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小学生の足部生体計測値

岡田守彦・進藤正雄・高橋 彬・森本光彦

Somatometrical features of the foot in primary school children

Morihiko OKADA, Masao SHINDO, Akira TAKAHASHI and Mitsuhiko MORIMOTO

小児の足の形態発育を知るために，6歳から12歳の男子489名，女子408名の足部の生体計測を行なった。計測は特殊な器具を用い，右足について，長径13項目，幅径2項目，高径2項目の合計17項目をしらべ，同時に第1中足骨傾斜角度の測定を行った。足部長径は体部高径と同じくS字状の一般型推移を示すが，女子では12歳でのスパートを欠く。足部幅径，高径には長径とやや異なる推移がみられた。足部各径とも，7歳から9歳にかけて男子が女子を上まわる傾向がある。その後，性差は縮小するが，12歳で再び強まる。足部各径をその長径で基準化した相対値からみると，足部のプロポーションは年齢により殆ど変化しないようである。但し女子は男子よりも足部全体がやや細く，後足部がやや短い傾向があり，また男女とも加齢とともに足部の細長化，及び第5指中足部の相対的伸長がやや進むことが示唆された。

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Introduction

Human foot is one of the regions where the structural and functional adaptation to bipedalism is manifest (Morton, 1935). Structural growth of the foot in response to genetic and environmental influences provides morphological correlates of the locomotor development in the young. Moreover, inasmuch as the locomotion is the most fundamental of motor behavior, a sound development of the foot may indicate an optimum care of physical activity in the young of a given population. A number of somatometrical growth studies of the foot have been done longitudinally (Anderson et al., 1956), or cross-sectionally (Kondo, 1953; Baba, 1979; Koyama et al., 1982). However, the number of metrical items are limited in these studies except Koyama et al. (1982) dealing with preschool children. We report in this paper on the result of multi-item somatometry of the foot in cross-sectional samples of primary-school-aged children. Fundamental statistics of the items and some of bivariate proportionalities will be given.

Subjects and Methods

We collected data in 1983 from primary schools in the vicinity of Tsukuba Academic Town in Ibaraki prefecture. The numbers of subjects for each sex and age are given in Table 1. Classification of age groups followed the 'median method', i. e. a group of x years of age covers subjects ranging in age from (x-1) years 7 months to x years 6 months. For some of the items, the number of subject was reduced due to the limitation of time available for measurements. Although direct comparisons may not be allowed because of different method of age-grouping, physical growth of our subjects seems to approximate the national average as reported in School Health Statistics 1982 by The Ministry of Education, Science and Culture.

Table 1. Number of subjects. The figure in parenthesis applies to certain metrical items as indicated in Fig. 1

	Age (years)							
	6	7	8	9	10	11	12	Total
Male	30	73	81	62	77	76	90	489
	(30)	(31)	(36)	(29)	(34)	(32)	(40)	(232)
Female	25	69	64	64	58	67	61	408
	(25)	(35)	(27)	(29)	(23)	(35)	(23)	(197)
Total	55	142	145	126	135	143	151	897
	(55)	(66)	(63)	(58)	(57)	(67)	(63)	(429)

