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INTER-GENERATION DIFFERENCES IN FOOT MORPHOLOGY: AGING OR SECULAR CHANGE?

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Inter-generation differences in foot dimensions were examined using ANCOVA to determine whether aging or secular change is the more important causal factor. In examining the results, bone size was assumed not to change after the end of linear growth, while foot arches were assumed to become flatter rather than higher if there were any changes in skeletal structure. Changes in overall body build according to age were examined using statistical data collected by the government through population-follow-up. Secular changes in foot length (FL) and foot breadth, diagonal (FB) as well as the changes with age in FB were examined using data measured at ages younger than 50 years. The effects of overall body build were examined using the body mass index (BMI).

Compared to the 1970 group (birth year: 1960-78) of the same FL, the 1930 group (birth year: 1909-39) had larger foot circumferences, wider breadth measurements, higher dorsal arches and ball, and greater toe 5 angle, but had shorter fibular instep lengths and shorter 5th metatarsal bones. The 1930 groups tended to have larger FB than the 1970 group of the same foot circumference. No inter-generation differences were observed in the heights at the medial and lateral malleoli, toe 1 angle, or the relationship between FB and heel breadth. These findings are discussed in terms of the effects of weight increase after the end of linear growth, changes in skeletal structure, overall body build as young adults, socioeconomic status during the growth period, as well as differential growth rates of foot bones. The conclusions are 1) changes in foot length and longitudinal arches due to aging are negligible, 2) the large circumferences, breadths, and higher dorsal arches and ball of the 1930 group for their foot length are better explained by their robust bones than by the increase in soft tissue after the end of linear growth, and 3) the larger FB of the 1930 group for their foot circumference is partly explained by their shorter fibular instep length. As a whole, factors affecting growth (secular change) are more important than changes after the end of growth (aging) in the inter-generation differences in foot morphology.

Key Words: foot; anthropometry; aging; sex difference; secular change; body build; BMI

INTRODUCTION

Elderly Japanese have relatively and absolutely larger foot circumferences despite their smaller foot lengths (Kouchi, 1998). It is not clear whether these differences are caused by aging or secular change. A longitudinal study is the only way to clarify the main causes of such inter-generation differences. Unfortunately, such data has not been accumulated in any country. As the direction of change in foot morphology caused by aging can be assumed theoretically, it should be possible to judge whether aging or secular change is more important in determining the foot morphology of elderly Japanese. The purpose of the present paper was to deduce the main cause of inter-generation differences in foot morphology by examining cross-sectional data. Such studies are important for last design, as foot morphology is closely related to this field. Whether lasts designed for the current elderly population will also fit future elderly populations will depend on the causes of the morpho-

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logical features of the elderly.

SUBJECTS AND METHODS

Subjects

The subjects were 135 males and 133 females born before 1940 (the 1930 group below), and 383 males and 414 females born between 1960 and 1979 (the 1970 group below). All the subjects were healthy Japanese adults and were not selected according to foot morphology. The subjects were part of the three somatometric surveys outlined below. In order to eliminate the influence of inter-observer measurement errors, only measurements taken by the same observer(s) for the different age groups were compared.

1) IPRI series: This survey was conducted in 1991 and 1992 by the Industrial Products Research Institute (National Institute of Bioscience and Human Technology, 1996). The subjects in the 1930 group were healthy people living in Tsuchiura City, Ibaraki Prefecture, Japan. The subjects in the 1970 group were young adults living in and around Tsukuba City, Ibaraki Prefecture, and 72% of them were students. All of the male subjects were measured by one observer, and all of the female subjects were measured by another observer.

2) NIBH series: This survey was conducted in 1997 and 1998 by the National Institute of Bioscience and Human Technology and the National Institute of Technology and Evaluation (Kouchi and Mochimaru, 2000). The subjects in the 1930 group were healthy people living in Ami Town, Ibaraki Prefecture, and the subjects in the 1970 group were students of a fashion college in Tokyo. All the measurements were taken by one observer. The original data is available from Digital Human Research Center (http://www.dh.aist.go.jp/). For each subject, a plaster model of the right foot with landmarks on it was made in a standing posture with weight equally distributed on both feet. Another 43 young adult female students from the same fashion college were measured in 1996 by the same observer, but only plaster models of the right foot were available for them. This group is referred to as the 1970-2 group (Table 1).

Table 1. Subject characteristics.

Males

Series	Group	N	Birth year (mean)	Age (mean)	Mean height (cm)	Mean weight (kg)	Mean BMI
IPRI	1930	50	1909-30 (1917)	61-81 (73.3)	158.9	56.8	22.5
	1970	217	1961-73 (1968)	18-29 (22.7)	171.4	63.3	21.5
NIBH	1930	50	1919-38 (1929)	56-71 (64.7)	160.9	60.6	23.4
	1970	110	1970-78 (1976)	19-27 (20.5)	170.6	59.5	20.4
JLIA	1930	35	1929-39 (1934)	48-58 (53.1)	165.1	61.9	22.7
	1970	56	1960-69 (1965)	18-27 (22.5)	170.4	62.0	21.3

Females

Series	Group	N	Birth year (mean)	Age (mean)	Mean height (cm)	Mean weight (kg)	Mean BMI
IPRI	1930	49	1911-32 (1922)	60-80 (70.3)	146.9	51.1	23.8
	1970	206	1962-74 (1971)	18-29 (21.6)	159.1	52.6	20.8
NIBH	1930	49	1922-37 (1931)	60-75 (66.6)	149.3	55.4	24.8
	1970	107	1971-78 (1976)	19-26 (20.4)	158.7	53.4	21.2
	1970-2*	43	1971-78 (1976)	18-26 (20.2)	158.9	52.1	20.6
JLIA	1930	35	1928-39 (1934)	48-59 (53.5)	153.0	50.7	21.6
	1970	58	1961-69 (1965)	18-26 (22.4)	156.8	49.1	20.0

* Only the measurements taken on a plaster model are available

3) JLIA series: This survey was conducted by the Japan Leather and Leather-Good Industries Association (JLIA) in 1987 and 1988 in four cities (Japan Leather and Leather-Good Industries Association, 1988). Measurements were taken by researchers from a company in each city. In the present study, data taken by a company in the Kyushu district was used. Seven observers were involved in the survey. The subjects were students and company employees.

In the following text, the differences between the 1930 and 1970 groups from the same series are referred to as inter-generation differences.

The number of subjects by series and sex are shown in Table 1. Figures 1 and 2 show the mean height and mean weight of the 1930 and 1970 groups for each series compared with the average height and weight of the Japanese at 20 years and at about 65 years based on nationwide research published periodically. The data of 20-year-old male general population measured before 1938 were obtained from the Yearbook of Japan Empire Statistics (Kouchi, 1996). Other general population data were taken from the reports of the National Nutrition Survey conducted from 1947 to 2001 (The Study Circle for Health and Nutrition Information, 2001). Data for 20-year-old students were obtained from the Report of School Health and Hygiene (1990-1971) or Report on Physical Strength and Motor Ability Research (1972-2001) by the Ministry of Education, Science and Culture, Japan.

Height was measured using a stadiometer in the government reports, with an anthropometer for the IPRI and NIBH series, and was a self-reported value for the JLIA series. Measurements by stadiometer are higher than measurements by anthropometer by 5-10 mm in young adult subjects (National Institute of Bioscience and Human-Technology, 1996). Considering the differences in the measurement method (stadiometer vs. anthropometer), the mean heights for the 1930 groups of the IPRI and NIBH series are comparable to the mean height of 65-year-old Japanese in the government data. The 1930 group in the JLIA series was taller than the 65-year-old Japanese of the same generation, especially males. The mean weight of the 1930 group was comparable to the mean 65-year-old Japanese male weight in all three series, as well as for females in the IPRI series. However, the female 1930 group in the NIBH series was heavier, and the female 1930 group in the JLIA series was lighter than the mean 65-year-old Japanese female weight of the same generation.

The mean height of the 1970 group was close to the all Japan average for 20-year-old Japanese, both males and females, in all three series. The mean weight of the 1970 group was lighter than the all Japan average for males in the NIBH series and for females in the JLIA series.

For all three series, the 1930 group was shorter and had larger body mass index (BMI=weight/height^2, weight in kg and height in m) than the 1970 group of the same series. The differences in mean birth year and body size were smallest in the JLIA series (see Table 1).

Measurement items

Most of the measurements were taken on living subjects. For the NIBH series, a plaster model of the right foot with landmarks on it was made for each subject, and measurements were also taken from the plaster model. All the measurements, the plaster models, and foot outlines were taken from the right foot of a subject in a standing position with weight distributed equally on both feet.

Figure 3 shows the 28 measurement items used for the analysis (see Table 2). Among them, 15 were taken from a foot outline (Figure 3A), and 13 were measured directly from the foot or plaster model (Figure 3B). A height measurement was the height of a landmark from the floor taken directly using a height gauge. Bimalleolar breadth and circumference measurements were taken directly using a sliding caliper and tape measure, respectively. A foot outline was taken using a scriber, and length, breadth, and angle measurements were taken from the foot outline. All the length measurements were distances between two landmarks projected on the foot axis, which was defined as the line connecting the pternion and the tip of the 2nd toe. Most of the measurements were taken according to the guidelines of the National Institute of Bioscience and Human Technology (1994).

Definitions of the directly measured measurements are as follows (numbers are those used in Tables 2 and 5): (8) foot circumference (FC): circumference of the foot passing through the metatarsale

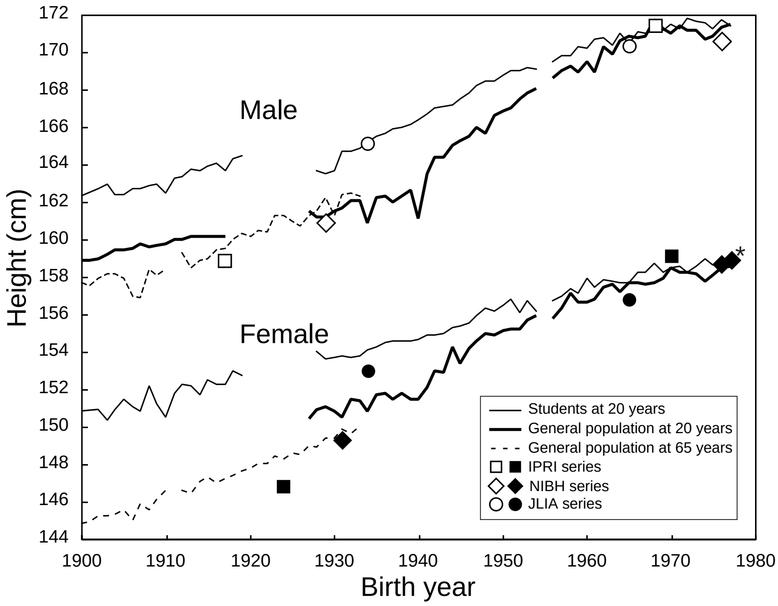

Fig. 1. Height in the present data compared to the statistical data of the Japanese Government. Mean height in the present data is plotted against the mean birth year. *: 1970-2 group in Table 1. See text for the reference.

