subject has not been described in previous reports. Such a difference in growth suggests that there is a difference in the quality and quantity of stress between the upper and lower limb bones. Since the male patient we examined had been bedridden for 16 years, he had never been in an upright position, and

Fig. 8. Deviation graph of lower limb bones. M: mean for recent Japanese.

therefore his lower limb bones had not been placed under axial stress. Normally, the lower limb bones are under stress due to muscle action and also due to the body weight. The growth in thickness of the lower limb bones was markedly delayed in our patient probably because the bones had not been subjected to very much of either of these stresses.

This suggests that the delayed growth in the thickness of the lower limb bones was due to disturbance of bone deposition. However, bone absorption was not very much disturbed. Fig. 9 shows a CT-scan cross-section of the materials; one is the mid-shaft of the femur from the male patient with hydrocephalus, and the other is the same region of the femur from a male aged 21 years. Both femurs are of the same length, but the medullary cavity of the male patient is large despite the thinness of the shaft. The thickness of adult limb bones increases with age (SELDIN, 1964; TAKEUCHI *et al.*, 1990). For this reason, subjects used for comparison by CT-scan should be of similar ages.

The average cross-sectional area, the circum-

Fig. 9. CT cross-section image at the mid-shaft of femur: 1. normal male aged 21; 2. male patient with hydrocephalus.

ference of the shaft, the area of the medullary cavity, the circumference of the medullary cavity and other data for the male patient are shown in Table 4. When these materials are compared with the normal ones, the outer circumference of the shaft is -4.64 SD, and the inner circumference of the medullary cavity is -1.63 SD. The cross-sectional area of the shaft is -3.97 SD and the area of the medullary cavity is only -1.66

Table 4. Circumference and area of right femoral mid-shaft

	Hydrocephal. H	Recent N	Japan. males M	SD	Differ. [H-M]/SD
Circumference of shaft (mm)	51	44	83.0	6.9	-4.64
Circumference of marrow cavity (mm)	31	44	41.1	6.2	-1.63
Area of cross section (mm ²)	193	44	522.5	83.0	-3.97
Area of marrow cavity (mm ²)	66	44	126.6	36.6	-1.66

SD. The ratio of the outer circumference of the shaft compared with the inner circumference for the normal group was 49.5%, and that for the subject was 60.8%.

When the cross-sectional area was compared with the area of the medullary cavity, the ratio for the normal group was 24.2%, and that for the subject was 34.2%. The outer circumference was larger than the inner circumference. This indicates that the area of the medullary cavity of the male patient was large. Therefore the circumference of the medullary cavity of our unexercised male patient was almost normal, and the area of the medullary cavity was normal, in spite of the smaller outer circumference.

Above observation indicates that there is no correlation between resorption of the medullary cavity and additional deposition on the outer surface of the shaft. The growth in thickness of limb bones due to additional deposition is delayed due to lack of exercise, but resorption of the medullary cavity by osteoclasts is nearly normal, and growth in the length of the limb bone is not markedly delayed by chondral deposition. Consequently, mechanical stress appears to be a very important factor for acceleration of thickness growth of the long bones.

Conclusion

Growth transformation and deformation of the long limb bones of a male patient with hydrocephalus who had been bedridden for 16 years without exercise are summarized as follows:

1. Strong deformation was seen in the left clavicle (curvature of the shaft) and the upper part of the femur (torsion), which had been kept in the same position for a long time. This indicates that external stress caused bone deformation during the growth period.

2. The shaft-circumference of each long bone was smaller than the average for normal contemporary Japanese because the patient had not created stress on the bone by exercise which would have contributed to acceleration of the periosteal growth in thickness.

3. The upper and lower limb bones of the patient were thin, especially the lower limb bones. This is because the lower limbs had not been subjected to stresses from muscle action and supporting the body weight. Thus growth in thickness of the lower limb bones seems to be a result of not only the stress due to movement, but also the stress due to supporting the body weight.

4. Each length measurements was not much different from that in the normal adult, which

suggests the mechanical stresses had very little influence on the axial growth attained by cartilaginous deposition.

5. The circumference and area of the medullary cavity showed no large difference from the normal, despite the smaller outer circumference of the shaft. Thus, lack of exercise influences periosteal growth in thickness, but not bone resorption in the medullary cavity by osteoclasts. As a result, there are no correlations between bone deposition and absorption due to lack of exercise.

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抄 録

非運動下における四肢骨成長の変異の1例

竹内修二

四肢長骨の成長には、骨端軟骨の増殖による長さの成長と、骨膜内面に骨質をつくり骨周囲に付加される太さの成長とがあり、また、太さの成長では、付加増骨のみならず、破骨細胞による髓腔の拡大も行われている。

この、長骨の長さと太さとの成長の様式の違いが、成長そのものの違いとして現れた例に遭遇した。16年間寝たきりの状態であった水頭症男子を剖検する機会を得、その骨格標本の四肢長骨を観察した結果、非常に細く病的状態を呈していた。しかし、これらの四肢骨を計測した結果、長径では成人平均値との間に、大きな差を見いだせなかった。つまり、成長阻害は骨膜性の太さの成長には現れたが、軟骨性の長さの成長はさほど阻害されておらず、成長の遅延はなかった。また、骨体中央の周径及び断面積が成人平均値と比較して非常に小さく細いの、髓腔の周径及び面積は成人平均値と余り差はなかった。成長期の長期間にわたる非運動下における骨形態の変

異を示すと考えられるこの資料をもとにして、負荷に対する骨の適応的成長の方向性等に付いての、次のような考察を行った。

1. 各長骨の骨体の周径が、正常な現代日本人成人平均値と比較して非常に細いのは、非運動下において力学的負荷が余り与えられなかったためであり、骨膜性の太さの成長促進には力学的負荷を要する。

2. 同じく細い骨体を持つ上肢骨と下肢骨を比べると下肢骨の方がより細いのは、筋運動による力学的負荷と、体重の支持による力学的負荷の両負荷がほとんど掛からなかったためであり、下肢の太さの成長には運動による負荷のみならず身体荷重負荷が促進の要因となっている。

3. 各長径が、成人平均値と比較して差がないことから、軟骨性増殖による長さの成長に力学的負荷は殆ど影響を与えない。

4. 骨体の周径が細い割に、髓腔の周径、面積には成人平均値とあまり差がないことから、骨膜性の太さの成長に影響を与えた運動の欠如は、破骨細胞による髓腔の骨吸収には影響しない。その結果、非運動下では増骨付加と破骨吸収とは関連しない。

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