

RADIOGRAPHIC MEASUREMENTS OF METACARPOPHALANGEAL LENGTHS IN JAPANESE CHILDREN

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Summary The lengths of 19 tubular bones of the hand were measured on radiographs of 1,585 Japanese children aged 0 to 17 years. The means and standard deviations related to age and sex were calculated and presented in tables. Using the standards, examples of the metacarpophalangeal pattern profile analysis are presented.

Key Words metacarpals, phalanges, hand, Japanese children

INTRODUCTION

The lengths of metacarpals and phalanges are altered in a wide variety of multiple malformation syndromes. Thus, metacarpophalangeal pattern profile (MCP) analysis, in which the plus or minus deviations of the bone length from the age- and sex-related mean values are displayed on a graph, has been increasingly used as a means of defining hand malformations in known syndromes (Al-Awadi *et al.*, 1988; Butler *et al.*, 1985a, 1985b, 1986, 1987a, 1987b, 1988), or as a tool in the diagnosis of patients with hand malformations (Tonoki *et al.*, 1988). It is also a powerful tool in the identification of affected individuals in pedigree studies of malformation syndromes (Poznanski *et al.*, 1972, 1983).

There is a dearth of data for the lengths of hand tubular bones in Japanese children (Hasue *et al.*, 1955; Kato *et al.*, 1955; Kunishima, 1965). In view of this, we carried out such measurements in 1,585 normal Japanese children of the ages 0 to 17 years.

MATERIALS AND METHODS

Hand radiographs of 1,585 normal infants and children of both sexes, aged 0 to 17 years, were studied (Table 1). They included 1) 481 infants and children of up to 15 years of age, who visited the Department of Orthopedics, Nagoya University, and other orthopedic clinics in the Tokai area, for accidental injuries during

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Table 1. Distribution of the materials by age.

Age (yr)	Boys			Total	Girls			Total
	Nagoya	Saga	Nagasaki		Nagoya	Saga	Nagasaki	
0	15			15	15			15
1	12			12	13			13
2	15			15	12			12
3	21			21	9			9
4	27		24	51	21		27	48
5	12		38	50	13		36	49
6	14	36		50	11	39		50
7	19	31		50	15	39		54
8	13	37		50	11	39		50
9	20	45		65	14	52		66
10	15	32	4	51	11	51		62
11	17	45		62	14	30	6	50
12	16	34		50	11	49		60
13	20	29		49	27	25		52
14	10	41		51	15	37		52
15	9	39	3	51	14	36		50
16		50		50		47		47
17		50		50		53		53
Total	255	469	69	793	226	497	69	792

the period from 1976 to 1983, and were judged otherwise normal (Sugiura, 1985); 2) 966 children, 6 to 17 years of age, drawn from a primary school, a junior high school and a senior high school in Ogi, Saga Prefecture, collected between 1982 and 1985 (part of Ogi Longitudinal Growth Study projected by T. Akiyoshi); and 3) 138 children mainly consisting of those who attended two kindergartens in Nomozaki, Nagasaki Prefecture, in 1978 and 1979 (Takai and Akiyoshi, 1983).

The infants and children were grouped according to sex and yearly age intervals. Those at the 0 to 3 year age range had 9 to 21 infants and children in each sex and age group, while those at the 4 to 17 year range consisted of 49 to 66 children in each group (Table 1).

All hand radiographs were taken in the postero-anterior position with uniform focal-tube distance of 100 cm. Of the 1,585 infants and children radiographs of the right hand were used for study in 1,146 subjects, while those of the left hand were studied in the remaining 439 subjects. No appreciable difference between the right and left hands was noted in 42 children whose radiographs of both hands were available. Figure 1 shows measurements of bone lengths. Measure-

