

## Limb Segment Proportions in Human Skeletal Remains of the Jōmon Period

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**Abstract** Comparative studies were made on brachial, crural, and humero-femoral indices of prehistoric Jōmon skeletal material. The sample from eastern Japan showed slight tendency toward shortening of distal limb segments as compared with those from central and western Japan. The Jōmon physique as a whole, however, is quite distinct from modern Japanese, with relatively longer radius and tibia and shorter humerus. Their crural index is moderately high, being close to those of the Ainu and some other prehistoric and modern hunter-gatherers. On the other hand, their brachial index is considerably high owing to the short humerus in addition to the relatively long radius, and ranks among the highest known for any human sample.

The relative longness of distal limb segments in the skeletal remains of the prehistoric Jōmon period in comparison with modern Japanese skeletons had long been noticed by HASEBE (1920) and KOGANEI (1928) in reference to small samples. But it was first documented statistically by OKAMOTO and SEKI (1930) on a larger sample of skeletal remains from the Tsukumo shell mound in Okayama Prefecture. The present author enumerated this character as one of the morphological features of the Jōmon population that are common to the Ainu in Hokkaidō and many other hunter-gatherers including the Upper Palaeolithic ones (YAMAGUCHI, 1981, 1982). Distal elongation of the Jōmon limb bones has subsequently been confirmed on further Jōmon skeletal samples by YAMAGUCHI (1983), BABA (1988), and KATO and OGATA (1989).

The purposes of this article are to examine geographic variation in limb segment proportions among different regional samples of the Jōmon population and to compare the Jōmon series as a whole with other samples of different times and regions.

### Materials and Methods

Calculations of limb segment proportions were made on the basis of the individual metric data of the following skeletal series published by various authors: western Jōmon sample from the Tsukumo site in Okayama Prefecture (KIYONO and HIRAI, 1928), central Jōmon sample from the Yoshiko site in Aichi Prefecture (ISHISAWA, 1931; OHBA, 1935), eastern Jōmon sample from the Ebishima and other sites in the Kantō and Tōhoku districts (BABA, 1988; DODO, 1980; DODO and SUZUKI, 1986; HAYASHI, *et al.*, 1981; IKEDA and SHIGEHARA, 1975; OGATA, *et al.*, 1971; OGATA, *et al.*,

1973; SUZUKI, *et al.*, 1957; SUZUKI and HOJO, 1966; YAMAGUCHI, 1983), Yayoi sample from the Doigahama site in Yamaguchi Prefecture and the Kanenokuma site in Fukuoka Prefecture (KYŪSHŪ-DAIGAKU IGAKUBU KAIBŌGAKU DAINIKŌZA, 1988), modern Japanese sample from the Kinai district (MIYAMOTO, 1925; HIRAI and TABATA, 1928), and modern Ainu sample from Hokkaidō and adjacent islands (KOGANEI, 1893).

Calculated proportions are 1) radio-humeral or brachial indices (maximum length of the radius (M1): maximum length of the humerus (M1)), 2) tibio-femoral or crural indices (maximum length of the tibia (M1a): maximum length of the femur (M1)), and 3) humero-femoral indices (maximum length of the humerus (M1): maximum length of the femur (M1)). M1 and M1a in parentheses refer to the number of definition in the osteometric system of MARTIN (1928).

As for the side, the first choice was given to the set of right bones, but when bone preservation was incomplete, set of left bones or even of right and left bones was used for obtaining the proportional index.

Allometric coefficients of limb segment pairs were calculated for the combined Jōmon sample and for the modern Japanese sample of each sex. The coefficients varied between 0.90 and 1.06 for the radius and humerus, 0.96 and 1.08 for the tibia and femur, and 0.86 and 1.07 for the humerus and femur. In no case was the hypothesis of isometry rejected at the level of 5 percent, indicating that the relationships between limb segments are basically linear and can be analyzed by means of simple indices.

### Regional Variation in the Jōmon Materials

Statistical comparison of the mean proportional indices in the three Jōmon skeletal samples showed significant differences at the level of 5 percent between Tsukumo and eastern Jōmon male samples in brachial index, between Tsukumo and eastern Jōmon female samples in crural index, and between Yoshiko and eastern Jōmon male samples in crural index (Table 1). No significant differences were dis-

Table 1. Comparison of limb segment indices in three regional Jōmon samples.