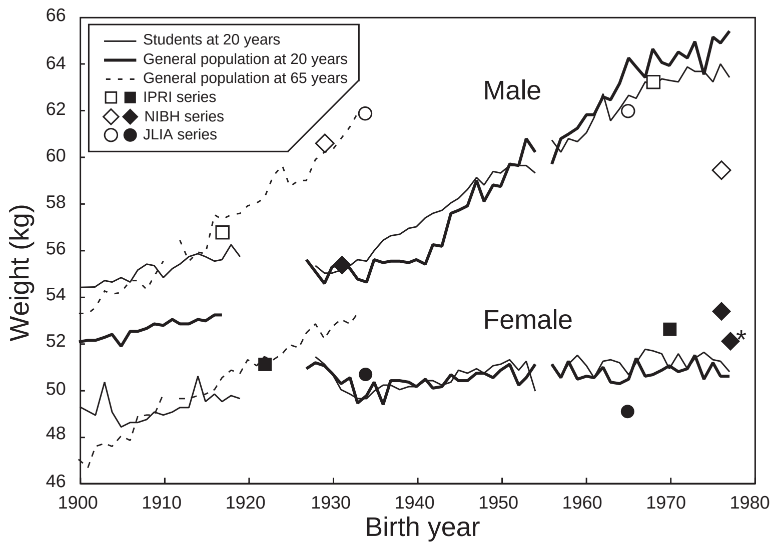

Fig. 2. Weight in the present data compared to the statistical data of the Japanese Government. Mean weight in the present data is plotted against the mean birth year. *: 1970-2 group in Table 1. See text for the reference.

tibiale (MT) and metatarsale fibulare (MF), (9) instep circumference: circumference of the foot passing through the highest point at 54% of foot length (FL) from the pternion, (10) bimalleolar breadth: distance between the most medially protruding point on the medial malleolus (MM) and the most laterally protruding point on the lateral malleolus (LM), (16) medial malleolus height: height of the MM, (17) lateral malleolus height: height of the LM, (18) sphyrion height: height of the sphyrion,

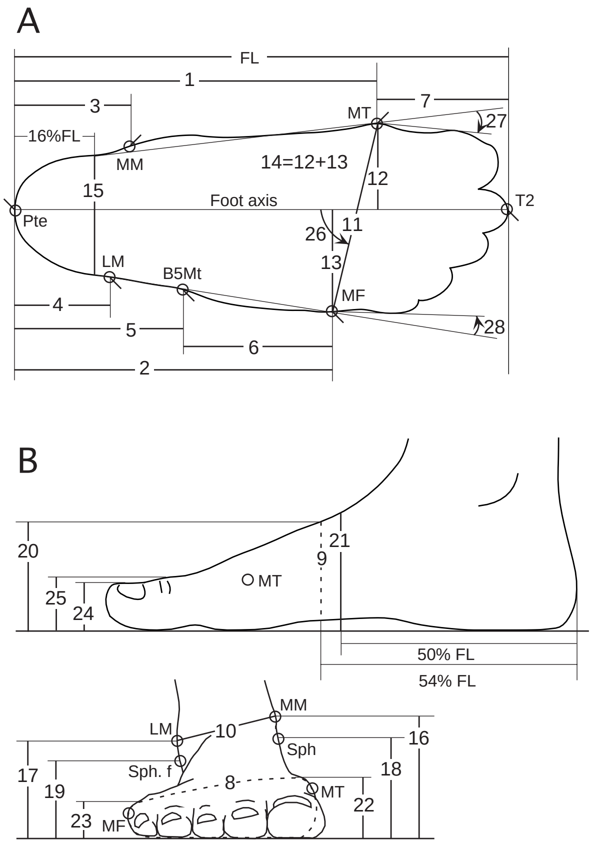

Fig. 3. Foot measurements. A. Measurements taken from a foot outline. B. Measurements taken on a living subject or a plaster model of the foot. The numbers are the same as those in Tables 2 and 5. T2: tip of the 2nd toe, B5Mt: the most laterally protruding point at the base of the 5th metatarsal bone, FL: foot length, LM: the most laterally protruding point of the lateral malleolus, MF: metatarsale fibulare, MM: the most medially protruding point of the medial malleolus, MT: metatarsale tibiale, Sph: sphyrion, Sph. f: sphyrion fibulare, Pte: pternion.

(19) sphyrion fibulare height: height of the sphyrion fibulare, (20) dorsal arch height at 54% of FL: maximum height of the vertical cross section at 54% of FL from the pternion, (21) dorsal arch height at 50% of FL: maximum height of the vertical cross section at 50% of FL from the pternion, (22) ball height: height of the dorsal foot surface at the 1st metatarsal head, (23) outside ball height: height of the dorsal foot surface at the 5th metatarsal head, (24) great toe tip height: height of the highest point at the nail of the big toe, and (25) great toe height: height of the highest point at the interpharangeal joint of the big toe.

Assumptions

Bone size was assumed not to change due to aging. The following four factors were considered as the possible causes of inter-generation differences in foot morphology.

(1) Changes in the skeletal structure of the foot: If any skeletal structural changes occur at all, then the longitudinal and transverse arches were assumed to become lower rather than higher. Such changes would be due to changes in the material properties of the ligaments. Since no data is available on such changes, it was assumed that this type of change begins at the same time as the shorten-

ing in stature begins.

(2) Weight increase after the end of linear growth (ELG): The robustness of the foot is considered to be related to the robustness of the whole body. If body build at the time of measurement influences foot morphology, then the weight increase after ELG should be related to foot morphology. However, if body build at the time of ELG is the most important factor, then the effects of weight increase after ELG on foot morphology should be small. Weight increase after ELG is mainly due to the increase in soft tissue, and would mainly influence breadth and circumference measurements. If the weight increase after ELG is the main cause of large FC or foot breadth, diagonal (FB) of the 1930 groups, then FC and FB measured at younger ages would be systematically smaller than measurements taken at older ages when cross sectional data are examined.

(3) Body build at the end of growth: Previous studies on secular changes indicate that the body build of the 1930 groups differs from that of the 1970 groups, even when the 1930s subjects were young adults. A more robust body build of the 1930 groups as young adults than that of the 1970 groups may explain the inter-generation differences in foot morphology.

(4) Differential bone growth: Conspicuous secular changes in height in recent years are mainly due to increases in leg length rather than in sitting height (Kouchi, 1996; Ohyama et al., 1987). This fact indicates that the growth of long bones is influenced by environmental changes much more than the growth of short bones. If there is an inter-generation difference in length proportions, then it may be the result of differential growth rates in the bones.

(1) and (2) are related to changes after ELG (aging), and (3) and (4) are related to changes during growth (secular change).

Mathematical method

If the longitudinal arch becomes lower during the course of aging, then instep length should become longer for a given FL. If the ball cross section flattens due to the loosening of ligaments caused by aging, then the 1930 group should have a larger FB for a given FC. Furthermore, since heel breadth is not related to the loosening of ligaments, if the ball cross section flattens due to aging, then the 1930 group should have smaller heel breadth for a given FB. To test these hypotheses, indices can be used and the differences in the proportion between two measurements examined. However, the proportion changes according to size (allometry), and the feet of the 1930 and 1970 groups differ in size. Thus, inter-generation differences in proportion can be caused by this size difference. Therefore, instep length was regressed on FL for the two groups, and the equality of regression lines was tested in order to compare the proportions in the two groups for the same FL. If the longitudinal arch becomes lower due to aging, then instep length should become longer for a given FL, and thus the regression line for the 1930 group would have a larger y-intercept than that for the 1970 group. These hypotheses were tested using ANCOVA (analysis of covariance) with Statview for Macintosh.

When a significant inter-generation difference in the y-intercepts of the regression lines was found, the direction of the difference was examined to determine whether this was congruent with the assumptions stated above.

RESULTS

Basic statistics for the three data series are shown in appendices 1 to 4. Table 2 shows the results of ANCOVA testing of the equality in y-intercepts of regression lines for the 1930 and 1970 groups. When FL was the same, (1) no consistent inter-generation difference was observed for the relationship between FL and instep length, (2) the 1970 groups had a larger fibular instep length, a larger heel to 5th metatarsal base length, and a longer 5th metatarsal bone, while (3) the 1930 groups had larger heel to medial malleolus length and larger heel to lateral malleolus length, as well as larger circumference and breadth measurements (Table 2A). (4) The 1970 groups were larger in heights at the medial and lateral malleoli when the inter-generation difference was significant, but the heights of

Table 2. Results of the analysis of covariance for inter-generation differences.

A. Regression on the foot length

	Somatometric data						Plaster models	
	IPRI series		NIBH series		JLIA series		NIBH series	
Measurement item	Male	Female	Male	Female	Male	Female	Male	Female
1 Instep length	ns	ns	ns	*Y	ns	ns	ns	**A
2 Fibular instep length	**Y	**Y	**Y	**Y	**Y	ns	**Y	**Y
3 Heel to medial malleolus length	ns	**A	-	-	ns	*A	*A	**A
4 Heel to lateral malleolus length	*A	**A	-	-	ns	ns	ns	ns
5 Heel to 5th metatarsal base length	-	-	-	-	-	-	*Y	*Y
6 Length of 5th metatarsal	-	-	-	-	-	-	**Y	**Y
7 Length of big toe	ns	ns	-	-	*A	ns	ns	*Y
8 Foot circumference	**A	**A	**A	**A	**A	**A	-	-
9 Instep circumference	**A	**A	-	-	**A	**A	-	-
10 Bimalleolar breadth	**A	**A	-	-	-	-	**A	**A
11 Foot breadth, diagonal	**A	**A	**A	**A	*A	**A	**A	**A
12 Foot breadth, medial half	ns	**A	ns	ns	-	-	ns	*Y
13 Foot breadth, lateral half	**A	**A	**A	**A	-	-	**A	**A
14 Ball breadth	**A	**A	**A	**A	-	-	**A	**A
15 Heel breadth	**A	**A	**A	**A	ns	**A	**A	**A
16 Medial malleolus height	ns	ns	ns	**Y	-	-	ns	*Y
17 Lateral malleolus height	ns	ns	ns	**Y	-	-	ns	ns
18 Sphyrion height	ns	ns	-	-	-	-	ns	**Y
19 Sphyrion fibulare height	ns	ns	-	-	ns	ns	ns	ns
20 Dorsal arch height at 54% of FL	ns	*A	-	-	-	-	**A	**A
21 Dorsal arch height at 50% of FL	-	-	-	-	-	-	*A	**A
22 Ball height	ns	**A	-	-	-	-	**A	**A
23 Outside ball height	ns	ns	-	-	-	-	**A	**A
24 Great toe tip height	**A	*A	-	-	-	-	-	-
25 Great toe height	ns	ns	-	-	-	-	ns	**A
26 Ball flex angle	**Y	ns	**Y	*Y	ns	ns	-	-
27 Toe 1 angle	ns	ns	*A	ns	ns	ns	-	-
28 Toe 5 angle	**A	**A	**A	**A	ns	ns	-	-

B. Regression on foot circumference based on somatometric data

	IPRI series		NIBH series		JLIA series	
Measurement item	Male	Female	Male	Female	Male	Female
11 Foot breadth, diagonal	ns	**A	**A	**A	**A	*A

C. Regression on foot breadth, diagonal based on somatometric data

	IPRI series		NIBH series		JLIA series	
Measurement item	Male	Female	Male	Female	Male	Female
15 Heel breadth	ns	ns	ns	ns	ns	ns

**: significant at the 1% level, *: significant at the 5% level, ns: not significant

A denotes that the 1930 group is larger, and Y denotes that the 1970 group is larger the dorsal arch and the ball were larger in the 1930 groups when the difference was significant. (5) Regressions of angle measurements on FL were not significant. The 1970 groups had a larger ball flex angle, and the 1930 groups had a larger toe 5 angle in IPRI and NIBH series (see results of a *t*-test in appendices 1 and 2). The JLIA series, which has the smallest inter-generation differences in age and body size at the time of measurement (Table 1), had the smallest number of measurement items that show significant inter-generation differences.