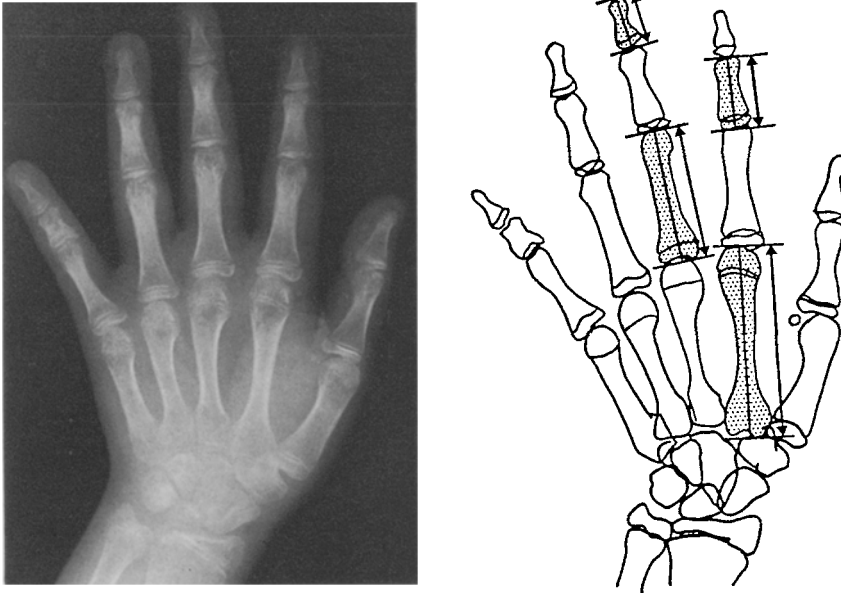


Fig. 1. Hand radiograph of a 16-year-old patient with the Turner syndrome with a 45,X karyotype. Length measurements of the metacarpals, the proximal, middle and distal phalanges made on the proximal-to-distal axis including the epiphysis when separate.

ments were made to nearest 0.1 mm with a Digimatic Caliper CD-15A (Mitutoyo) on the proximal-to-distal axial lengths of the 19 tubular bones of the hand. The tubular bones studied included the metacarpals and the proximal, middle and distal phalanges. All measurements were carried out by one of the authors (S.M.) and recorded by an assistant. For details of measurement, the reader is referred to Garn *et al.* (1972).

The data thus obtained were analyzed essentially according to the method as described previously (Igarashi and Kajii, 1988). Briefly, all computations were performed by an Epson PC-286 personal computer using programs written in Lotus 1-2-3 and Audemain Kagaku Keisan Forms. The raw data for each sex and age group were used to calculate the means, standard deviations, and minimal and maximal values. Exceptional, outlying values were rejected referring to the expected extreme values for a normal distribution of the estimated mean and standard deviation. The expected extreme values were calculated at the 1% level referring to Smirnov's constant. Thus, of a total of 30,115 measurements, 107 (0.4%) derived from 63 children were disregarded.