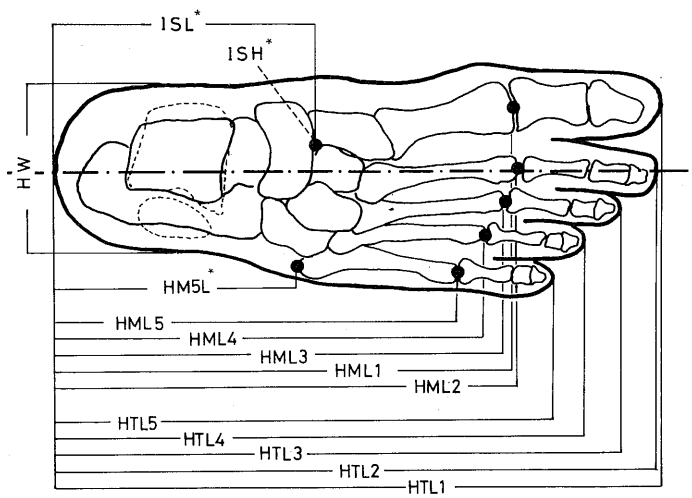

Fig. 1. Metrical items and landmarks (filled circles) put on the foot. Chain line indicates the foot axis along which length items were measured from the heel edge (pternion) to the tip of toes 1-5 (HTL 1-5); to the head of the metatarsals 1-5 (HML 1-5); to the base of the metatarsal 5 (HM5L); to the instep point (ISL) which is defined as the point where the medial- and intermediate cuneiform and navicular bones adjoin with each other. Heel width (HW) and height of the instep point (ISH) were also measured. Foot length, width, and medial malleolus height, which are not shown in the figure, were measured according to the method of Martin & Saller (1957). For items affixed with an asterisk, number of the subject was reduced to those parenthesized in Table 1.

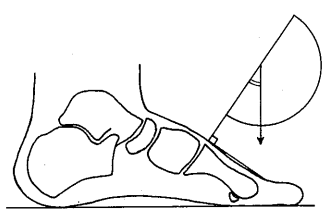

Fig. 2. Measurement of the instep inclination.

Somatometry was made on the right foot. Metrical items and landmarks for measurements are shown in Fig. 1. The items consist of 13 measurements in length, 2 in width, 2 in height, and 1 in inclination. The foot length, foot width, and medial malleolus height were measured according to the Martin's method (Martin & Saller, 1957). The heel width was measured transversely with a sliding caliper applied underneath the lateral malleolus. Inclination of the instep was measured

Table 2. Mean and SD (in parenthesis) of somatometrical items in boys. For explanation of the items, see Fig. 1. Asterisks indicate sex difference at 1% (**) or 5% (*) level of significance