When FC was the same, the 1930 groups had a larger FB (Table 2B). No difference was observed in the relationship between FB and heel breadth (Table 2C). The 1930 groups were wider at the ball as well as at the heel than the 1970 groups.

DISCUSSION

Foot length and changes in the longitudinal arch

If the longitudinal arch flattens due to aging, then the 1930 group should have had a longer instep length, a longer fibular instep length, and a lower dorsal arch height compared to the 1970 group of the same FL. However, there were no significant inter-generation differences in instep length, and the 1930 group had significantly shorter fibular instep lengths and higher dorsal arches (Table 2A). These facts are incompatible with this hypothesis. It can be concluded that the changes in FL and longitudinal arches due to aging are very small, if at all.

Foot breadth and changes in transverse arch

The 1930 groups had larger breadth measurements and a larger FC than the 1970 groups of the same FL (Table 2A). If the larger breadth measurements were due to a flattening of the ball cross section, then the 1930 group should have had a larger FB than the 1970 groups of the same FC, and a smaller heel breadth than the 1970 groups of the same FB. In fact, the 1930 groups had a larger FB than the 1970 groups of the same series when FC was the same (Table 2B). The result is compatible with the ball cross section flattening hypothesis. However, there were no inter-generation differences in the relationship between FB and heel breadth (Table 2C). In addition, since bone size has been assumed not to change, the ball cross section flattening hypothesis cannot explain the fact that the 1930 groups were absolutely larger in FC, ball height, and outside ball height than the 1970 groups of the same FL.

Effects of body build

In the present study, two aspects of the effects of body build were considered: 1) the effect of the increase in body weight after the end of linear growth (ELG), and 2) the effect of body build when the growth has stopped. We then attempted to determine which of these aspects is more useful in explaining the observed inter-generation differences.

(1) Changes in body build after the end of linear growth

To examine the relationship between the foot morphology of the 1930 groups and the soft tissue increase after ELG, it was necessary to estimate the amount of weight increase and the amount of height decrease due to aging (assumption (2)). Consequently, changes in height and weight after ELG were examined using published statistical data from the reports of the National Nutrition Survey. The mean height, weight, and birth year were calculated for the 20-29 year-old group, and taken as the measurements at 25 years, the age of ELG. The mean height and weight of this population were compared with those of a 35-year-old group (population of age 30-39) measured 10 years later, a 45-year-old group (population of age 40-49) measured 20 years later, and so on. For the groups born between 1898 and 1963, the changes during each 10-year-period were calculated. The mean changes in height and weight during each 10-year-period are listed in Table 3. Figures 4 and 5 show the relationship between birth year and height or weight, respectively, at the ages of 25, 35, 45, 55, and 65 years.

Table 3. Estimated changes in height and weight from 25 to 65 years old.

Age	Changes in height (cm)		Changes in weight (kg)		Birth Year
	Male	Female	Male	Female	
25 to 35	0.45	0.19	2.74	1.39	1922-63
35 to 45	0.10	0.02	1.76	1.94	1912-53
45 to 55	-0.26	-0.58	0.60	0.44	1902-43
55 to 65	-0.63	-1.19	-0.17	-0.38	1898-1933
25 to 65	-0.34	-1.56	4.93	3.39	

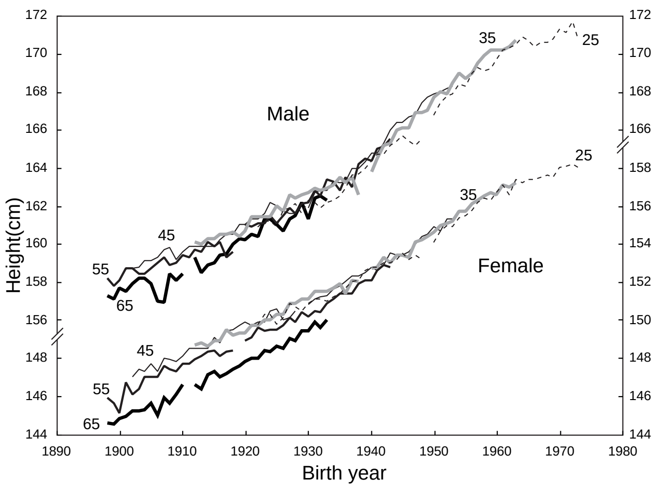

Fig. 4. Height at age 25, 35, 45, 55, and 65 years based on the results of the National Nutritional Survey.

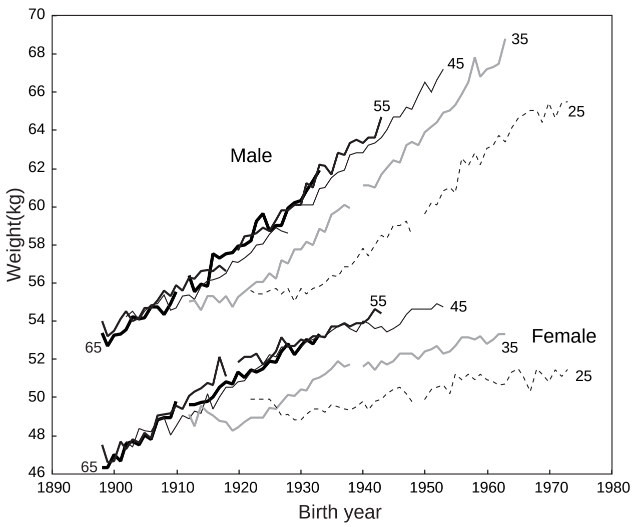

Fig. 5. Weight at age 25, 35, 45, 55, and 65 years based on the results of the National Nutritional Survey.

A small increase in height was observed between the ages of 25 and 45 years. Height starts to decrease after the age of 45 years, in particular after 55 years, and the decrease is twice as much in females as in males. The total change in height between 25 and 65 years was -0.34 cm in males, and -1.56 cm in females. On the other hand, weight increases between 25 and 45 years, and changes after 45 years are very small in both sexes. The total change in weight between 25 and 65 years was about 5 kg in males, and about 3.5 kg in females.

These findings suggest that if inter-generation differences in foot morpholoy are due to increases in soft tissue after ELG, most of the changes would occur by 50 years of age. Furthermore, if the main cause was the change in arch structure, this would occur mainly after the age of 50.

Table 4 shows the estimated height, weight, and BMI of the 1930 groups as young adults compared with the measured data for the 1930 and 1970 groups. According to Takasaki, et al. (1984), the rate of height decrease between 64 and 90 years is 0.2 cm/year for males, and 0.34 cm/year for females. These values as well as the data shown in Table 2 were used for the estimation. It seems that for the 1930 groups in the IPRI and NIBH series, the changes in BMI between 25 years and the age of measurement was 2-2.5 (kg/m^2) in both sexes. The female 1930 groups in the IPRI and NIBH series had larger BMI than the 1970 groups in the same series, even when they were young adults, but BMI for the female 1930 group in the JLIA series as young adults was about the same as that for the 1970 group. For the male 1930 groups of IPRI and JLIA series, BMI as young adults was rather smaller than that for the 1970 group in the same series. These results agree with the reported secular changes in BMI in which males have become heavier and females have become leaner (Kouchi, 1996).

(2) Body build as represented by BMI

If the 1930 groups have robust feet because they are robust in overall body build, then the

Talbe 4. Estimated body size of the 1930 group at the age of about 25 years.

A. Males

1930 group: average measurement in 1987-98

Item	IPRI	NIBH	JLIA
Age (yrs.)	73.3	64.7	53.1
Height (cm)	158.9	160.9	165.1
Weight (kg)	56.8	60.6	61.9
BMI	22.5	23.4	22.7

1930 group: estimated value at 25 years

Item	IPRI	NIBH	JLIA
Height (cm)	160.8	161.2	165.1
Weight (kg)	51.9	55.7	56.8
BMI	20.1	21.4	20.8

1970 group

Item	IPRI	NIBH	JLIA
Age (yrs.)	22.7	20.5	22.5
Height (cm)	171.4	170.6	170.4
Weight (kg)	63.3	59.5	62.0
BMI	21.5	20.4	21.3

B. Females

1930 group: average measurement in 1987-98

Item	IPRI	NIBH	JLIA
Age (yrs.)	70.3	66.6	53.5
Height (cm)	146.9	149.3	153.0
Weight (kg)	51.1	55.4	50.7
BMI	23.8	24.8	21.6

1930 group: estimated value at 25 years

Item	IPRI	NIBH	JLIA
Height (cm)	150.2	150.9	153.4
Weight (kg)	47.7	52.0	46.9
BMI	21.2	22.9	20.0

1970 group

Item	IPRI	NIBH	NIBH*	JLIA
Age (yrs.)	21.6	20.4	20.2	22.4
Height (cm)	159.1	158.7	158.9	156.8
Weight (kg)	52.6	53.4	52.1	49.1
BMI	20.8	21.2	20.6	20.0

*: 1970-2 group in Table 1

differences in foot morphology between the 1930 and 1970 groups would have been similar to the differences between the 1970 groups with smaller BMI and the 1970 groups with larger BMI. The relationship between BMI and foot morphology was examined by comparing two groups of young adults with different BMI. The 1970 groups in the IPRI and NIBH series were divided into two groups, one with BMI smaller than or equal to 21.0 (1970-S group below) and the other with BMI larger than 21.0 (1970-H group below). The 1970-S and 1970-H groups in the same series and of the same sex were compared for the equality of y-intercepts of regression lines by ANCOVA. Regression analyses of foot dimensions on FL, of FB on FC, and of heel breadth on FB were performed.

Basic statistics of measurements by BMI group are shown in Appendices 5-7. The differences in height and age between the 1970-S and 1970-H groups were not significant, but the 1970-H group was heavier (8-10 kg) and had a larger BMI (3.0-4.1 kg/m^2) than the 1970-S group of the same series and same sex ($p<0.001$). The differences in BMI between the 1970-S and 1970-H groups were as large as the differences between the 1930 and 1970 groups of the same series and same sex. The differences in weight between the 1970-S and 1970-H groups were also larger than the increase in weight after the end of linear growth (Table 3).

