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Limb Bone Characteristics in the Hawaiian and Chamorro Peoples

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The metric characteristics of the limb bones of the Hawaiian and Chamorro were investigated. Although there is no difference between the Hawaiian and Chamorro in bone length, the diameters and circumferences of the shafts show a considerable difference. Compared with the skeletal samples from Japan, the Hawaiian are similar to the Jomon and Ainu while the Chamorro are at a good distance from the Japanese series. However, the Jomon and Ainu form a contrast to the Hawaiian in relative length of radius and ulna. Because both the functional adaptations and some genetic factors may contribute to the formation of limb bone morphology, it is necessary to select useful items for understanding human variation.

Keywords: Limb bones, Hawaiian, Chamorro, Measurements

INTRODUCTION

It is said that the morphology of limb bones reflects biological adaptation to environment and function. However, some limb bone characteristics are useful for understanding human variation. As for the Jomon people, their relative longness of distal limb segments has been noticed (Yamaguchi, 1989; Kato and Ogata, 1989), in comparisons with historic Japanese and Asian populations. Tagaya (1987) also analyzed limb bone measurements of the Japanese series to evaluate the interpopulation variation of sex differences.

Cranial and dental morphologies of the Pacific peoples have been investigated by many biological anthropologists (Pietrusewsky, 1984, 1990a, 1990b; Howells, 1989, 1990; Turner, 1989, 1990). However, there are a few papers on the morphology of their limb bones. Pietrusewsky (1971) and Snow (1974) reported that the Hawaiian have long tibiae and short forearm bones.

In 1989, I had the opportunity to investigate postcranial skeletons of the Hawaiian and Chamorro peoples at the B.P. Bishop Museum, Honolulu. The purposes of this article are to present the metric characteristics of those limb bones and to preliminarily compare that data with the skeletal series from Japan.