Items	Age (years) 6	7	8	9	10	11	12
Length (mm) from the pternion to							
the tip of 1st toe	175.5	186.3*	193.5	203.5	209.8	216.1	230.6**
	(8.4)	(8.3)	(9.6)	(11.1)	(10.9)	(10.0)	(10.4)
2nd toe	171.7	183.7*	190.1	200.3*	206.8	212.6	225.7*
	(9.1)	(8.4)	(10.0)	(10.2)	(10.6)	(10.5)	(10.3)
3rd toe	165.9	177.0	183.0	193.1*	199.1	204.9	216.8*
	(9.3)	(8.0)	(10.0)	(9.2)	(10.0)	(9.7)	(10.1)
4th toe	156.0	166.8*	172.3	182.0*	187.4	192.7	204.1
	(8.9)	(7.4)	(9.1)	(9.1)	(9.6)	(9.1)	(9.5)
5th toe	142.0	153.7	158.5	167.1	172.4	177.6	187.9
	(8.0)	(7.1)	(8.6)	(8.3)	(9.4)	(8.9)	(8.8)
the head of 1st metatarsal	137.1	146.6	152.4	160.2	163.9	171.1	182.5
	(7.4)	(6.6)	(8.7)	(8.2)	(10.6)	(7.9)	(7.7)
2nd metatarsal	137.7	145.5	152.0	160.7*	165.0	170.5	179.8**
	(8.6)	(6.5)	(8.3)	(8.2)	(8.8)	(8.8)	(8.1)
3rd metatarsal	133.0	142.3	147.9	156.4	162.1	167.0	175.3**
	(7.8)	(6.5)	(8.0)	(8.1)	(8.2)	(8.6)	(7.7)
4th metatarsal	124.9	134.9	140.2	147.9	153.1	158.2	166.2**
	(7.5)	(6.6)	(7.7)	(7.9)	(8.3)	(8.1)	(7.5)
5th metatarsal	112.4	123.4*	127.1	134.0	139.2	144.8	152.1*
	(7.5)	(6.1)	(6.8)	(7.3)	(7.4)	(8.0)	(7.3)
the base of 5th metatarsal	84.0	89.3	92.0	97.4	100.1	99.5	106.7
	(4.7)	(4.5)	(5.1)	(5.4)	(6.9)	(6.6)	(7.8)
the instep point	83.7	92.2	98.4**	101.3*	105.7	108.4	115.2*
	(6.7)	(5.8)	(5.0)	(6.4)	(7.6)	(5.6)	(9.8)
Height (mm) of							
the instep point	45.0	46.4	48.0	50.0	52.4	52.8	55.2
	(3.6)	(3.9)	(4.6)	(4.5)	(3.4)	(4.4)	(4.9)
the medial malleolus	50.3	53.0**	55.3	58.5*	61.2**	62.7**	65.2
	(4.8)	(3.9)	(4.4)	(5.2)	(4.3)	(5.4)	(6.4)
Foot length (mm)	174.7	184.9*	192.0	201.9	208.0	215.0	227.7*
	(8.6)	(8.5)	(9.5)	(10.9)	(10.3)	(9.8)	(9.5)
Foot width (mm)	73.3**	75.1	78.8**	81.0**	84.3	87.1	90.7
	(4.8)	(4.7)	(4.4)	(4.3)	(5.4)	(5.0)	(6.9)
Heel width (mm)	48.1	49.7	52.7**	54.1**	54.8	56.9	59.2
	(3.7)	(4.6)	(4.7)	(3.9)	(4.4)	(4.0)	(4.5)
Instep inclination (degree)	22.8	22.3**	21.3	20.9*	22.3**	20.6	21.4
	(2.4)	(2.7)	(2.8)	(2.8)	(2.7)	(3.0)	(3.1)
Ant. sup. iliac spine height (mm)	578.4	627.9	658.0	702.9	723.2	757.6	813.6
	(29.5)	(28.1)	(35.2)	(33.9)	(36.4)	(37.9)	(43.0)
Body height (mm)	1117.0	1184.2	1231.0	1298.0	1336.3	1382.6	1466.9
	(48.3)	(41.6)	(53.2)	(50.4)	(53.0)	(56.8)	(62.9)
Body weight (kg)	20.0	22.5	24.7	28.0	31.3	34.0	39.7
	(2.6)	(3.2)	(4.6)	(4.6)	(5.9)	(6.3)	(7.5)

with a protractor placed along the top of the first metatarsal bone (Fig. 2). All the other measurements were carried out by using a device specifically designed for foot somatometry by Koyama et al. (1982). Landmarks determined through palpation were put on the foot before the measurement. For measuring length items with the above device, the foot was placed along an axis connecting the pternion (the most posteriorly projected point of the heel) with the tip of the

Table 3. Mean and SD (in parenthesis) of somatometrical items in girls. Asterisks indicate sex difference at 1% (**) or 5% (*) level of significance