Table 5 shows the results of ANCOVA testing of the equality in y-intercepts of regression lines between the 1970-S group (BMI ≤ 21) and the 1970-H group (BMI > 21). In both males and females, the 1970-H group had larger FC, breadth measurements (except foot breadth, medial half), heel to medial malleolus length, dorsal arch height, ball height, outside ball height, and height of the great toe, than the 1970-S group of the same FL (Table 5A). The differences in FB were not significant when the FC was the same (Table 5B). The 1970-H group had a larger heel breadth than the 1970-S group of the same FB (Table 5C).

Interestingly, the characteristics of the 1930 groups were similar to those of the 1970-H groups of young adults, in having longer heel to medial malleolus length, larger FC and breadth measurements, larger dorsal arch height and ball height for their FL (Table 2A and 5A). The main difference between the 1930 groups and 1970-H groups was that the 1930 groups had still more robust feet than the 1970-H groups of the same FL (larger in FC, FB, heel breadth, bimalleolar breadth, and ball height). Further, the 1970-H groups were not similar to the 1930 groups in that they did not have larger FB for their FC (Tables 2B and 5B), and had a wider heel for their ball (Tables 2C and 5C). When the 1970-H groups were compared with the 1930 groups, the 1930 groups had larger FB than the 1970-H groups of the same FC, but no difference was found in the proportion between FB and heel breadth. These findings do not well fit into the ball cross-section flattening hypothesis.

The present findings indicate that BMI is related to foot morphology. The larger BMI of the 1930 groups may explain the robustness of their feet (large FC, FB, and dorsal arch height for FL). A shortcoming of BMI as an indicator of body build is that it cannot distinguish a heavy person with a lot of fat from a heavy person with well developed muscles and skeleton. The 1930 groups had smaller BMI than the 1970-H groups when they were young (Table 4). The larger BMI in the 1930 groups at the time of measurement was mainly due to the increase in weight (fat). If the breadth and height measurements increase due to weight gain after ELG, then robust feet of the 1930 groups may have been caused by aging. If they did not, the robust feet of the 1930 groups both at the ball and heel would have represented their characteristic morphology since youth, and thus inter-generation differences in foot morphology are caused by secular change.

(3) Foot breadth, diagonal and the age at measurement

If FC and FB increase due to weight gain after ELG, then the changes should have occurred by age 50, by which age almost all weight increase has occurred (Table 3). To test this hypothesis, the relationship between FB and the age at measurement was examined using the published data taken for subjects younger than 50 years. Only FB was examined because little circumference and height measurement data is available. The data used for this analysis were the present data and the findings of Kondo (1953), Yanagisawa (1961), Uchimura (1972), Hoshi and Kouchi (1978), Hoshi et al. (1980), Baba (1979), Aeromedical Laboratory (1972, 1980, 1990), and JLIA (1988). The measurement meth-

Table 5. Results of the *t*-test and the analysis of covariance for differences between groups with different BMI.

A. Regression on the foot length

	Somatometric data				Plaster models	
	IPRI series		NIBH series		NIBH series	
Measurement item	Male	Female	Male	Female	Male	Female
1 Instep length	ns	ns	ns	ns	ns	ns
2 Fibular instep length	ns	ns	ns	ns	ns	ns
3 Back-of -foot length	ns	**S	-	-	ns	ns
4 Heel to medial malleolus length	**H	**H	-	-	ns	**H
5 Heel to lateral malleolus length	ns	**H	-	-	ns	**H
6 Length of 5th metatarsal length	-	-	-	-	ns	ns
7 Length of big toe	ns	ns	-	-	ns	ns
8 Foot circumference	**H	**H	**H	**H	-	-
9 Instep circumference	**H	**H	-	-	-	-
10 Bimalleolar breadth	**H	**H	-	-		
11 Foot breadth, diagonal	**H	**H	**H	**H	*H	**H
12 Foot breadth, medial half	ns	ns	ns	ns	ns	ns
13 Foot breadth, lateral half	**H	**H	*H	**H	ns	**H
14 Ball breadth	**H	**H	*H	**H	ns	**H
15 Heel breadth	**H	**H	ns	**H	ns	**H
16 Medial malleolus height	ns	ns	ns	ns	ns	ns
17 Lateral malleolus height	ns	ns	ns	ns	ns	ns
18 Sphyrion height	ns	ns	-	-	ns	ns
19 Sphyrion fibulare height	ns	ns	-	-	*H	ns
20 Dorsal arch height at 54% of FL	*H	**H	-	-	ns	ns
21 Dorsal arch height at 50% of FL					ns	ns
22 Ball height	**H	**H	-	-	ns	ns
23 Outside ball height	**H	**H	-	-	**H	*H
24 Great toe tip height	ns	**H	-	-	-	-
25 Great toe height	ns	**H	-	-	**H	ns
26 Ball flex angle	ns	ns	ns	ns	-	-
27 Toe 1 angle	ns	ns	ns	ns	-	-
28 Toe 5 angle	ns	ns	ns	ns	-	-

B. Regression on foot circumference based on somatometric data

	IPRI series		NIBH series	
Measurement item	Male	Female	Male	Female
11 Foot breadth, diagonal	ns	ns	ns	ns

C. Regression on foot breadth, diagonal based on somatometric data

	IPRI series		NIBH series	
Measurement item	Male	Female	Male	Female
15 Heel breadth	**H	*H	ns	**H

**: significant at the 1% level, *: significant at the 5% level, ns: not significant.
H denotes that group with higher BMI (>21) is larger, and S denotes that group with lower BMI (≤21) is larger.

ods adopted in some studies differ from the present method, but the differences in means due to such differences were small enough to observe an overall trend (National Institute of Bioscience and Human Technology, 1996). When birth year of the subjects was not cited in the studies, the mean birth year was calculated by subtracting the mean age at the time of measurement from the year of measurement. The correlation coefficient between FB and the age at measurement was calculated as an indicator of the relationship. A regression analysis was conducted, and the significance of the effect of age was tested by ANOVA (analysis of variance) (Statview for Macintosh).

Figure 6 shows the relationship between FB and the age at measurement. The 1930 groups are also shown in Figure 6, but were not used for the analysis. The correlation coefficient was 0.53 for males and 0.22 for females and neither was statistically significant. There was a tendency for older subjects to be born earlier. Therefore, a partial correlation coefficient between FB and the age at measurement with birth year partialed out was calculated. The partial correlation coefficient was 0.50 for males and 0.34 for females and neither was statistically significant. The results of ANOVA also showed that the effects of age at measurement were not statistically significant.

When the 1930 groups were added to the analysis, the conclusion was the same for males. The partial correlation coefficient was 0.12 and was not statistically significant. However, for females, the partial correlation coefficient was 0.79 and was statistically significant when the 1930 groups were used for the analysis. This is because the female 1930 groups of the IPRI and NIBH series have exceptionally large FB (arrows in Figure 6).

Since no relationship was observed between FB and the age at measurement, it can be concluded that the effects of weight increase on FB are small. As for the very large FB of the female 1930 groups in the IPRI and NIBH series, it seems more fruitful to search for the causes of their very robust feet.

(4) Secular change

Data for FL and FB measured for subjects younger than 50 was collected from the literature, and the relationship with the birth year (BY) of the subjects was examined. The age of 50 was chosen as the cut-off criterion because height decreases before this age were small (Table 3). The data used for this analysis were the same as those used for the analysis of the relationship between FB and the age at measurement. For FL, the data from the Japanese Standards Association (1984) was also used. Correlation coefficients between the foot measurements and BY were calculated as indicators of the trends in secular change. A regression analysis was conducted, and the significance of the effect of BY tested by ANOVA.

The relationships between the mean BY and mean FL or mean height, are shown in Figures 7

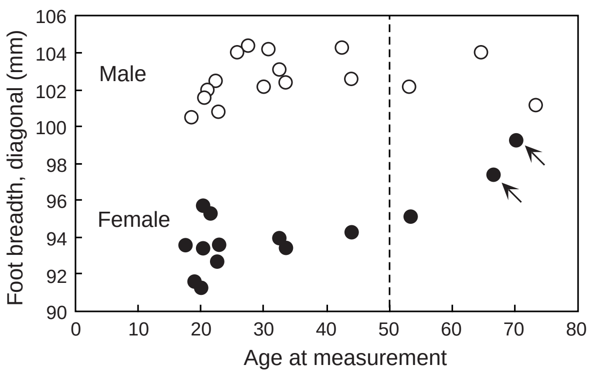

Fig. 6. Relationship between foot breadth, diagonal and the age at measurement. Arrows indicate female 1930 groups in the IPRI and NIBH series. See text for the reference.

and 8, respectively. The 1930 groups of the present study are also plotted in these figures, but were not used in the analysis. Foot length increased with BY for both males and females. The correlation coefficient between FL and BY was 0.84 (df=19, $p<0.0001$) for males and 0.83 (df=18, $p<0.0001$) for females, while the correlation coefficient between height and BY was 0.94 (df=19, $p<0.0001$) for males, and 0.92 (df=18, $p<0.0001$) for females. The effect of BY on foot length and height was highly statistically significant for both males and females.

The relationship between the BY and FB is shown in Figure 9. No trend was observed for the change in FB with BY. The correlation coefficient between FB and BY was -0.22 for males and -0.29 for females and neither was significant. When the age at measurement is partialed out, the correlation coefficients remained statistically insignificant (0.07 for males, 0.43 for females). Since FB does not increase with age after ELG (see the previous section), and since FB does not show a statistically significant trend with time, the secular change in the foot to an increasingly slender form is due to the fact that the size of the ball does not change with time in spite of the increase in the length of the foot. It seems that the size of the metatarsal head does not change but bone length increases, and thus the younger generation have longer and more slender feet. The female 1930 groups in the IPRI and NIBH series are the outlying samples, having very large FB (arrows in Figure 9) and larger FL (arrows in Figure 7) for their BY. They have extremely robust feet that are absolutely larger than the 1970 group of the same series in FC, dorsal arch height, and ball height. Since FL does not increase due to aging, and the effect of weight increase after ELG on the size of the ball is small (previous section), and the size of bones does not change by aging (assumption), it is reasonable to conclude that the female 1930 groups in the IPRI and NIBH series had very robust feet even as young adults.

(5) Socioeconomic status (SES)

We speculated on why only the female 1930 groups of the IPRI and NIBH series had exceptionally robust feet, and concluded that the sex difference in the secular change in BMI may partly explain this finding, that is, BMI has been increasing for males, but has been decreasing for females (Kouchi, 1996). Another possible cause is the differences in socioeconomic status (SES).

The female 1930 groups in the JLIA (Appendix 4) and NIBH series (Appendices 2 and 3) were born around the same period, but the JLIA series was taller (3.7 cm difference) even when the differences in the age at the time of measurement (13 years) were taken into account. ANCOVA analysis of the differences between these two groups in the relationships between FL, FC, FB, and heel breadth revealed that the JLIA females had a smaller FC ($p<0.001$) and FB ($p=0.033$) than the NIBH females of the same FL, and had a larger FB than the NIBH females of the same FC ($p<0.001$), but no difference was found in the relationship between FB and heel breadth ($p=0.9739$). In other words, the JLIA female 1930 group was closer to the 1970 groups than to the NIBH females of the same generation except the relationship between FC and FB.