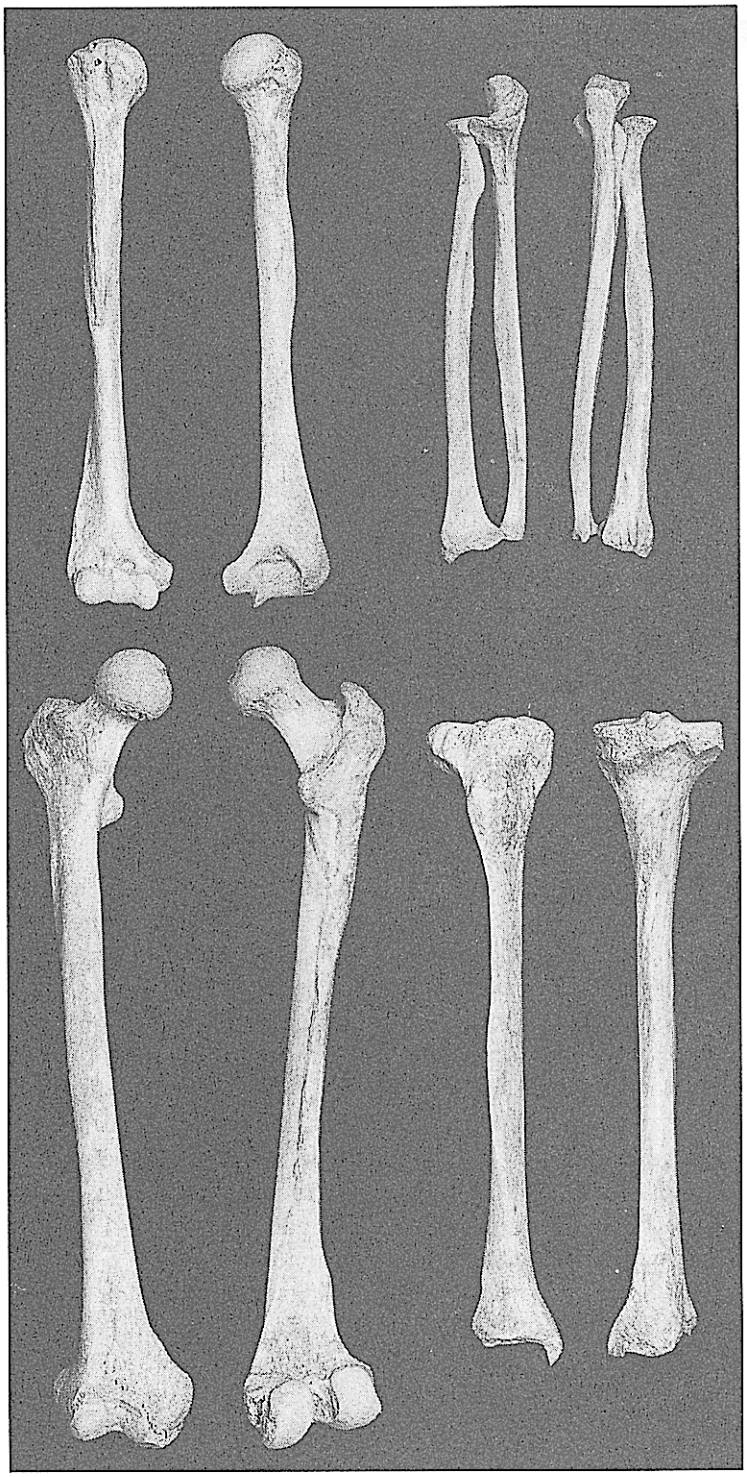

Fig. 1. Limb bones of the Hawaiian from the Mokapu site, Oahu Island.