Items	Age (years) 6	7	8	9	10	11	12
Length (mm) from the pternion to							
the tip of 1st toe	171.5	183.1*	191.2	200.2	208.7	217.0	226.2**
	(9.4)	(9.0)	(9.8)	(10.4)	(11.2)	(12.9)	(8.6)
2nd toe	169.5	180.8*	188.6	196.2*	204.4	213.0	221.7*
	(9.3)	(9.0)	(9.4)	(10.3)	(11.0)	(12.9)	(9.2)
3rd toe	163.8	174.6	181.3	188.8*	196.9	204.7	212.8*
	(8.6)	(8.8)	(9.5)	(9.7)	(10.0)	(12.6)	(9.0)
4th toe	154.2	164.0*	170.6	177.7*	185.2	192.6	201.1
	(8.0)	(8.1)	(9.2)	(9.4)	(9.0)	(12.2)	(8.6)
5th toe	141.3	151.9	157.3	164.6	169.9	176.7	185.3
	(8.4)	(8.0)	(9.1)	(8.7)	(9.4)	(9.9)	(8.8)
the head of 1st metatarsal	133.4	144.1	148.4	156.8	165.6	169.9	178.7
	(7.9)	(6.3)	(7.9)	(7.2)	(7.2)	(9.9)	(5.2)
2nd metatarsal	134.4	143.7	149.7	157.1*	163.2	169.7	176.0**
	(7.5)	(7.5)	(7.8)	(8.6)	(8.9)	(10.0)	(6.6)
3rd metatarsal	130.2	140.4	146.9	153.8	159.5	165.5	171.7**
	(7.6)	(7.1)	(7.6)	(8.7)	(8.2)	(9.9)	(6.8)
4th metatarsal	122.8	133.2	139.3	145.6	150.8	156.7	162.9*
	(6.8)	(6.6)	(7.7)	(8.6)	(8.1)	(9.6)	(6.6)
5th metatarsal	111.4	120.8*	126.7	132.7	137.3	143.7	149.0*
	(7.3)	(6.7)	(7.9)	(7.3)	(8.2)	(10.0)	(6.8)
the base of 5th metatarsal	82.7	88.4	92.1	95.6	98.7	98.7	104.5
	(4.8)	(5.4)	(5.4)	(5.0)	(4.8)	(5.5)	(5.0)
the instep point	81.1	90.1	94.6**	97.2*	104.4	106.3	110.5*
	(6.1)	(5.7)	(4.4)	(5.8)	(5.1)	(6.0)	(4.3)
Height (mm) of							
the instep point	43.8	44.9	48.2	49.5	54.0	52.2	56.0
	(3.5)	(2.6)	(3.8)	(4.4)	(4.0)	(5.2)	(3.1)
the medial malleolus	49.0	50.6**	55.4	56.3**	59.0**	60.1**	64.2
	(5.0)	(4.1)	(4.6)	(5.3)	(4.4)	(6.2)	(5.5)
Foot length (mm)	170.7	181.1*	190.7	199.2	206.6	215.8	224.0*
	(10.0)	(10.3)	(9.6)	(10.6)	(11.0)	(13.1)	(8.7)
Foot width (mm)	69.2**	73.9	76.5**	78.4**	82.6	86.4	88.9
	(4.7)	(4.1)	(4.5)	(5.3)	(5.5)	(5.6)	(5.2)
Heel width (mm)	46.2	48.4	50.4**	51.6**	54.9	55.7	58.0
	(3.8)	(3.5)	(3.8)	(4.4)	(4.7)	(4.2)	(3.9)
Instep inclination (degree)	21.7	21.0**	20.6	19.4*	20.3**	19.9	20.6
	(2.2)	(2.4)	(3.0)	(3.6)	(2.7)	(2.3)	(2.9)
Ant. sup. iliac spine height (mm)	575.4	624.6	668.2	696.0	729.3	769.1	820.4
	(35.3)	(28.1)	(33.9)	(31.7)	(44.3)	(53.8)	(40.6)
Body height (mm)	1107.6	1177.7	1235.2	1281.7	1336.5	1395.7	1480.7
	(53.8)	(45.1)	(51.2)	(49.4)	(65.3)	(80.6)	(66.9)
Body weight (kg)	19.4	22.5	24.3	27.7	31.4	35.4	41.6
	(2.1)	(3.3)	(3.4)	(5.2)	(6.7)	(6.7)	(6.8)