Index	Sex	Western Jōmon (Tsukumo)			Central Jōmon (Yoshiko)			Eastern Jōmon (Ebishima, etc.)			Comparison of sample means		
		n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	W-C	W-E	C-E
Brachial	M	14	81.5	2.14	23	80.9	2.95	26	79.7	2.05	ns	*	ns
	F	12	77.6	2.75	16	78.2	2.03	17	78.9	3.25	ns	ns	ns
Crural	M	12	83.9	2.25	23	83.8	2.21	22	82.5	1.86	ns	ns	*
	F	14	84.1	2.17	14	83.1	1.16	11	82.2	1.18	ns	*	ns
Humero-femoral	M	12	69.4	1.87	17	69.0	2.02	23	70.1	1.65	ns	ns	ns
	F	12	69.7	2.05	11	70.2	2.03	11	70.2	1.05	ns	ns	ns

\* Significant at the 0.05 level.

closed in the humero-femoral index. In every pair that showed significant difference, the index of eastern Jōmon sample was always lower than that of the other. The average crural index of a small sample of Jōmon remains from Hokkaidō at 82.4 (ISHIDA, *et al.*, 1988) is also lower than those of Tsukumo and Yoshiko samples and close to that of the eastern Jōmon sample. These indications of slight regional variation seem to conform with BERGMANN'S and ALLEN'S ecogeographical rules.

Incidentally, a constant sex dimorphism was recognized in the brachial index. As was the case with the materials reported by TRINKAUS (1981), the mean brachial index of the male was higher than that of the female in every sample of the Jōmon materials.

### Comparisons with Other Series from Japan

Overall means and standard deviations of the limb segment indices for the combined Jōmon series are given in Table 2, along with the statistics of another Jōmon sample (KATO and OGATA, 1989), the combined Doigahama-Kanenokuma Yayoi

Table 2. Comparison of limb segment indices in the combined Jōmon and other series from Japan.

	Male			Female		
	n	$\bar{x}$	s	n	$\bar{x}$	s
<b>Brachial index</b>						
Combined Jōmon <sup>1)</sup>	<b>63</b>	<b>80.5</b>	<b>2.51</b>	<b>45</b>	<b>78.3</b>	<b>2.72</b>
KATO & OGATA'S Jōmon <sup>2)</sup>	23	80.9	2.95	19	78.7	3.98*
Yayoi <sup>3)</sup>	23	78.1**	2.12	22	77.2	2.95
Modern Japanese <sup>4)</sup>	85	75.5**	2.35	66	73.0**	2.45
Ainu <sup>5)</sup>	39	77.8**	2.54	23	76.4**	2.55
<b>Crural index</b>						
Combined Jōmon	<b>57</b>	<b>83.3</b>	<b>2.15</b>	<b>39</b>	<b>83.2</b>	<b>1.74</b>
KATO & OGATA'S Jōmon	30	83.3	2.63	13	83.6	1.66
Yayoi	23	81.4**	2.02	29	81.0**	1.92
Modern Japanese	83	80.6**	2.35	66	80.5**	2.29
Ainu	38	82.8	2.24	22	83.4	2.22
<b>Humero-femoral index</b>						
Combined Jōmon	<b>52</b>	<b>69.6</b>	<b>1.86</b>	<b>34</b>	<b>70.0</b>	<b>1.75</b>
KATO & OGATA'S Jōmon	25	69.1	2.20	19	69.8	2.29
Yayoi	21	70.9*	2.18	22	70.8	1.32
Modern Japanese	83	71.5**	2.06	66	71.8**	1.75
Ainu	42	72.6**	1.83	23	72.3**	1.45

1) Tsukumo, Yoshiko, and Ebishima, etc. combined. 2) Data from KATO and OGATA (1989). 3) Doigahama and Kanenokuma samples (KYŪSHŪ-DAIGAKU IGAKUBU KAIBŌGAKU DAINIKŌZA, 1988) combined. 4) Kinai data, based on MIYAMOTO (1925) and HIRAI and TABATA (1928), combined with those of Niigata series (KATO and OGATA, 1989). 5) Based on KOGANEI (1893).

\*\*\* Significantly different from the combined Jōmon at the 0.05 or 0.01 level.

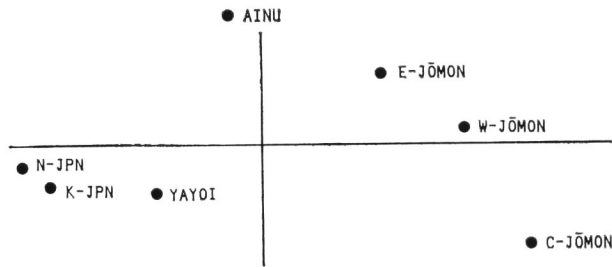


Fig. 1. Two-dimensional plotting of male skeletal samples from Japan based on the PENROSE's shape distances that were obtained by the lengths of four major limb bones given in Table 3. Abbreviations are: W=Western, C=Central, E=Eastern, K=Kinai, and N=Niigata.