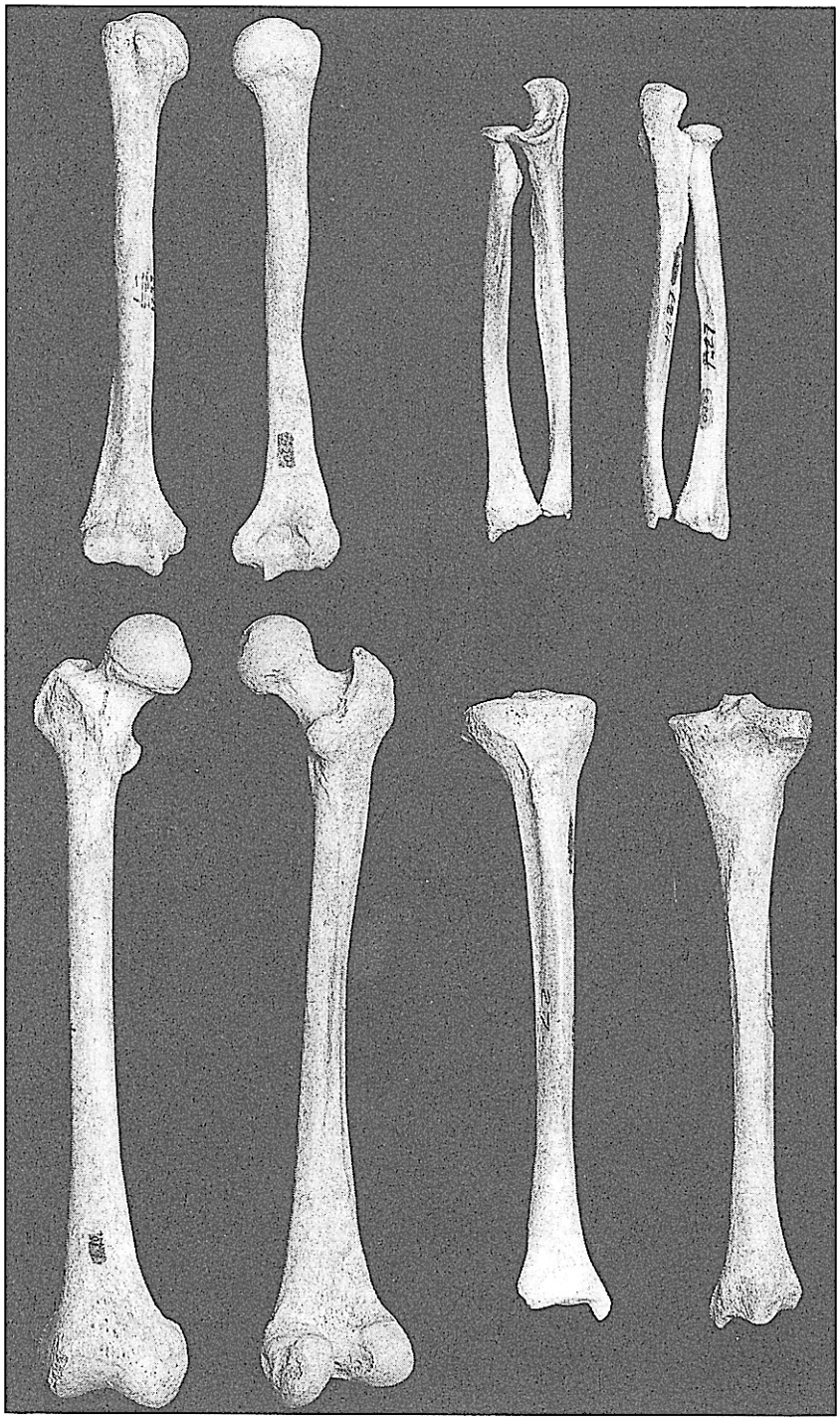

Fig. 2. Limb bones of the Chamorro from the Guam Island.

MATERIALS AND METHODS

The materials examined in Honolulu consisted of two skeletal series; one was a sample of 85 male and 98 female Hawaiian skeletons from the Mokapu site, Oahu island, and the other was a sample of 49 male and 26 female Chamorro skeletons from the Mariana islands (Figures 1 and 2). In principle, I measured the bones of the right side, but when the maximum length of a right limb bone was not able to be measured, the left side was used in order to calculate mean value and its proportion. Sexes were estimated by morphological examinations referring to the whole skeletons.

Limb bones were measured following Martin's methods (Knussmann, 1988). However, when subtrochanteric diameters of femur were measured, the sagittal and transverse ones were not used, but instead the maximum and minimum ones were applied. Transverse diameters of tibial shaft were measured with the definition given by Vallois (Olivier, 1960).

The averages of the measurements and indices were calculated for the male and female series. Using the pooled covariance matrix obtained from 39 male sets of 12 measurements of the Mokapu series, the Mahalanobis' distances (D^2) between them and the Japanese groups were computed. In order to graphically represent mutual relationships of samples, clustering and principal coordinate analyses were applied to the distance matrix of D^2.

RESULTS

Numbers, means and standard deviations of the measurements and indices of limb bones are listed in Tables 1-6. Proportions between proximal and distal segments are also given in Table 7.

Humerus

Humeral lengths of the Hawaiian are almost equal to those of the Chamorro, whereas diameters of the epiphysis and shaft are significantly larger in the Chamorro than in the Hawaiian.

Radius and Ulna

Radial and ulnar lengths of the Chamorro are a little longer than those of the Hawaiian, but those differences are not statistically significant. Circumferences and diameters of the shaft, as well as the humerus, are also larger in the Chamorro than in the Hawaiian.

Femur

Length differences between the Hawaiian and Chamorro are not statistically significant, whereas differences of shaft diameters are significant. The sagittal and transverse diameters of the mid-shaft are larger in the Chamorro than in the

Table 1. Measurements and indices of humerus in the Hawaii and Chamorro series.

Measurements		Hawaii				Chamorro		
		n	Mean	SD	Dif.	n	Mean	SD
1. Maximum length	(M)	72	319.2	13.04	–	33	320.9	9.41
	(F)	92	291.6	11.23	–	21	291.6	10.70
2. Total length	(M)	70	314.7	12.84	–	33	314.6	9.97
	(F)	91	287.8	11.17	–	21	286.3	10.93
3. Breadth of the proximal epiphysis	(M)	63	48.4	2.43	<<	29	51.0	3.09
	(F)	86	42.5	1.76	<<	16	44.3	1.71
5. Maximum diameter of mid-shaft	(M)	80	23.2	1.46	<<	38	26.3	2.11
	(F)	95	19.0	1.41	<<	24	21.1	1.58
6. Minimum diameter of mid-shaft	(M)	80	17.4	1.11	<<	38	20.7	1.57
	(F)	95	13.9	1.17	<<	24	16.6	1.22
6:5	(M)	80	74.9	4.17	<<	38	79.0	4.99
	(F)	95	73.5	5.56	<<	24	79.0	5.24
7. Least circumference of the shaft	(M)	79	64.8	3.55	<<	39	74.7	4.59
	(F)	94	53.3	3.36	<<	24	60.4	3.95
7:1	(M)	71	20.2	1.30	<<	33	23.3	1.65
	(F)	91	18.3	1.13	<<	21	20.8	1.15
9. Transverse head diameter	(M)	68	41.6	1.88	<<	26	43.2	2.33
	(F)	84	36.2	2.09	–	11	36.6	1.15
10. Longitudinal diameter of the head	(M)	73	45.5	2.05	<<	34	47.6	3.07
	(F)	89	39.3	1.80	<	20	40.3	1.76
9:10	(M)	68	91.5	2.98	–	26	91.2	4.25
	(F)	83	91.7	5.14	–	11	90.9	3.59

<< (<): Significantly different between the Hawaiian and the Chamorro at the level of 0.01 (0.05).