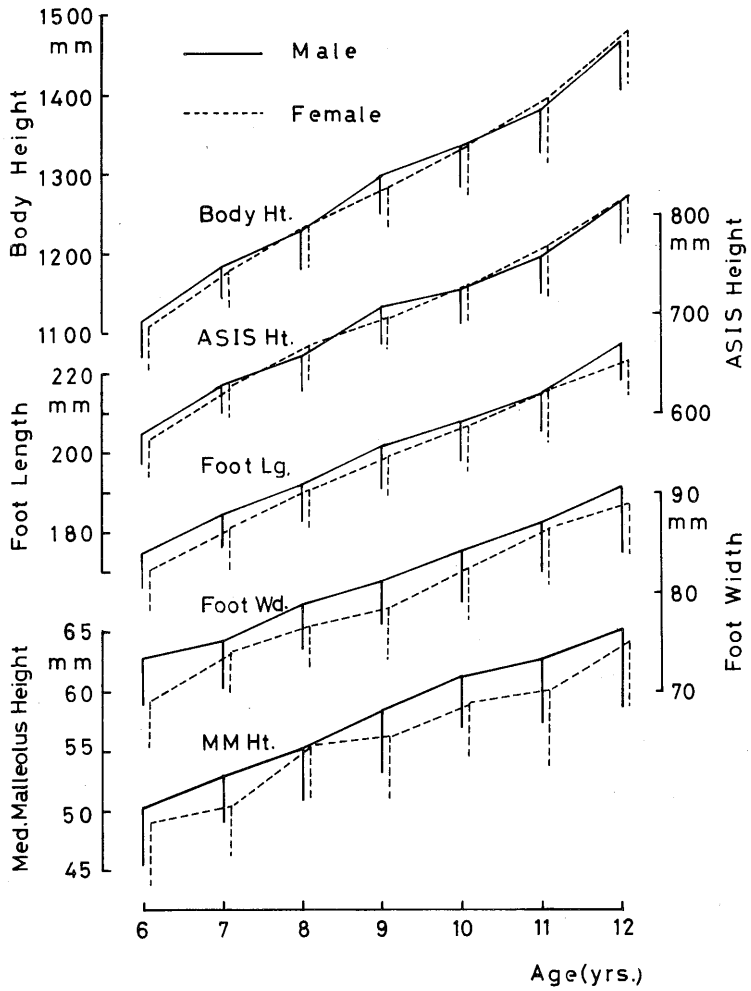

Fig. 3. Distane curves of representative items. ASIS : anterior superior iliac spine ; MM: medial malleolus. Vertical lines indicate the standard deviation. Asterisks show statistical difference between sexes at 5%(*) or 1% (**) level of significance.

second toe, and the distance was measured from the pternion to a landmark as projected on the axis.

Results and Discussion

The mean and standard deviation for each metrical item is tabulated by sex and age in Tables 2 and 3. Despite that no sex difference exists at each age in the whole body measurements, males appear to surpass females in various foot measurements including length, width, height, and inclination items. Superiority of the male was particularly remarkable in length items at 12 years of age.

Several items given here have been measured in primary school children by Kondo (1953) and Baba (1979). The foot length and instep height reported by Kondo (1953) more than 30 years ago are, even with the subjects grouped by age in full, considerably smaller than those presented above by us. These differences are a reasonable consequence of the continuing acceleration of physical growth in the past decades. It is noticeable, however, that the foot width is almost the same between the two investigations which are widely separated in time. The age-grouping way is not described in Baba (1979). If the grouping was done by age in full, the