The subjects in the JLIA series were city dwellers, while the subjects of the 1930 groups in the NIBH and IPRI series were from rural areas. Students measured around 1950 were taller than country women of the same age by 3.6 cm, but smaller in chest circumference by 2 cm (Yanagisawa, 1961). In the 1930s, female “mental workers”, including students, were taller than physical workers, including country women, by 3.9 cm (Takeuchi, 1932). Such differences in body size and body build for people of different occupations or socioeconomic status were common in the generation born before 1940. It is likely that the differences in foot morphology observed between the female 1930 groups in the JLIA and NIBH series are related to the differences in nutrition and activity levels during the growth period caused by SES differences. While the mechanical stress due to daily activities is related to the geometrical properties of the shaft of long bones (for example, Ruff, 1992), whether the dimensions of the epiphysis are also related to mechanical stress is unknown. The fact that the morphological differences in the foot for the 1930 groups in the JLIA and NIBH series were smaller in males than in females may be explained by the smaller SES differences in physical activities for males.

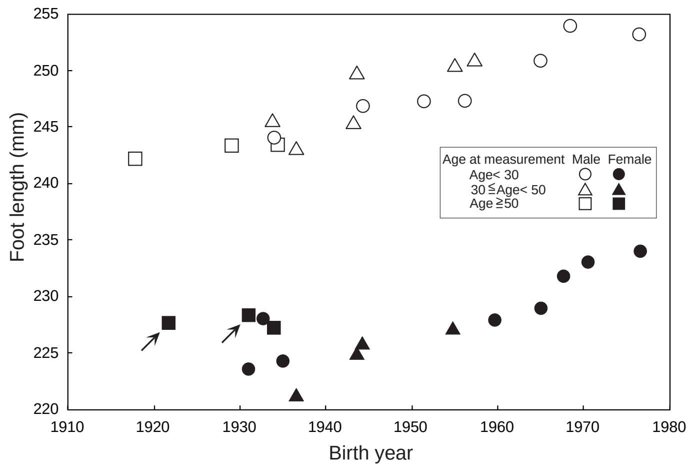

Figure 7. Relationship between foot length and birth year. Arrows indicate female 1930 groups in the IPRI and NIBH series. See text for the reference.

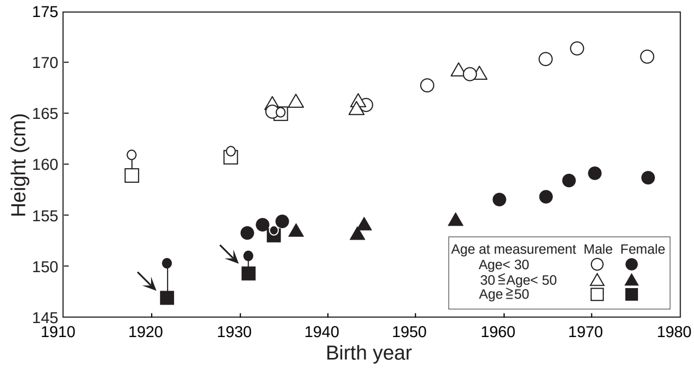

Figure 8. Relationship between height and birth year. Arrows indicate female 1930 groups in the IPRI and NIBH series. Small circles indicate the estimated values at the age of 25. See text for the reference.

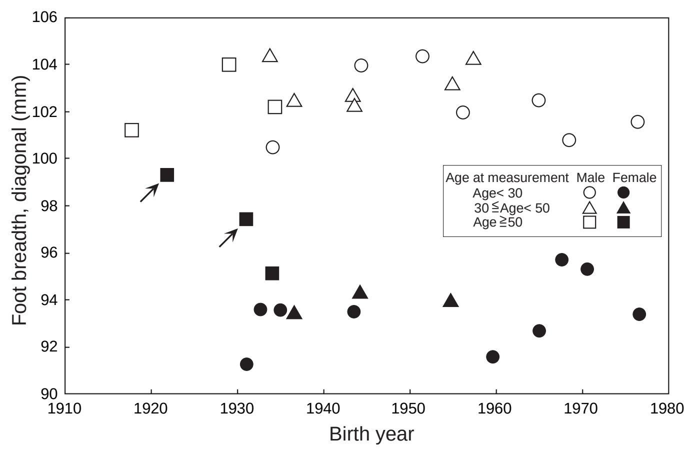

Figure 9. Relationship between foot breadth, diagonal and birth year. Arrows indicate female 1930 groups in the IPRI and NIBH series. See text for the reference.

Differential growth

The 1930 groups had a shorter fibular instep length, a shorter heel to the 5th metatarsal length, a shorter 5th metatarsal bone for their FL, and a larger toe 5 angle than the 1970 group of the same FL (Table 2). These characteristics can be explained neither by the flattening of the longitudinal arch nor by differences in body build.

If the growth of long bones is influenced by environmental changes much more than the growth of short bones (assumption (4)), the differential growth for long bones and short bones of the foot may explain the longer fibular instep length and the longer 5th metatarsal bone in the 1970 groups.

The 1930 groups tended to have smaller ball flex angles, which are related to their shorter fibular instep length (Table 2A). The inter-generation difference in ball flex angle was 1.2-1.6 degrees when the difference was statistically significant (see Appendices). The smaller ball flex angle may explain the larger FB for the same FC in the 1930 groups. To examine this possibility, the 1970 groups in the IPRI and NIBH series were divided into two groups according to ball flex angle; one group consisting of subjects with a ball flex angle equal to or smaller than the mean (SA group), and the other group consisting of subjects with a ball flex angle larger than the mean of the series (LA group). Table 6 shows the data by group. The LA group had a significantly larger ball flex angle than the SA group by 3.9-4.7 degrees. In addition, (1) the differences in FB and FC between the two groups were not significant, and (2) the SA group had a significantly larger FB than the LA group of the same FC as expected ($p<0.05$ for the female 1970 group in the IPRI series, and $p<0.01$ for the other three groups). Although the differences in ball flex angle between the LA and SA groups were much larger than the inter-generation differences in the angle, these results suggest that the larger FB of the 1930 groups for their FC can be partly explained by their shorter fibular instep length.

Table 6. Number of subjects by group based on ball flex angle.

A. Males

	IPRI series			NIBH series		
	SA group	LA group		SA group	LA group	
Measurement item	BLA≤77	BLA>77	*t*-test	BLA≤78	BLA>78	*t*-test
N	86	130		57	53	
Ball flex angle (deg.)	74.8	78.9	**	75.9	80.6	**
Foot circumference (mm)	250.0	249.3	ns	251.2	250.1	ns
Foot breadth, diagonal	101.4	100.3	ns	102.2	100.9	ns

B. Females

	IPRI series			NIBH series		
	SA group	LA group		SA group	LA group	
Measurement item	BLA≤76	BLA>76	*t*-test	BLA≤78	BLA>78	*t*-test
N	112	94		46	61	
Ball flex angle (deg.)	74.3	78.2	**	76.1	80.2	**
Foot circumference (mm)	232.5	231.3	ns	231.4	231.2	ns
Foot breadth, diagonal	95.8	94.8	ns	93.9	92.7	ns

**: significant at the 1% level, ns: not significant

Other factors

(1) Footwear

The inter-generation differences in toe 5 angle cannot be explained without considering the relationship between feet and shoes. The shoe size for the average female subjects of the 1930 group in the IPRI series was judged to be 22.5 cm and EEE in the Japanese Industrial Standard for shoe size, while that for the average female subjects of the 1970 group in the same series was 23.5 cm and E (Dohi et al., 2001). Generally speaking, not many wide shoes are commercially available, and people with wider feet tend to wear longer shoes of standard width. Moreover, shoes with larger widths tend to have pointed toes (Kouchi and Yamazaki, 1992). The large toe 5 angle of subjects in the 1930 groups may be partly explained by deformation due to ill-fitting shoes.

(2) Hallux valgus

The higher proportion of subjects with hallux valgus in the 1930 groups is a possible cause of the very large FC and FB of the female 1930 groups in the IPRI and NIBH series. Table7 shows the number of subjects with hallux valgus. However, when the subjects with hallux valgus were excluded from the analyses, the means of these measurements changed less than 1 mm, and the results of ANCOVA did not change.

Table 7. Number of female subjects with hallux valgus (h. v.).

Series	Group	Total number	with h. v.
IPRI	1930	49	8
	1970	206	3
NIBH	1930	49	2
	1970	107	1

(3) Pregnancy

Female feet are thought to become wider after their first pregnancy because the ligaments of the feet loosen due to hormonal effects. If this is true, inter-generation differences in foot dimensions would be larger in females than in males, and the differences between a 18-year-old and a 30-year-old would be much larger than the differences between a 30-year-old and a 50-year-old. Inter-generation differences in females were in fact larger than those in males in the present study (Table 2), but this was due to the exceptionally robust feet of the female 1930 groups in the IPRI and NIBH series. The trend in FB with age or with BY does not support this hypothesis (Figures 6 and 9).

SUMMARY AND CONCLUSIONS

Inter-generation differences in foot dimensions between groups born before 1940 (1930 groups) and after 1960 (1970 groups) were examined using ANCOVA to determine whether aging or secular change is more important in explaining the inter-generation differences. The changes in foot breadth, diagonal (FB) with age and the secular changes in foot length (FL) and FB were examined using the data from the literature as well as the present data measured at ages younger than 50 years. The results were discussed in relation to the changes in skeletal structure, overall body build, weight increase after the end of linear growth, and differential growth of foot bones. Conclusions are:

1) When FL is the same, there are no inter-generation differences in instep length, and the 1970 groups have a longer fibular instep length than the 1930 groups. These findings indicate that the flattening of the longitudinal arch caused by aging is negligible.

2) When foot circumference (FC) is the same, the 1930 groups have a larger FB than the 1970 groups. This finding does not contradict the ball cross-section flattening hypothesis. However, the

findings that there are no inter-generation differences in the relationship between FB and heel breadth and that when FL is the same the 1930 groups have an absolutely larger FC, cannot be explained by this hypothesis.

3) When the subjects in the 1970 group were divided into a 1970-H group (BMI>21) and an 1970-S group (BMI≤21), the feet of the 1970-H groups are similar to those of the 1930 groups in having a larger foot circumference (FC), larger breadth measurements, and higher dorsal arches and balls. This finding indicates that the BMI is related to foot morphology.

4) Most of the weight increase after the end of linear growth (ELG) occurs by age 50. Using the data measured in subjects younger than 50, FB does not have any significant relationship with the age at measurement. This finding indicates that the effects of weight increase on FB are small, if any.

5) The female 1930 groups in the IPRI and NIBH series, who were from rural areas, have exceptionally large FB, but the male 1930 groups in these series do not. One possible cause of this sex difference is the difference in the secular change in BMI, in which males have become heavier and females have become more slender.