Hawaiian, while both have the pilaster formations in the mid-shaft. Because the maximum subtrochanteric diameter is significantly larger in the Hawaiian than in the Chamorro, while the minimum diameter is conversely larger in the Chamorro, the platymeric index shows a considerable difference between them.

Tibia and Fibula

The lengths of the tibia and fibula of the Hawaiian tend to be longer than those of the Chamorro, but the differences are not significant. Most of the diameters and circumferences of both sexes are larger in the Chamorro than in the Hawaiian. The degree of medio-lateral shaft flatness of the Hawaiian are in the mesocnemic range, while those of the Chamorro belong to the eurycnemic range. This platycnemic index shows a significant difference in the male series, but not in the female series.

Proportions between proximal and distal limb bones

In the male series, the Hawaiian and Chamorro have almost equivalent values of

Table 2. Measurements and indices of radius in the Hawaii and Chamorro series.

Measurements		Hawaii				Chamorro		
		n	Mean	SD	Dif.	n	Mean	SD
1. Maximum length	(M)	69	246.9	10.45	−	29	249.0	10.64
	(F)	88	222.0	9.98	−	19	219.4	9.04
2. Physiological length	(M)	69	232.2	10.15	−	31	233.9	11.11
	(F)	90	208.8	9.31	−	19	206.6	9.06
3. Minimum circumference	(M)	77	41.9	2.82	<<	35	49.0	3.30
	(F)	93	34.8	2.25	<<	21	40.8	2.97
3:2	(M)	69	18.1	1.36	<<	31	20.9	1.60
	(F)	90	16.7	1.15	<<	19	19.8	1.62
4. Maximum transverse shaft diameter	(M)	77	16.8	1.43	<<	35	18.8	1.59
	(F)	93	13.9	1.39	<<	21	15.8	1.19
5. Sagittal shaft diameter	(M)	77	11.9	0.82	<<	35	14.7	1.21
	(F)	93	9.9	0.72	<<	21	11.7	0.78
5:4	(M)	77	70.9	5.99	<<	35	78.4	4.74
	(F)	93	72.0	6.64	−	21	74.4	7.41

<< : Significantly different between the Hawaiian and the Chamorro at the level of 0.01.

Table 3. Measurements and indices of ulna in the Hawaii and Chamorro series.

Measurements		Hawaii				Chamorro		
		n	Mean	SD	Dif.	n	Mean	SD
1. Maximum length	(M)	56	265.8	10.12	−	20	266.6	10.79
	(F)	76	240.6	9.21	−	14	236.1	9.98
2. Physiological length	(M)	67	233.0	9.73	−	26	233.7	12.11
	(F)	82	212.2	8.73	−	19	207.4	10.03
3. Minimum circumference	(M)	70	36.0	3.34	<<	30	40.4	3.17
	(F)	88	31.3	2.46	<<	21	35.2	2.11
3:2	(M)	66	15.4	1.41	<<	26	17.4	1.37
	(F)	82	14.7	1.11	<<	19	17.0	0.93
11. Dorso-ventral shaft diameter	(M)	74	13.3	1.54	<<	33	15.1	1.36
	(F)	89	10.6	0.99	<<	23	12.7	1.63
12. Transverse shaft diameter	(M)	74	16.1	1.60	<<	33	18.7	1.56
	(F)	89	14.0	1.29	<<	23	15.2	1.24
11:12	(M)	74	83.3	15.47	−	33	81.1	10.43
	(F)	89	76.6	11.08	−	23	84.1	14.67

<< : Significantly different between the Hawaiian and the Chamorro at the level of 0.01.

Table 4. Measurements and indices of femur in the Hawaii and Chamorro series.