RESULTS

Table 2 shows the means and standard deviations for the lengths of 19 tubular

Table 2A. Means and standard deviations (S.D.) for the lengths of the 19 tubu-

Bones		0		1		2		3	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Distal	5	5.2	0.6	5.9	0.6	7.2	0.8	8.6	1.4
	4	6.5	0.6	7.3	0.8	9.1	1.0	10.4	1.2
	3	6.3	0.5	7.1	0.6	9.0	1.0	10.1	1.2
	2	5.6	0.5	5.8	0.7	7.4	0.8	9.1	1.1
	1	7.5	0.6	9.3	1.1	11.3	0.9	12.6	1.1
Middle	5	6.0	0.9	7.4	1.0	8.4	1.0	9.5	1.4
	4	9.6	1.0	11.6	1.1	13.5	1.1	14.8	1.5
	3	10.1	0.9	11.6	0.9	13.8	1.2	15.5	1.6
Proximal	2	8.2	0.8	9.5	0.6	11.0	0.8	12.9	1.2
	5	11.5	1.5	14.2	1.3	16.8	1.3	18.7	1.7
	4	14.9	1.9	18.7	1.8	22.0	1.7	24.2	2.0
	3	15.8	1.8	20.1	1.8	23.1	2.0	25.7	2.0
Metacarpal	2	13.8	2.3	17.8	1.6	20.8	1.8	23.1	1.8
	1	10.2	1.2	12.6	1.2	14.4	1.5	16.6	1.7
	5	15.3	1.7	18.8	1.8	23.1	2.3	26.7	2.1
	4	16.7	2.0	21.3	2.1	25.9	2.7	30.1	2.9
	3	18.9	2.1	23.9	2.4	29.4	2.8	33.3	2.4
	2	20.2	2.4	25.1	3.3	31.7	2.8	35.4	2.3
Distal	1	12.8	1.5	15.7	1.6	19.6	2.0	23.1	1.6
	5	5.5	1.5	6.3	0.9	8.3	0.4	8.7	1.0
	4	6.2	0.5	8.0	1.1	9.7	0.9	10.4	1.0
	3	6.2	0.5	7.9	0.9	9.4	0.8	10.2	0.9
	2	5.3	0.6	6.7	0.8	8.5	0.5	9.3	1.1
Middle	1	7.3	1.2	10.1	0.8	11.6	1.0	12.1	1.3
	5	6.1	0.5	7.4	1.0	9.0	1.2	9.5	1.5
	4	9.4	1.4	11.9	1.2	13.9	1.2	14.5	1.5
	3	9.8	1.2	12.5	1.2	14.4	1.3	15.3	1.5
Proximal	2	8.3	0.8	10.1	0.8	11.8	1.2	12.9	1.4
	5	11.1	1.6	15.1	1.3	17.0	1.2	18.1	1.6
	4	14.6	2.4	19.6	1.2	22.1	1.3	23.4	2.1
	3	15.5	2.5	20.8	1.2	23.6	1.6	25.0	2.3
	2	13.9	2.2	18.7	1.1	21.0	1.4	22.6	1.9
Metacarpal	1	9.7	1.4	12.7	1.1	15.5	1.4	16.4	1.6
	5	14.5	1.8	20.3	2.5	23.3	2.1	26.5	2.7
	4	16.3	2.3	22.7	3.1	26.2	1.8	29.9	3.0
	3	18.5	2.5	25.3	3.0	29.4	2.2	33.5	3.4
	2	19.3	2.8	27.3	3.3	31.5	2.2	35.4	3.3
	1	12.6	1.9	17.4	2.0	20.5	2.1	23.0	2.9

lar bones related to age (0-8 years) and sex (upper half, boys; lower half, girls).