6) The exceptionally large FB of female 1930 groups in the IPRI and NIBH series may be explained by environmental factors present during the growth period, namely the physical activities required in rural life.

7) The longer fibular instep length and the longer 5th metatarsal bone in the 1970 groups may be explained by differential growth of the long and short bones of the foot which react differently to environmental changes.

8) The above findings indicate that the foot morphology of the 1930 groups are better explained by secular change (effects of environmental factors during the growth period) than by aging (changes occurring after the end of growth).

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REFERENCES

Aeromedical Laboratory, Japan Air Self Defense Force (1972) Anthropometry of JASDF personnel and its application for human engineering (in Japanese).

Aeromedical Laboratory, Japan Air Self Defense Force (1980) Anthropometry of JASDF personnel and its application for human engineering (in Japanese).

Aeromedical Laboratory, Japan Air Self Defense Force (1990) Anthropometry of JASDF personnel and its application for human engineering-1988 (in Japanese).

Baba, K (1979) Foot measurement for shoe construction with reference to the relationship between foot length, foot breadth, and ball girth. *J. Human Ergol*., 3:149-156.

Dohi, M, Mochimaru, M, and Kouchi, M (2001) Foot shape and shoe fitting comfort for elderly Japanese women. *Jpn. J. Ergonomics.*, 37:228-237 (in Japanese with English summary).

Hoshi, H and Kouchi, M (1978) Anthropometry of adult male Japanese with remarks on correlation coefficients. *Acta Anatomica Nipponica*, 53:238-247 (in Japanese with English summary).

Hoshi, H, Kouchi, M, and Tsutsumi, E (1980) Anthropometry of adult female Japanese with remarks on correlation coefficients. *Acta Anatomica Nipponica*, 55:525-534 (in Japanese with English summary).

Japan Leather and Leather-good Industries Association (1988) Report of the Research and Development on Foot Studies (Showa 62 nendo) (in Japanese).

Japanese Standards Association (1984) Report of the Anthropometric Survey of Japanese for the Japanese Industrial Standard of Readymade Clothing (1978/81). Japanese Standards Association (in Japanese).

Kondo, S (1953) Growth of the foot of the school boys and girls in Tokyo. *J. Anthrop. Soc. Nippon*, 63:22-32 (in Japanese).

Kouchi, M (1996) Secular change and socioeconomic difference in height in Japan. *Anthrop. Sci.*, 101: 325-340.

Kouchi, M (1998) Foot dimensions and foot shape: differences due to growth, generation and ethnic origin. *Anthrop. Sci.*, 106(Suppl.):161-188.

Kouchi, M and Mochimaru, M (2000) Anthropometry data base. *Human Interface*, 2:252-258 (in Japanese).

Kouchi, M and Yamazaki, N (1992) Allometry of the foot and shoe last. *J. Anthrop. Soc. Nippon*, 100:101-118 (in Japanese with English summary).

National Institute of Bioscience and Human-Technology (1994) Reference Manual of Anthropometry in Ergonomic Designing, Nippon Shuppan Service, Tokyo (in Japanese).

National Institute of Bioscience and Human-Technology (1996) Human Body Dimensions Data for Ergonomic Design, Nippon Shuppan Service, Tokyo (in Japanese).

Ohyama, S, Hisanaga, A, Inamasu, T, Yamamoto, A, Hirata, M, and Ishinishi, N (1987) Some secular changes in body height and proportion of Japanese medical students. *Am. J. Phys. Anthropol.*, 73:179-183.

Ruff, C (1992) Biomechanical analysis of archaeological human skeletal samples. *In* : Skeletal Biology of Past Peoples: Research Methods, ed. by Saundes, SR and Katzenberg, MA,Wiley-Liss, New York, pp. 37-58.

Takasaki, Y, Kaneko, S, and Anzai, S (1984), The effect of aging on stature and body weight for the aged. *J. Anthrop. Soc. Nippon*, 92:79-86.

Takeuchi, S (1932) Studien über die Konstitution der japanischen Frau. I. Teil. Untersuchungen über die Körpergrösse, Beinlänge und Sitzhöhe der japanische Frau. *Tokyo J. of Med. Sci.*, 46:2252-2322 (in Japanese with German summary).

The Study Circle for Health and Nutrition Information ed. (2001) The Nutrition Survey in Japan, Daiichi Shuppan, Tokyo (in Japanese).

Uchimura, Y (1972) Anthropometric survey of human figure. Measurement of leg and foot. *Bulletin of Industrial Products Research Institute*, 69:57-62 (in Japanese with English abstract).

Yanagisawa, S (1961) Body proportion of the Japanese women. *J. Anthrop. Soc. Nippon*, 69:55-66 (in Japanese with English summary).

Appendix 1. Statistics for IPRI data. The item numbers are those used in Figure 3 and Tables 2 and 5.

Item	Males 1930 group N	Mean	S.D.	Males 1970 group N	Mean	S.D.	*t* -test	Females 1930 group N	Mean	S.D.	Females 1970 group N	Mean	S.D.	*t* -test
Birth year	50	1917.8	4.93	217	1968.4	3.21	**Y	49	1921.4	5.33	206	1970.5	3.24	**Y
Age (year)	50	73.3	4.89	217	22.7	3.24	**A	49	70.7	5.39	206	21.6	3.23	**A
Height (cm)	46	158.9	4.20	217	171.4	6.26	**Y	48	146.8	5.36	205	159.1	5.28	**Y
Weight (kg)	46	56.8	7.68	216	63.3	8.28	**Y	49	50.7	7.90	205	52.6	6.25	ns
BMI	46	22.5	2.72	216	21.5	2.30	*A	48	23.7	3.37	205	20.8	2.05	**A
Foot length (mm)	50	242.2	10.50	216	254.0	10.90	**Y	49	227.7	8.00	206	233.1	9.80	**Y
1 Instep length	50	178.1	9.00	217	185.6	8.40	**Y	49	167.6	5.60	206	172.0	7.60	**Y
2 Fibular instep length	50	152.9	7.60	217	163.1	7.70	**Y	49	142.7	6.40	206	148.9	7.10	**Y
3 Heel to medial malleolus length	50	64.2	6.80	216	66.9	6.30	**Y	49	59.3	5.10	206	55.6	4.70	**A
4 Heel to lateral malleolus length	50	52.6	4.90	216	53.0	5.80	ns	49	50.7	4.80	206	49.3	5.20	ns
7 Length of big toe	50	63.7	5.60	217	67.4	4.80	**Y	49	59.6	3.80	206	60.5	4.00	ns
8 Foot circumference	50	249.6	12.50	217	249.5	12.12	ns	49	237.4	11.45	206	231.9	10.23	**A
9 Instep circumference	50	244.2	11.67	216	247.9	11.74	*Y	49	229.0	10.58	206	227.2	10.28	ns
10 Bimalleolar breadth	49	72.9	3.04	212	73.4	3.52	ns	49	67.9	2.80	205	66.8	3.30	*A
11 Foot breadth, diagonal	50	101.2	5.50	217	100.7	5.40	ns	49	99.2	5.30	206	95.3	4.50	**A
12 Foot breadth, medial half	50	44.8	5.80	217	45.7	4.10	ns	49	45.0	4.20	206	44.4	4.10	ns
13 Foot breadth, lateral half	50	53.1	6.10	217	52.4	4.80	ns	49	51.1	4.70	206	48.0	3.90	**A
14 Ball breadth	50	97.9	5.20	217	98.2	5.20	ns	49	96.0	5.20	206	92.5	4.30	**A
15 Heel breadth	50	63.5	3.30	217	63.8	3.70	ns	49	62.2	3.60	206	60.8	3.20	**A
16 Medial malleolus height	49	79.2	5.50	212	82.6	5.30	**Y	48	73.8	4.40	206	75.5	4.80	*Y
17 Lateral malleolus height	49	68.6	5.50	216	72.0	5.50	**Y	47	63.6	5.00	204	63.4	4.50	ns
18 Sphyrion height	49	63.5	4.90	216	67.5	5.90	**Y	47	63.8	4.20	205	65.9	4.60	**Y
19 Sphyrion fibulare height	50	52.1	4.30	215	54.7	4.50	**Y	49	50.4	3.80	205	51.2	4.00	ns
20 Dorsal arch height at 54% FL	49	61.1	5.00	212	61.9	5.40	ns	49	53.8	3.60	205	53.2	3.20	ns
22 Ball height	48	33.4	2.50	214	34.1	2.20	*Y	48	32.2	2.20	206	31.3	2.10	**A
23 Outside ball height	49	23.7	1.70	214	23.9	1.80	ns	48	22.3	1.80	206	22.2	1.70	ns
24 Great toe tip height	50	19.9	2.00	214	19.9	2.10	ns	49	19.5	2.10	206	19.1	1.90	ns
25 Great toe height	10	22.3	1.70	96	22.9	1.90	ns	49	19.2	1.50	206	19.7	1.70	*Y
26 Ball flex angle (deg.)	50	75.7	3.20	217	77.3	2.60	**Y	49	75.8	2.30	206	76.1	2.50	ns
27 Toe1 angle	50	9.7	7.70	217	8.6	4.60	ns	49	11.3	8.30	206	11.9	4.70	ns
28 Toe 5 angle	50	14.5	5.40	217	12.4	4.30	**A	49	13.7	4.90	206	11.7	4.50	**A

**: significant at the 1% level; *: significant at the 5% level, ns: the difference is not significant. A denotes that the 1930 group is larger, and Y denotes that the 1970 group is larger.

Appendix 2. Statistics for NIBH somatometric data. The item numbers are those used in Figure 3 and Tables 2 and 5.