Measurements		Hawaii			Dif.	Chamorro		
		n	Mean	SD		n	Mean	SD
1. Maximum length	(M)	68	444.2	19.13	–	33	451.5	14.32
	(F)	91	409.3	16.27	–	21	409.5	11.99
2. Physiological length	(M)	68	440.6	19.21	–	33	447.2	14.07
	(F)	91	404.7	16.36	–	21	405.1	11.86
6. Sagittal diameter of the mid-shaft	(M)	73	29.6	2.01	<<	40	31.1	1.65
	(F)	92	25.7	1.93	–	22	26.5	1.92
7. Transverse diameter of the mid-shaft	(M)	73	25.6	1.79	<<	40	27.1	1.62
	(F)	91	22.2	1.35	<<	22	23.6	1.30
6:7	(M)	73	116.2	9.72	–	40	114.8	6.42
	(F)	91	115.8	9.75	–	22	112.4	7.10
8. Circumference of the mid-shaft	(M)	73	88.5	5.07	<<	40	93.2	4.27
	(F)	91	76.5	4.17	<<	22	79.9	4.66
8:2	(M)	68	20.0	0.94	<<	33	20.7	0.81
	(F)	90	18.9	0.85	<<	21	19.6	0.97
9'. Maximum subtrochanteric diameter	(M)	73	32.1	1.98	>>	40	31.0	1.67
	(F)	92	28.4	1.69	>>	22	27.0	1.28
10'. Minimum subtrochanteric diameter	(M)	73	22.7	1.69	<<	40	25.6	1.56
	(F)	92	19.7	1.57	<<	22	22.5	1.59
10':9'	(M)	73	71.0	4.96	<<	40	82.8	5.68
	(F)	92	69.6	5.85	<<	22	83.2	5.12
18. Medio-lateral head diameter	(M)	63	45.6	1.88	<<	26	47.9	2.15
	(F)	82	40.4	1.87	–	17	41.1	1.78
19. Transverse diameter of the head	(M)	65	45.4	1.88	<<	27	47.7	2.07
	(F)	86	40.3	1.85	–	12	41.0	1.08
19:18	(M)	63	99.6	1.24	–	23	99.8	1.33
	(F)	81	99.7	1.28	>	12	98.8	1.55

<< (>): Significantly different between the Hawaiian and the Chamorro at the level of 0.01 (0.05).

the radio-humeral index, whereas the tibio-femoral index shows a considerable difference.

Yamaguchi (1983), based on 13 main postcranial measurements, calculated the Penrose's shape distances between the two Jomon, Hokkaido Ainu and modern Japanese series. After his method, I computed the Mahalanobis' distances (D^2) between the skeletal series from the Pacific and Japan islands, based on the following 12 postcranial measurements; the maximum length, maximum and minimum diameters of mid-shaft (humerus), the maximum length (radius), the maximum length, sagittal and transverse diameters of mid-shaft, and maximum and minimum subtrochanteric diameters (femur), the maximum length, sagittal and transverse diameters of mid-shaft (tibia). The skeletal series compared consist of the Tsukumo

Table 5. Measurements and indices of tibia in the Hawaii and Chamorro series.

Measurements		Hawaii			Dif.	Chamorro		
		n	Mean	SD		n	Mean	SD
1. Total length	(M)	59	365.5	15.30	–	27	362.6	13.03
	(F)	86	335.4	14.75	–	15	330.3	10.94
1a. Maximum length	(M)	59	370.2	15.14	–	27	367.1	12.55
	(F)	86	340.3	14.71	–	15	334.1	10.75
8. Sagittal diameter at the mid-shaft	(M)	69	32.7	2.23	–	30	32.6	2.26
	(F)	92	26.8	1.59	<<	19	28.6	1.60
8a. Sagittal diameter at nutrient foramen	(M)	68	36.4	2.31	–	30	37.1	2.38
	(F)	93	30.8	1.78	<<	19	32.8	1.72
9'. Transverse diameter at the mid-shaft	(M)	69	21.5	1.70	<<	30	24.3	1.64
	(F)	92	18.9	1.55	<<	19	20.6	1.49
9':8	(M)	69	65.9	4.79	<<	30	74.7	5.55
	(F)	92	70.4	5.62	–	19	72.1	4.10
9a'. Transverse diameter at nutrient foramen	(M)	68	24.0	1.99	<<	30	27.6	1.94
	(F)	93	21.5	1.96	<<	19	23.2	1.73
9a':8a	(M)	68	66.2	5.74	<<	30	74.5	4.42
	(F)	93	69.7	5.46	–	19	70.7	4.50
10. Circumference of the mid-shaft	(M)	69	87.2	5.27	<<	30	91.5	5.54
	(F)	92	73.2	4.07	<<	19	79.2	4.37
10a. Circumference at nutrient foramen	(M)	68	96.3	5.63	<<	30	101.6	5.86
	(F)	92	82.7	4.75	<<	19	88.7	4.86
10b. Minimum circumference of the shaft	(M)	67	78.9	4.53	<<	30	81.6	4.00
	(F)	92	67.6	3.76	<<	18	72.7	3.54
10b:1	(M)	57	21.4	1.17	<<	27	22.5	1.20
	(F)	86	20.1	0.99	<<	14	22.0	1.05