4		5		6		7		8	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Boys									
9.4	0.8	10.3	0.7	10.8	0.6	11.5	0.9	12.3	1.0
10.9	0.8	11.9	0.8	12.3	0.8	13.1	0.9	14.2	1.1
10.6	0.8	11.6	0.8	12.0	0.7	12.8	0.8	13.8	1.1
9.7	0.9	10.7	0.8	11.2	0.7	11.7	0.7	12.8	1.1
13.1	0.9	14.0	1.0	14.8	1.0	15.6	1.2	17.0	1.3
10.5	1.0	11.1	1.3	11.5	1.3	12.1	1.4	13.5	1.3
15.6	1.0	16.6	1.2	17.2	1.2	17.9	1.3	19.5	1.3
16.4	1.0	17.4	1.2	18.1	1.2	18.9	1.3	20.5	1.4
13.6	0.9	14.6	1.1	15.2	1.1	15.9	1.2	17.2	1.3
19.3	1.1	20.6	1.3	21.6	1.3	22.4	1.6	24.2	1.5
25.0	1.3	26.6	1.5	28.1	1.6	29.0	2.0	31.1	1.5
26.9	1.5	28.3	2.1	30.2	1.9	31.1	2.1	33.2	1.7
23.9	1.4	25.4	1.5	27.0	1.7	27.7	1.9	30.1	1.9
17.5	1.1	18.7	1.4	19.7	1.6	20.5	1.7	22.5	1.7
28.7	2.2	31.3	2.2	33.4	2.5	35.0	2.3	38.5	2.3
31.7	2.4	34.5	2.2	36.5	2.7	38.4	2.5	41.9	2.4
35.5	2.7	38.4	2.5	41.0	3.0	42.8	2.9	46.7	2.5
38.0	2.6	40.7	2.3	43.5	3.0	45.3	3.1	49.2	2.7
24.7	1.8	26.6	2.0	28.6	2.0	29.9	2.3	33.1	2.2
Girls									
9.8	0.7	10.4	0.8	11.1	1.0	11.8	1.0	12.2	1.0
11.0	0.8	11.9	0.8	12.8	1.0	13.4	1.2	14.1	0.9
10.7	0.8	11.6	0.7	12.5	1.0	13.1	1.2	13.7	0.9
9.9	0.8	10.7	0.8	11.5	0.9	12.3	1.1	12.9	0.9
13.0	1.1	13.9	0.9	15.1	1.0	15.9	1.6	16.7	1.0
10.7	1.4	11.3	1.3	12.0	1.6	12.8	1.5	12.8	1.7
15.9	1.1	16.8	1.0	17.8	1.5	18.8	1.6	19.4	1.4
16.6	1.3	17.7	1.1	18.9	1.4	19.9	1.5	20.6	1.3
13.9	1.1	14.8	1.0	15.7	1.3	16.7	1.4	17.2	1.3
19.4	1.3	20.5	1.2	22.1	1.6	23.1	1.8	24.0	1.5
25.2	1.4	26.6	1.5	28.4	2.0	29.8	2.1	31.1	1.8
27.1	1.5	28.6	1.5	30.7	2.0	32.0	2.1	33.7	1.9
24.3	1.4	25.8	1.3	27.6	1.9	29.1	2.4	30.3	1.7
17.6	1.0	18.7	1.3	20.0	1.7	21.4	1.9	22.4	1.5
29.6	2.4	32.0	2.2	34.6	2.6	36.4	2.6	38.4	2.4
32.9	2.6	35.2	2.3	37.8	2.7	39.6	2.6	42.1	2.4
36.6	2.6	39.2	2.5	42.3	3.0	44.3	2.9	46.7	3.0
38.4	2.6	41.1	2.5	44.5	2.8	46.7	2.9	49.1	2.7
25.7	1.7	27.4	1.7	30.0	2.6	31.5	2.3	33.5	2.0