	Males							Females						
	1930 group			1970 group				1930 group			1970 group			
Item	N	Mean	S.D.	N	Mean	S.D.	*t* -test	N	Mean	S.D.	N	Mean	S.D.	*t* -test
Birth year	50	1929.3	3.72	110	1976.4	1.65	**A	49	1931.1	3.94	107	1976.6	1.26	**A
Age (years)	50	64.4	3.70	110	20.5	1.60	**A	49	66.6	3.9	107	20.4	1.35	**A
Height (cm)	50	161.1	5.70	110	170.6	5.40	**Y	49	149.3	5.4	107	158.7	5.32	**A
Weight (kg)	50	60.6	8.20	110	59.5	6.90	ns	49	55.4	8.0	107	53.4	7.40	ns
BMI	50	23.3	2.59	110	20.4	1.91	**A	49	24.8	3.2	107	21.2	2.56	**A
Foot length (mm)	50	243.6	10.80	110	253.2	10.70	**Y	49	228.3	9.8	107	234.0	10.50	**Y
1 Instep length	50	174.5	8.80	110	182.0	8.00	**Y	49	163.4	7.3	107	168.7	8.30	**Y
2 Fibular instep length	50	150.7	6.90	110	160.8	7.90	**Y	49	140.2	7.0	107	148.6	7.90	**Y
8 Foot circumference	50	254.0	13.30	110	250.7	10.20	ns	49	238.1	11.2	107	231.3	9.54	**A
11 Foot breadth, diagonal	50	104.1	6.10	110	101.6	4.60	**A	49	97.4	5.6	107	93.4	4.30	**A
12 Foot breadth, medial half	50	45.0	5.50	110	45.6	3.70	ns	49	41.6	4.8	107	43.3	3.30	**Y
13 Foot breadth, lateral half	50	56.1	4.50	110	53.6	4.20	**A	49	53.3	4.4	107	48.0	4.20	**A
14 Ball breadth	50	101.2	5.80	110	99.3	4.40	*A	49	94.8	5.2	107	91.3	4.20	**A
15 Heel breadth	50	65.5	3.60	110	64.6	3.10	ns	49	62.4	3.8	107	60.5	3.20	**A
16 Medial malleolus height	50	79.4	4.00	110	82.8	5.10	**Y	49	70.3	3.5	107	75.5	4.60	**Y
17 Lateral malleolus height	50	66.7	4.28	110	69.7	4.99	**Y	49	58.7	4.2	107	62.7	4.20	**Y
26 Ball flex angle (deg.)	50	76.8	2.60	110	78.2	3.10	*Y	49	76.7	2.9	107	77.9	2.60	*Y
27 Toe1 angle	50	10.1	6.20	110	8.7	3.50	ns	49	9.6	6.0	107	10.7	4.60	ns
28 Toe 5 angle	50	14.1	3.50	110	11.4	4.80	**A	49	13.0	4.9	107	8.5	5.30	**A

**: significant at the 1% level; *: significant at the 5% level, ns: the difference is not significant. A denotes that the 1930 group is larger, and Y denotes that the 1970 group is larger.

Appendix 3. Statistics for NIBH data for plaster models. The item numbers are those used in Figure 3 and Tables 2 and 5.

	Males							Females						
	1930 group			1970 group				1930 group			1970 and 1970-2 groups			
Item	N	Mean	S.D.	N	Mean	S.D.	*t* -test	N	Mean	S.D.	N	Mean	S.D.	*t* -test
Birth year	50	1929.3	3.72	110	1976.4	1.65	**A	49	1931.1	3.94	150	1976.5	1.20	**A
Age (years)	50	64.4	3.70	110	20.5	1.60	**A	49	66.6	3.9	150	20.2	1.15	**A
Height (cm)	50	161.1	5.70	110	170.6	5.40	**Y	49	149.3	5.4	149	158.9	4.80	**A
Weight (kg)	50	60.6	8.20	110	59.5	6.90	ns	49	55.4	8.0	149	52.1	6.80	ns
BMI	50	23.3	2.59	110	20.4	1.91	**A	49	24.8	3.2	149	20.6	2.40	**A
Foot length (mm)	50	246.3	11.00	110	256.1	10.70	**Y	49	231.2	9.80	150	236.7	10.10	**Y
1 Instep length	50	182.2	8.50	110	188.6	7.80	**Y	49	170.3	7.50	150	172.9	7.90	*Y
2 Fibular instep length	50	152.0	7.00	110	162.9	7.70	**Y	49	142.6	6.80	150	150.5	7.50	**Y
3 Heel to medial malleolus length	50	62.8	5.10	110	63.9	4.70	ns	49	58.7	5.70	150	56.3	4.20	**A
4 Heel to lateral malleolus length	50	52.3	4.10	110	53.7	5.40	ns	49	49.6	6.10	150	50.6	5.00	ns
5 Heel to 5th metatarsal base length	50	97.6	5.10	110	102.8	5.30	**Y	49	91.3	5.10	150	95.6	5.10	**Y
6 Length of 5th metatarsal length	50	54.9	4.80	110	60.0	4.51	**Y	49	51.3	3.67	150	55.0	4.23	**Y
7 Length of big toe	50	63.8	4.1	110	67.1	4.30	**Y	49	60.7	4.00	150	63.2	4.00	**Y
10 Bimalleolar breadth	50	75.4	3.9	110	75.1	3.79	ns	49	69.9	3.82	150	68.0	3.47	**A
11 Foot breadth, diagonal	50	108.0	5.90	110	106.1	4.50	*A	49	101.3	5.10	149	97.7	4.50	**A
12 Foot breadth, medial half	50	46.4	5.00	110	48.1	3.60	**Y	49	43.3	4.50	150	45.5	3.50	**Y
13 Foot breadth, lateral half	50	57.3	4.80	110	54.8	4.00	**A	49	54.2	3.80	150	49.6	4.00	**A
14 Ball breadth	50	103.8	5.50	110	102.9	4.30	ns	49	97.5	4.90	150	95.1	4.40	**A
15 Heel breadth	50	67.8	3.50	110	67.5	3.20	ns	49	64.3	3.60	150	63.3	3.30	ns
16 Medial malleolus height	50	78.5	4.42	110	81.3	4.97	**Y	49	71.7	3.71	150	74.0	4.52	**Y
17 Lateral malleolus height	50	69.1	4.88	110	70.3	5.42	ns	49	61.6	4.94	150	61.1	4.20	ns
18 Sphyrion height	50	68.2	4.41	110	71.0	4.97	**Y	49	61.8	3.60	150	64.8	4.90	**Y
19 Sphyrion fibulare height	50	54.4	4.43	110	56.3	4.70	ns	49	50.4	4.10	150	50.7	4.40	ns
20 Dorsal arch height at 54% FL	50	62.2	3.60	110	61.0	3.81	ns	49	57.4	3.80	150	54.8	3.25	**A
21 Dorsal arch height at 50% FL	50	66.1	3.50	110	65.8	4.00	ns	49	60.7	3.70	150	58.6	3.80	**A
22 Ball height	50	38.5	2.46	110	36.2	2.07	**A	49	36.2	1.99	150	33.4	2.05	**A
23 Outside ball height	50	27.0	2.29	110	25.7	1.78	**A	49	25.6	2.14	150	24.7	1.85	**A
25 Great toe height	50	22.7	1.90	110	23.0	1.90	ns	49	21.4	1.70	150	20.9	1.60	ns

**: significant at the 1% level; *: significant at the 5% level, ns: the difference is not significant. A denotes that the 1930 group is larger, and Y denotes that the 1970 group is larger.

Appendix 4. Statistics for JLIA data. The item numbers are those used in Figure 3 and Tables 2 and 5.

		Males							Females						
		1930 group			1970 group				1930 group			1970 group			
	Item	N	Mean	S.D.	N	Mean	S.D.	*t* -test	N	Mean	S.D.	N	Mean	S.D.	*t* -test
	Birth year	35	1934.4	3.05	56	1964.9	2.88	**Y	35	1934.0	2.61	58	1965.0	2.57	**Y
	Age (years)	35	53.1	3.00	56	22.4	2.90	**A	35	53.5	2.64	58	22.4	2.57	**A
	Height (cm)	35	165.1	5.01	56	170.4	5.31	**Y	35	153.0	4.41	58	156.8	4.49	**Y
	Weight (kg)	35	61.9	5.77	56	62.0	9.04	ns	35	50.7	6.20	58	49.1	5.60	ns
	BMI	35	22.7	1.82	56	21.3	2.64	**A	35	21.6	2.49	58	20.0	1.98	**A
	Foot length (mm)	35	243.5	10.00	56	250.9	10.30	**Y	35	227.2	7.90	58	229.0	8.90	ns
1	Instep length	34	176.4	7.80	56	183.2	8.30	**Y	35	166.4	6.50	57	167.3	7.10	ns
2	Fibular instep length	35	153.6	7.40	56	160.5	6.90	**Y	35	143.5	6.80	57	145.2	7.50	ns
3	Heel to medial malleolus length	34	58.2	3.50	55	61.2	6.00	**Y	35	54.8	5.90	58	53.1	4.50	ns
4	Heel to lateral malleolus length	35	50.2	4.70	56	51.8	5.80	ns	35	47.3	5.80	58	46.8	4.80	ns
7	Length of big toe	34	66.7	3.70	56	66.9	4.90	ns	35	60.7	4.60	58	61.6	3.60	ns
8	Foot circumference	35	248.2	8.90	56	246.8	9.40	ns	35	227.2	8.40	58	223.1	9.30	*A
9	Instep circumference	35	251.3	8.05	56	249.8	10.79	ns	35	227.6	9.24	58	224.7	9.62	ns
11	Foot breadth, diagonal	35	102.2	3.90	56	102.5	4.10	ns	35	95.1	3.80	58	92.7	4.00	**A
15	Heel breadth	35	65.1	3.40	56	65.6	3.40	ns	35	61.4	3.00	58	59.4	2.90	**A
19	Sphyrion fibulare height	35	51.4	4.80	56	52.0	4.40	ns	35	45.7	3.30	58	46.7	3.50	ns
20	Dorsal arch height at 54% FL	35	58.9	4.70	56	58.6	3.90	ns	35	52.1	3.90	58	51.2	3.60	ns
26	Ball flex angle (deg.)	35	77.0	1.90	56	77.2	2.40	ns	35	75.9	2.50	58	76.2	2.20	ns
27	Toe 1 angle	35	8.7	4.10	56	8.9	4.00	ns	35	10.3	5.90	58	11.0	4.70	ns
28	Toe 5 angle	35	13.0	4.00	56	12.2	4.20	ns	35	12.9	4.70	58	11.2	4.20	ns

**: significant at the 1% level; *: significant at the 5% level, ns: the difference is not significant. A denotes that the 1930 group is larger, and Y denotes that the 1970 group is larger.

Appendix 5. Statistics for IPRI data by group based on BMI. The item numbers are those used in Figure 3 and Tables 2 and 5.