<< : Significantly different between the Hawaiian and the Chamorro at the level of 0.01.

Table 6. Measurements and indices of fibula in the Hawaii and Chamorro series.

Measurements		Hawaii			Dif.	Chamorro		
		n	Mean	SD		n	Mean	SD
1. Maximum length	(M)	36	357.3	13.48	–	13	356.4	9.24
	(F)	57	330.1	15.02	–	5	324.0	10.66
2. Maximum diameter of mid-shaft	(M)	54	17.2	1.94	<<	19	18.5	1.31
	(F)	78	15.3	1.47	<<	8	17.0	1.41
3. Minimum diameter of mid-shaft	(M)	54	11.7	1.26	<<	19	12.8	1.18
	(F)	78	10.3	1.10	–	8	10.3	1.09
3:2	(M)	54	68.3	7.59	–	19	69.5	6.30
	(F)	78	67.6	8.50	>	8	60.6	6.98

<< (>): Significantly different between the Hawaiian and the Chamorro at the level of 0.01 (0.05).

Table 7. Proportions between proximal and distal limb bones in the Hawaiian and Chamorro series.

Measurements		Hawaii				Chamorro		
		n	Mean	SD	Dif.	n	Mean	SD
Radio-humeral index (R1:H1)	(M)	61	77.2	2.40	—	23	77.9	2.61
	(F)	84	76.2	2.12	>>	16	74.6	2.41
Tibio-femoral index (T1a:F1)	(M)	56	83.4	2.16	>>	22	81.6	1.27
	(F)	83	83.3	1.89	>>	14	80.9	1.87
Tibio-femoral index (T1a:F2)	(M)	56	84.1	2.18	>>	22	82.4	1.27
	(F)	83	84.3	2.00	>>	14	81.8	1.84

>>: Significantly different between the Hawaiian and the Chamorro at the level of 0.01.

Table 8. Mahalanobis' D^2 matrix computed from 12 postcranial bone measurements.

	1	2	3	4	5	6
1. Hawaii	—					
2. Chamorro	34.4	—				
3. Tsukumo Jomon	13.1	38.7	—			
4. Modern Japanese	44.4	40.1	57.0	—		
5. Hokkaido Ainu	14.7	48.1	10.0	33.3	—	
6. Ebishima Jomon	11.0	27.9	8.5	28.9	10.2	—

Jomon (Kiyono and Hirai, 1928), Ebishima Jomon (Yamaguchi, 1983), Hokkaido Ainu (Koganei, 1893), and modern Japanese from the Kanto area (Oba, 1950; Ebina, 1951; Nishihara, 1953; Suzuki, 1961).

The Mahalanobis' distances (D^2) obtained are given in Table 8. The closest to the Hawaiian are the Ebishima Jomon, with the next closest being the Tsukumo Jomon. However, the Chamorro exhibited somewhat far distances from the other peoples. Distances between the two Jomon series and the Hokkaido Ainu show that their closest relationships are with one another. The modern Japanese are not close to any of the other populations used.

Clustering analysis (group average method) and principal coordinate analysis were applied to the Mahalanobis' distances (D^2) matrix. The results are shown in Figures 3 and 4. The results from the two analyses are almost the same. The two

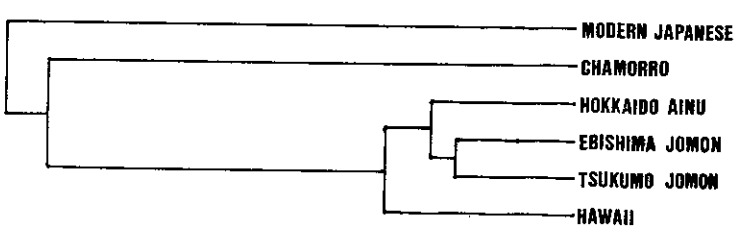

Fig. 3. Cluster analysis (group average method) based on the Mahalanobis' distance matrix of Table 8.