Table 2B. Means and standard deviations (S.D.) for the lengths of the 19 tubu-

Bones		9		10		11		12	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Distal	5	12.8	1.1	13.7	1.0	14.2	1.4	15.0	1.3
	4	14.9	1.0	15.6	1.1	16.5	1.4	17.1	1.4
	3	14.5	1.0	15.4	1.3	16.2	1.4	16.6	1.3
	2	13.4	1.0	14.3	1.1	15.0	1.2	15.5	1.1
	1	17.8	1.2	18.6	1.4	19.7	1.6	20.3	1.7
Middle	5	13.8	1.6	14.9	1.2	15.5	1.8	16.3	1.6
	4	20.3	1.4	21.4	1.5	22.3	2.2	23.5	1.9
	3	21.4	1.4	22.7	1.6	23.9	1.8	24.8	1.7
	2	18.0	1.3	18.9	1.4	19.9	1.5	20.8	1.5
Proximal	5	25.1	1.6	26.1	1.6	28.0	1.8	29.3	2.2
	4	32.4	1.9	33.7	2.1	36.0	2.6	37.5	2.7
	3	35.0	2.0	36.2	2.2	38.6	2.6	40.1	2.8
	2	31.4	1.9	32.5	2.1	34.7	2.1	36.0	3.0
Metacarpal	1	23.5	1.8	24.7	1.9	26.4	2.1	27.8	2.3
	5	39.9	2.6	41.9	3.2	44.4	3.1	45.4	5.3
	4	43.4	2.8	45.3	2.8	48.3	3.4	49.7	3.8
	3	48.8	3.3	50.5	3.0	54.2	3.8	55.9	4.6
	2	51.5	3.3	53.2	3.2	56.6	4.6	59.1	4.2
	1	34.7	2.3	35.9	2.6	38.9	2.7	40.3	3.0
Distal	5	13.2	1.1	14.1	1.0	14.5	1.1	15.1	1.0
	4	15.0	1.1	15.8	1.2	16.3	1.1	17.1	1.0
	3	14.7	1.1	15.5	1.2	16.0	1.1	16.8	1.0
	2	13.7	1.0	14.6	1.1	14.9	1.0	15.5	1.0
	1	17.9	1.4	19.0	1.3	19.6	1.3	20.6	1.5
Middle	5	13.9	2.1	15.2	1.7	15.9	1.5	16.8	2.2
	4	20.6	1.8	22.1	1.7	23.1	1.3	24.5	1.5
	3	21.9	1.9	23.5	1.8	24.4	1.4	26.0	1.8
	2	18.3	1.7	19.8	1.6	20.5	1.3	21.9	1.3
Proximal	5	25.6	2.0	27.5	1.9	28.9	1.6	30.7	1.7
	4	32.9	2.2	35.2	2.4	36.9	2.0	39.0	2.1
	3	35.4	2.4	38.0	2.5	39.7	2.1	42.2	2.6
	2	31.9	2.1	34.3	2.3	35.9	1.9	38.0	2.1
	1	24.0	2.2	26.1	2.2	27.3	1.7	29.0	1.7
Metacarpal	5	40.5	3.3	43.3	2.7	45.2	2.7	47.6	2.6
	4	44.1	3.1	47.1	2.9	48.9	2.6	51.6	2.7
	3	49.5	3.6	52.7	3.3	54.9	3.0	58.3	3.5
	2	52.1	3.8	55.6	3.5	57.4	4.2	61.5	3.4
	1	35.4	2.7	37.8	2.5	39.5	2.1	41.5	2.0

lar bones related to age (9–17 years) and sex (upper half, boys; lower half, girls).