	Male							Female						
	1970-S (BM≤21)			1970-H (BM>21)				1970-S (BMI≤21)			1970-H (BM>21)			
Item	N	Mean	S.D.	N	Mean	S.D.	*t* -test	N	Mean	S.D.	N	Mean	S.D.	*t* -test
Birth year	93	1968.495	3.12	123	1968.317	3.29	ns	116	1970.4	3.22	89	1970.6	3.29	ns
Age (years)	93	22.6	3.14	123	22.8	3.34	ns	116	21.7	3.19	89	21.5	3.30	ns
Height (cm)	93	171.0	6.27	123	171.7	6.28	ns	116	159.2	4.72	89	159.0	5.96	ns
Weight (kg)	93	57.1	5.39	123	68.0	6.88	**H	116	49.1	3.55	89	57.3	5.98	**H
BMI	93	19.5	1.15	123	23.0	1.70	**H	116	19.4	1.01	89	22.6	1.53	**H
Foot length (mm)	92	251.2	10.10	123	256.0	11.10	**H	116	232.5	9.00	89	233.9	10.80	ns
1 Instep length	93	183.5	7.50	123	187.2	8.70	**H	116	171.2	7.00	89	172.9	8.20	ns
2 Fibular instep length	93	161.8	7.20	123	164.2	7.90	*H	116	148.4	6.50	89	149.5	7.90	ns
3 Heel to medial malleolus length	93	64.9	6.10	122	68.4	6.00	**H	116	54.6	4.50	89	56.9	4.60	**H
4 Heel to lateral malleolus length	93	52.0	5.50	122	53.8	5.90	*H	116	48.2	5.40	89	50.7	4.50	**H
7 Length of big toe	93	67.2	4.60	123	67.5	4.90	ns	116	60.4	4.00	89	60.6	4.10	ns
8 Foot circumference	93	244.2	9.60	123	253.6	12.31	**H	116	228.3	9.41	89	236.4	9.18	**H
9 Instep circumference	93	241.5	9.13	122	252.8	11.16	**H	116	223.2	8.94	89	232.2	9.52	**H
10 Bimalleolar breadth	92	72.0	3.02	120	74.4	3.55	**H	116	66.1	3.20	89	67.7	3.30	**H
11 Foot breadth, diagonal	93	98.7	4.40	123	102.3	5.50	**H	116	94.0	4.10	89	97.0	4.20	**H
12 Foot breadth, medial half	93	45.4	4.00	123	45.9	4.10	ns	116	43.6	4.00	89	45.4	3.90	**H
13 Foot breadth, lateral half	93	50.8	4.30	123	53.7	4.70	**H	116	47.5	3.80	89	48.6	3.90	*H
14 Ball breadth	93	96.3	4.30	123	99.6	5.30	**H	116	91.1	4.00	89	94.2	4.10	**H
15 Heel breadth	93	62.3	3.10	123	65.0	3.80	**H	116	59.9	3.00	89	61.9	3.00	**H
16 Medial malleolus height	92	81.8	4.90	119	83.3	5.50	*H	116	75.0	4.80	89	76.2	4.70	ns
17 Lateral malleolus height	93	71.3	5.70	122	72.6	5.30	ns	115	63.1	4.40	88	63.7	4.60	ns
18 Sphyrion height	93	66.5	5.90	122	68.3	5.80	*H	115	65.4	4.50	89	66.6	4.70	ns
19 Sphyrion fibulare height	93	54.1	4.50	121	55.2	4.50	ns	116	50.9	3.90	88	51.4	4.00	ns
20 Dorsal arch height at 54% FL	91	60.6	5.30	120	62.9	5.20	*H	116	52.5	3.20	88	54.2	2.80	**H
22 Ball height	91	33.3	1.80	122	34.7	2.30	**H	116	30.8	1.80	89	31.8	2.30	**H
23 Outside ball height	91	23.2	1.80	122	24.4	1.60	**H	116	21.8	1.50	89	22.7	1.80	**H
24 Great toe tip height	91	19.4	2.10	122	20.2	2.00	**H	116	18.7	1.80	89	19.5	2.00	**H
25 Great toe height	45	22.3	1.50	50	23.4	2.00	**H	116	19.3	1.70	89	20.2	1.60	**H
26 Ball flex angle (deg.)	93	77.5	2.80	123	77.1	2.50	ns	116	76.1	2.70	89	76.1	2.40	ns
27 Toe1 angle	93	8.8	4.50	123	8.5	4.70	ns	116	11.3	4.50	89	12.6	4.80	ns
28 Toe 5 angle	93	11.9	4.50	123	12.9	4.10	ns	116	11.6	4.60	89	11.8	4.30	ns

**: significant at the 1% level; *: significant at the 5% level, ns: the difference is not significant. S denotes that the 1970-S group is larger, and H denotes that the 1970-H group is larger.

Appendix 6. Statistics for NIBH data by group based on BMI. The item numbers are those used in Figure 3 and Tables 2 and 5.

	Male							Female						
	1970-S (BMI≤21)			1970-H (BM>21)				1970-S (BMI≤21)			1970-H (BM>21)			
Item	N	Mean	S.D.	N	Mean	S.D.	*t* -test	N	Mean	S.D.	N	Mean	S.D.	*t* -test
Birth year	68	1976.5	1.56	42	1976.2	1.79	ns	54	1976.6	1.13	53	1976.7	1.38	ns
Age (years)	68	20.4	1.50	42	20.7	1.80	ns	54	20.5	1.21	53	20.3	1.47	ns
Height (cm)	68	170.7	5.60	42	170.4	5.00	ns	54	158.7	5.48	53	158.7	5.21	ns
Weight (kg)	68	56.2	5.60	42	64.9	5.20	**H	54	48.3	4.70	53	58.6	6.00	**H
BMI	68	19.3	1.22	42	22.3	1.17	**H	54	19.2	1.20	53	23.2	1.81	**H
Foot length (mm)	68	252.3	10.70	42	254.5	10.70	ns	54	231.7	10.50	53	236.3	10.10	*H
1 Instep length	68	181.1	7.90	42	183.5	8.10	ns	54	167.0	7.90	53	170.5	8.40	*H
2 Fibular instep length	68	160.2	7.90	42	161.7	8.00	ns	54	147.3	7.10	53	149.9	8.50	ns
8 Foot circumference	68	248.6	10.30	42	254.0	9.20	**H	54	227.1	8.16	53	235.6	9.00	**H
11 Foot breadth, diagonal	68	100.7	4.70	42	103.0	4.10	**H	54	91.7	3.70	53	95.2	4.20	**H
12 Foot breadth, medial half	68	45.5	3.90	42	45.8	3.50	ns	54	43.1	3.40	53	43.6	3.30	ns
13 Foot breadth, lateral half	68	52.9	4.30	42	54.8	3.80	*H	54	46.5	3.70	53	49.5	4.20	**H
14 Ball breadth	68	98.4	4.60	42	100.6	3.70	*H	54	89.6	3.50	53	93.0	4.20	**H
15 Heel breadth	68	64.2	3.30	42	65.3	2.80	ns	54	59.0	2.40	53	61.9	3.20	**H
16 Medial malleolus height	68	82.5	5.50	42	83.2	4.30	ns	54	75.4	4.80	53	75.6	4.60	ns
17 Lateral malleolus height	68	69.5	5.23	42	69.9	4.63	ns	54	62.8	4.50	53	62.6	4.00	ns
26 Ball flex angle (deg.)	68	78.2	2.80	42	78.1	3.50	ns	54	77.8	2.60	53	77.9	2.60	ns
27 Toe1 angle	68	8.9	3.70	42	8.3	3.20	ns	54	11.1	4.80	53	10.4	4.30	ns
28 Toe 5 angle	68	10.8	5.40	42	12.4	3.60	ns	54	8.3	5.10	53	8.7	5.50	ns

**: significant at the 1% level; *: significant at the 5% level, ns: the difference is not significant. S denotes that the 1970-S group is larger, and H denotes that the 1970-H group is larger.

Appendix 7. Statistics for NIBH data for plaster models by group based on BMI. The item numbers are those used in Figure 3 and Tables 2 and 5.

	Male							Female 1)						
	1970-S (BMI≤21)			1970-H (BM>21)				1970-S (BMI≤21)			1970-H (BM>21)			
Item	N	Mean	S.D.	N	Mean	S.D.	*t* -test	N	Mean	S.D.	N	Mean	S.D.	*t* -test
Birth year	68	1976.456	1.56	42	1976.214	1.79	ns	93	1976.409	1.18	55	1976.745	1.22	ns
Age (years)	68	20.4	1.48	42	20.7	1.82	ns	93	20.2	1.12	55	20.1	1.19	ns
Height (cm)	68	170.7	5.60	42	170.4	5.00	ns	94	159.0	4.70	55	158.8	5.10	ns
Weight (kg)	68	56.2	5.60	42	64.9	5.20	**H	94	48.5	4.10	55	58.4	5.90	**H
BMI	68	19.3	1.22	42	22.3	1.17	**H	94	19.1	1.12	55	23.2	1.82	**H
Foot length (mm)	68	255.1	10.70	42	257.6	10.60	ns	94	234.9	9.80	55	239.8	10.10	**H
1 Instep length	68	187.8	7.80	42	189.8	7.70	ns	94	171.8	7.60	55	175.1	8.00	*H
2 Fibular instep length	68	162.2	7.30	42	164.0	8.20	ns	94	149.4	7.20	55	152.5	7.70	*H
3 Heel to medial malleolus length	68	102.3	5.30	42	103.7	5.30	ns	94	94.7	4.60	55	97.1	5.60	**H
4 Heel to lateral malleolus length	68	63.3	4.70	42	64.9	4.60	ns	94	55.2	3.80	55	58.0	4.30	**H
5 Heel to 5th metatarsal base length	68	53.0	5.70	42	54.9	4.80	ns	94	49.1	4.50	55	53.0	4.80	**H
6 Length of 5th metatarsal	68	59.8	4.09	42	60.3	5.15	ns	94	54.7	4.30	55	55.3	4.12	ns
7 Length of big toe	68	66.9	4.30	42	67.4	4.40	ns	94	62.6	4.00	55	64.2	3.80	*H
10 Bimalleolar breadth	68	74.4	3.90	42	76.3	3.20	**H	94	66.9	2.9	55	69.9	3.50	**H
11 Foot breadth, diagonal	68	105.3	4.50	42	107.4	4.10	*H	93	96.4	4.00	55	99.9	4.40	**H
12 Foot breadth, medial half	68	48.0	3.80	42	48.3	3.40	ns	94	45.3	3.50	55	45.9	3.60	ns
13 Foot breadth, lateral half	68	54.2	4.00	42	55.8	3.80	ns	94	48.5	3.40	55	51.4	4.30	**H
14 Ball breadth	68	102.2	4.40	42	104.1	3.90	*H	94	93.8	4.00	55	97.3	4.30	**H
15 Heel breadth	68	67.2	3.30	42	68.0	2.90	ns	94	62.2	2.80	55	65.3	3.20	**H
16 Medial malleolus ht	68	81.1	5.30	42	81.6	4.30	ns	94	73.9	4.7	55	74.2	4.20	ns
17 Lateral malleolus ht	68	69.9	5.90	42	71.0	4.50	ns	94	61.2	4.3	55	60.9	4.10	ns
18 Sphyrion height	68	70.5	4.83	42	71.8	5.14	ns	94	64.1	5.00	55	66.0	4.50	*H
19 Sphyrion fibulare height	68	55.7	4.90	42	57.2	4.30	ns	94	49.9	4.60	55	52.0	3.80	**H
20 Dorsal arch height at 54% FL	68	60.6	4.00	42	61.6	3.4	ns	94	54.4	3.1	55	55.6	3.30	*H
21 Dorsal arch height at 50% FL	68	65.4	4.30	42	66.5	3.40	ns	94	58.3	3.80	55	59.1	3.70	ns
22 Ball height	68	36.1	2.30	42	36.4	1.70	ns	94	33.0	2.1	55	33.9	1.90	*H
23 Outside ball height	68	25.4	1.80	42	26.2	1.70	*H	94	24.1	1.7	55	25.6	1.80	**H
25 Great toe height	68	22.6	1.60	42	23.8	2.00	**H	94	20.6	1.60	55	21.5	1.60	**H

1): 1970 group and 1970-2 group in Table 1 were pooled.

**: significant at the 1% level; *: significant at the 5% level, ns: the difference is not significant. S denotes that the 1970-S group is larger, and H denotes that the 1970-H group is larger.