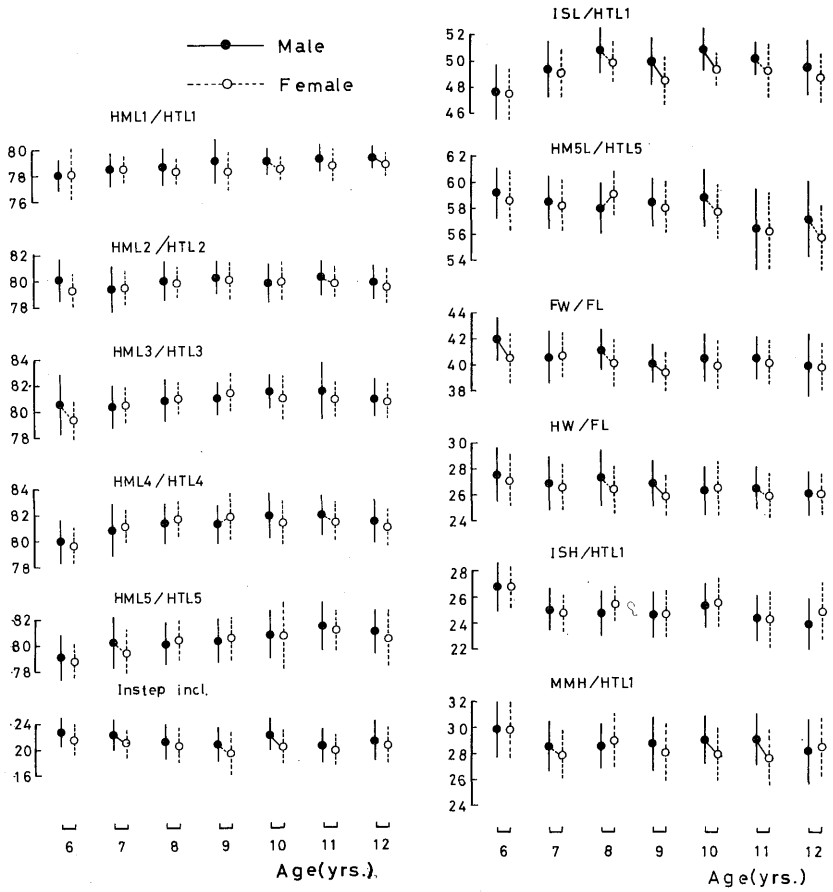

Fig. 4. Bivariate proportionalities and instep inclination at each age. Vertical lines indicate the standard deviation. Statistical differences between sexes are shown by a line connecting the means at 5% (broken line) or 1 % (solid line) level of significance. For abbreviations, see Fig. 1.

foot length and width, heel width, and instep height reported by Baba (1979), which were measured about 10 years ago, seem to fairly approximate to ours for younger age-groups, and somewhat smaller for older age-groups. Superiority of the male in foot dimension was more or less evident in both of the above reports.

Distance curves for some of the representative items are illustrated in Fig. 3. A sigmoid feature is obvious in curves of the body height and iliac spine height. Developmental pattern of the male foot length approximated those of the above height items. Female foot length, however, showed a retardation of growth rate at 12 years of age, suggesting a smaller foot length in females in the adulthood. The foot width and medial malleolus height were somewhat different from the foot length in the developmental pattern.

Fig. 4 shows, by sex and age, the instep inclination and some of the bivariate proportionalities which are normalized against length items. The inclination did not change with age, although the male tended to surpass the female. Exactly the same trend has been reported by Koyama et al. (1982) for preschool children. No substantial change with age was also demonstrated for the proportionalities, although several moderate features were observed as described below.

The position of the metatarsal head relative to the tip-toe was more forward in the lateral toes than in medial ones, reflecting the longer relative

toe length in the latter. In the intermediate three toes, as seen in Fig. 3, this position slightly advanced with age, and retreated again at higher ages. In the most lateral, or 5th, toe, the position seemed to consistently advance with age concerned. On the other hand, the relative position of the base of this toe markedly retreated at higher ages. It may thus follow that the relative length of the 5th metatarsal increases at higher ages. Relative position of the instep point, somewhat more forwardly located in the male than in the female, showed a trend similar to the intermediate toes. The forefoot as well as the heel had a tendency to be relatively wide in the male than in the female, and the relative width appeared to be slightly reduced, i.e. the foot appeared to become slightly narrower, with age.

Summary

Dimensional growth of the foot was investigated by somatometry of 489 male and 408 female children aged from 6 to 12 years. Measurements, including 13 length, 2 width, and 2 height items, were made of the right foot by using a device designed by Koyama et al. (1982). Instep inclination was measured as well. Length items of the foot like height items of the body exhibited a sigmoid growth pattern, although no growth spurt of the former items unlike the latter items was found in females at 12 years of age. Width and height items of the foot were somewhat different from length items in the growth pattern. Males between 7 and 9 yeras of age tended to surpass females in the foot measurements. Sex difference thus occurred was reduced at higher ages, but enhanced again at the age of 12. In view of the instep inclination, and relative ratios derived from normalizing certain items against length items of the foot, proportionalities of the foot seemed to be almost unchanged with age. In females than in males, however, the foot as a whole was somewhat narrower, and the hind-foot was somewhat shorter. Besides, it was suggested that narrowing of the foot and relative lengthening of the 5th metatarsals progressed, though slightly, with age in both sexes.

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