13		14		15		16		17	
Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Boys									
16.0	1.4	17.0	1.2	17.2	1.2	17.7	1.1	17.6	1.5
18.3	1.5	19.0	1.1	19.4	1.2	19.8	1.1	19.5	1.4
17.9	1.4	18.5	1.1	18.9	1.1	19.1	1.2	19.0	1.5
16.5	1.4	17.3	1.0	17.6	1.1	17.9	1.2	18.0	1.5
22.0	2.0	22.9	1.5	23.2	1.4	23.3	1.6	23.5	1.9
17.9	2.0	18.9	1.5	19.1	1.6	19.5	1.9	19.6	2.0
25.6	2.1	26.5	1.5	26.6	1.6	27.2	1.7	27.5	1.9
26.7	2.3	27.9	1.5	28.1	1.7	28.7	1.9	29.0	2.0
22.6	1.9	23.5	1.6	23.7	1.5	24.5	1.4	24.5	1.7
31.7	2.6	33.1	2.1	34.0	2.0	34.8	1.9	34.6	2.4
40.6	3.0	42.1	2.5	42.6	2.5	43.9	2.4	43.8	2.9
43.1	3.2	45.3	2.5	45.6	2.7	46.8	2.6	46.6	3.2
39.0	2.8	40.7	2.3	40.9	2.3	42.2	2.3	41.7	2.7
30.4	2.6	31.5	2.0	32.0	1.9	32.7	1.9	33.1	2.7
49.6	3.6	51.6	2.8	52.9	3.0	54.2	3.1	53.5	3.6
53.6	4.0	55.7	3.2	56.6	3.3	57.9	2.9	57.4	3.9
60.4	4.5	63.1	4.0	63.9	3.9	65.4	3.6	64.9	4.4
63.5	4.6	66.2	3.7	67.0	3.9	68.4	4.2	67.5	4.4
43.4	3.1	45.2	2.7	45.6	2.3	46.4	2.6	46.7	3.0
Girls									
15.6	1.2	15.6	1.0	15.9	1.3	16.0	1.2	15.8	1.2
17.7	1.0	17.6	0.9	17.7	1.1	18.0	1.1	17.8	1.3
17.2	1.0	17.1	1.0	17.3	1.1	17.5	1.0	17.4	1.1
16.1	1.0	15.9	0.9	16.2	1.1	16.5	0.9	16.3	1.1
21.1	1.4	20.9	1.1	21.1	1.5	21.3	1.2	21.3	1.5
17.1	1.8	17.3	1.6	17.3	1.8	17.5	1.8	17.5	1.6
24.6	1.8	25.0	1.3	25.2	1.5	25.2	1.3	25.0	1.7
26.1	2.0	26.4	1.3	26.4	1.7	26.8	1.6	26.5	1.3
21.9	1.7	22.2	1.2	22.2	1.3	22.4	1.1	22.4	1.4
31.5	1.6	31.6	1.4	32.0	1.6	32.0	1.6	32.0	2.0
40.0	2.1	40.2	1.7	40.5	2.1	40.4	1.8	40.4	2.3
42.4	2.4	42.9	1.7	43.3	2.3	43.3	1.9	43.0	2.1
38.6	2.3	38.8	1.6	38.9	2.0	39.0	1.8	38.9	2.2
29.5	1.7	29.7	1.5	29.9	1.8	29.9	1.5	30.1	1.9
48.7	2.4	49.3	2.1	50.0	2.8	50.0	2.6	49.3	3.2
53.0	2.5	52.9	2.0	54.0	3.3	53.7	2.7	53.2	3.2
60.0	2.9	60.1	2.7	60.8	3.7	60.4	3.3	60.3	3.7
62.5	2.5	63.2	2.7	63.9	3.5	63.2	3.3	63.0	3.7
41.9	2.2	42.5	2.0	42.6	2.3	43.0	2.1	42.4	2.7

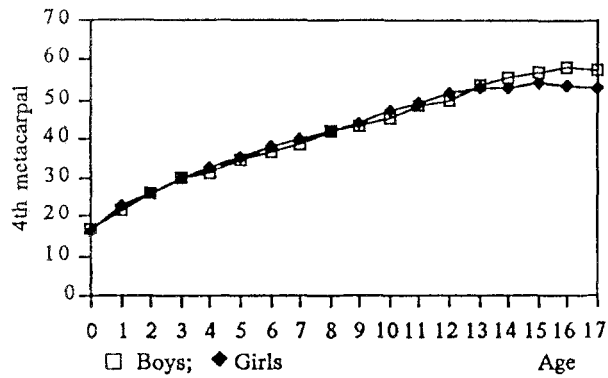


Fig. 2. The growth of the 4th metacarpal bone of the Japanese.