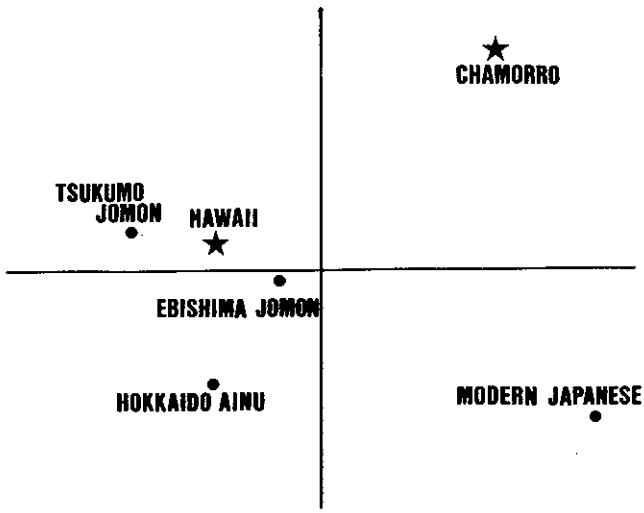

Fig. 4. Two-dimensional representation of 6 population samples by principal coordinate analysis computed from the Mahalanobis' distance matrix of Table 8.

Jomon series and Hokkaido Ainu are joined to make a cluster, in which the Hawaiian are found. However, the Chamorro and the modern Japanese are each situated in an isolated position.

DISCUSSION

Snow (1974) summarized the following characteristics of postcranial skeletons from the Mokapu site; flat of humeral shaft, thin shaft of tibia, and platymeric subtrochanteric region and pilaster form of mid-shaft of femur. He considered those characteristics to be the results of functional adaptations. Both Pietrusewsky (1971) and Snow (1974) compared the Hawaiian postcranial skeletons with those of the American Black and White as well as those of the Asian peoples, and they pointed out the peculiar characteristics of the Hawaiians. Katayama (1986), examining the skeletal series from the Cook Islands, found the morphological variation of the postcranial skeleton within the Polynesians. In my study on the postcranial skeleton, it is indicated that there is a considerable difference between the Hawaiian and the Chamorro peoples. These results together proved the great variation of limb bones within the Pacific region.

The preliminary distance analysis found that the Hawaiian are not close to the Chamorro, but are joined to make a cluster with the Jomon and Ainu. It is possible that functional adaptations to the hunter-gathering life style brought on the similarity between them. On the other hand, the similarity between the Hawaiian and the Jomon and Ainu might be partly attributed to some genetic factors. However, because the Jomon form a contrast to the Hawaiian in relative length of forearm bones, we have to recognized a certain difference between them.

It seems most likely that the Polynesian and Micronesian peoples are derived from the Asian continent, probably, from Southeast Asia, on the basis of the cranial and dental morphology (Pietrusewsky, 1984, 1990a, 1990b; Howells, 1989, 1990; Turner, 1989, 1990; Hanihara, 1992). Unfortunately, because I have just made a start on the morphological analysis of these postcranial skeletons, the variation of limb bones among the Asian and Pacific populations has not yet been analyzed in detail. We will have to collect the data of limb bone measurements from the Pan-Pacific regions for elucidating further variations.

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ハワイ人およびチャモロー人の四肢骨の形態特徴

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要旨：ハワイ人およびチャモロー人の四肢骨の計測を行い、分析した。両者の四肢骨の長さには差は認められないが、関節部の大きさ、骨体の周や径は、チャモロー人のほうが、有意に大きい。また、四肢の近位部と遠位部の比をとると、ハワイ人の四肢骨は、チャモロー人に比べ、有意に、遠位部が長い。予報的に、日本列島の諸集団と比較を行った。ハワイ人の四肢骨は、縄文時代人やアイヌに類似するが、チャモロー人は、日本列島の諸集団とは、似る傾向がない。一方、橈骨と上腕骨との長さの比では、縄文時代人とハワイ人は、大きく異なる。機能的な適応といくらかの遺伝的素因が四肢骨の形態形成に関与していると思われるので、人類集団の変異を理解するために、より良い項目を選び、比較していく必要があろう。