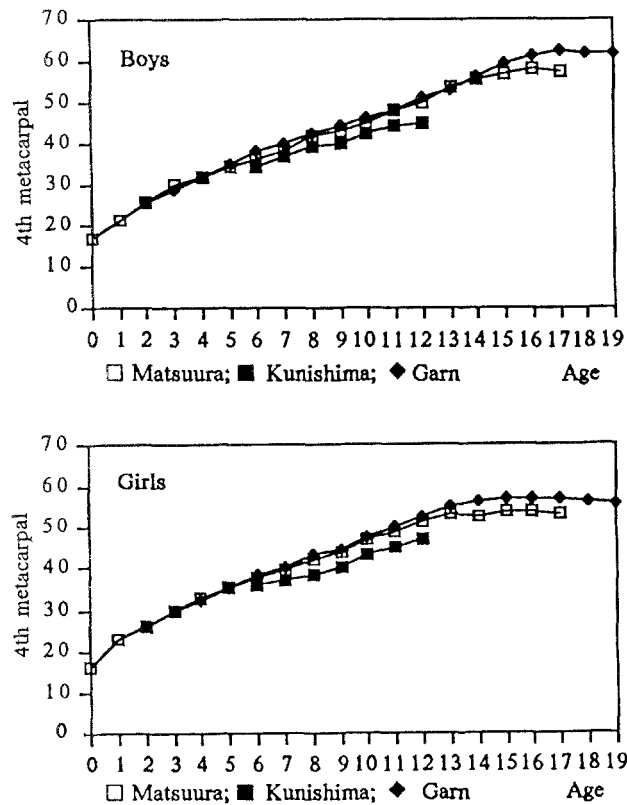


Fig. 3. Comparison between Japanese and Caucasian children. □, Matsuura, the present study; ■, Kunishima, 711 Japanese children of 6-12 years of age reported by Kunishima (1965); ◆, Garn, Caucasian children of 2-19 years of age reported by Garn *et al.* (1972).

bones of the hand of children grouped according to sex and yearly intervals. The *t*-test revealed no statistically significant regional difference at the 5% level in the lengths of the 19 tubular bones in 4- and 6-year-old children from Nagoya, Saga and Nagasaki.

Sex-associated differences were found in the growth of the 19 tubular bones. There was a tendency for boys to exceed girls at the 14 to 17 year intervals. This is illustrated in Fig. 2, showing the 4th metacarpal as an example.

Figures 3a and 3b show sex- and age-specific means of the 4th metacarpal lengths in our data (Matsuura) sampled between 1976 and 1985 in three separate areas of Japan, those of Japanese children collected in 1959 and 1960 in Shizuoka city (Kunishima, 1965), and those of Caucasian children (Garn *et al.*, 1972). Our data in the 6 to 12 year range show mean lengths longer than those by Kunishima (1965). This would reflect accelerated growth in Japanese children that occurred during the interval between the two studies, rather than regional differences. Overall, our data are close to those of Caucasian children until the age of 15 years in boys and 13 years in girls. Thereafter, Japanese figures level off, while Caucasian children keep growing a few more years. The mean lengths of the 2nd to 4th distal phalanges in the 3 to 13 year range in our data are longer than those of Caucasian children.

DISCUSSION

The present study, dealing with 1,585 children of 0–17 years of age studied during the period from 1976 to 1985, would serve as the only standard available

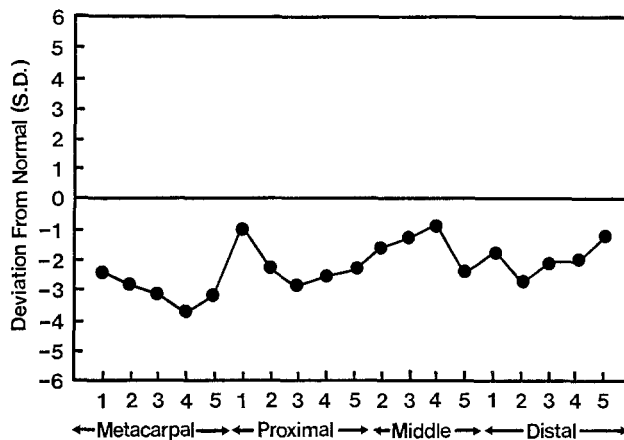


Fig. 4. Metacarpophalangeal pattern profile (MCP) analysis of the 45,X patient shown in Fig. 1. Standard deviations of the bone lengths from the mean values are displayed, with standard deviations on the ordinate and the 19 tubular bones, sequentially arrayed, on the abscissa. Overall shortening of the hand tubular bones, especially of the 4th metacarpal, and a relatively long proximal phalanx of the thumb.

for today's Japanese children. In the present study, the number of children in each group in the 0 to 3 year range was 9 to 12 while it was 49 to 66 in the 4 to 17 year range.

An example of metacarpophalangeal pattern profile analysis is being presented using the hand radiograph in Fig. 1 as the subject (Fig. 4). The patient, a 16-year-old girl with a 45,X karyotype, revealed overall shortened hand tubular bones, and relative lengthening of the proximal phalanx of the thumb.

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