Table 3. Mean maximum lengths of major limb bones in seven male skeletal samples from Japan.

	side	Humerus		Radius		Femur		Tibia	
		n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
Jōmon from Tsukumo	r	(15)	292.0	(12)	235.2	(13)	418.2	(8)	349.5
Jōmon from Yoshiko	r	(28)	282.5	(26)	230.1	(22)	412.9	(28)	343.5
Jōmon from Ebishima, etc.	r (or 1)	(35)	297.0	(29)	236.8	(33)	420.8	(24)	349.3
Yayoi from Doigahama and Kanenokuma	r	(32)	305.2	(28)	235.1	(30)	434.7	(29)	352.6
Japanese from Kinai	r	(30)	294.2	(30)	223.0	(30)	413.5	(30)	332.3
Japanese from Niigata		(54)	293.1	(54)	220.7	(53)	409.2	(54)	330.1
Ainu from Hokkaidō	r (or 1)	(45)	295.0	(39)	229.1	(38)	407.7	(38)	338.9
SD in Kinai Japanese	r		14.94		11.58		23.63		19.69

sample, the modern Japanese sample from the Kinai district combined with another Japanese sample from Niigata Prefecture (KATO and OGATA, 1989), and the modern Ainu.

KATO and OGATA's Jōmon materials that belong to the skeletal collection in the Department of Anatomy, Niigata University were excavated at various sites throughout the country except Hokkaidō and Okinawa. A remarkable consistency of the limb segment proportions is shown by the present Jōmon series and the Niigata series.

On the other hand, the modern Japanese are very far from the Jōmon with significantly lower brachial and crural indices and significantly higher humero-femoral index.

The Yayoi sample from Doigahama and Kanenokuma is regarded to comprise not a few immigrants from the Continent and their offspring who played a significant role in the development of the post-Jōmon agricultural society in Japan (NAGAI, *et al.*, 1985). They are intermediate in the limb segment proportions between the Jōmon and the modern Japanese. Both the male and female Yayoi series are significantly different from the Jōmon with lower crural indices, but the Yayoi females are not

significantly different from the Jōmon in other proportional indices.

The Ainu resemble the Jōmon with relatively high crural indices, but differ significantly with lower brachial and higher humero-femoral indices. The differences are essentially due to the unproportional shortness of the humerus in the Jōmon.

To summarize, the Jōmon are distinguished from the modern Japanese with the relative longness of the distal limb segments and the extraordinary shortness of the humerus, and share the long distal segments with the Ainu and the short humerus with the female Yayoi.

Fig. 1 shows a two-dimensional plotting of the seven skeletal samples from Japan based on the PENROSE's shape distances that were obtained by the lengths of four major limb bones given in Table 3. The two coordinates represent 99 percent of total distance. Differences and similarities in limb segment proportions among these samples are well summarized in the distance pattern.

### Comparisons with Samples from Other Parts of the World

Table 4 gives the statistical data of the limb segment indices for six overseas skeletal samples. The Australian Aboriginal series was measured by the present author (YAMAGUCHI, 1967), but the data of five other series are based on those published by TRINKAUS (1981). Since TRINKAUS had used the bicondylar length (M2) of the femur, rather than the maximum length (M1), in obtaining the crural and humero-femoral indices, the means of these two indices were multiplied by 0.991, the average ratio of bicondylar length to maximum length in the Jōmon and modern Japanese femora, so that provisional comparisons can directly be made with the Jōmon indices.

The brachial indices of the Jōmon are significantly higher than those of other samples, with the exceptions of the North African and Australian Aboriginal females. The Jōmon brachial index ranks among the highest known for any sample in the world.

The crural index of the male Jōmon is significantly higher than that of the Eskimo and significantly lower than those of the Amerindians, North Africans, and Australian Aborigines. The female Jōmon are also higher than the Eskimo and lower than the Australian Aborigines, but do not differ significantly from the rest in the crural index.

The humero-femoral indices of the Jōmon are significantly lower than those of other series, with the exceptions of the San and the female North Africans. The Jōmon thus ranks among those possessing the lowest humero-femoral index in the world.

Pooled-sex Jōmon data are compared in Table 5 with those of the Neanderthal, Upper Palaeolithic, and European Mesolithic skeletal materials, also published by TRINKAUS (1981). The mean crural and humero-femoral indices given by TRINKAUS were again multiplied by 0.991 in order to make comparable to the Jōmon means. The Jōmon are significantly different from the Neanderthals in all the proportions

Table 4. Comparison of limb segment indices in the combined Jōmon and six overseas skeletal series.

	Male			Female		
	n	$\bar{x}$	s	n	$\bar{x}$	s
<b>Brachial index</b>						
Combined Jōmon	<b>63</b>	<b>80.5</b>	<b>2.51</b>	<b>45</b>	<b>78.3</b>	<b>2.72</b>
Australian Aborigines <sup>1)</sup>	70	78.9**	2.36	40	77.3	1.94*
Alaskan Eskimos <sup>2)</sup>	40	75.4**	2.1	40	74.7**	2.7
Europeans <sup>2)</sup>	39	74.6**	2.6	37	73.4**	2.8
Amerindians (Pecos Pueblo) <sup>2)</sup>	40	77.7**	2.1	40	76.4**	2.1
San <sup>2)</sup>	17	77.5**	2.8	12	75.3**	3.5
North Africans (Naqada) <sup>2)</sup>	40	78.7**	2.1	40	78.6	2.0
<b>Crural index</b>						
Combined Jōmon	<b>57</b>	<b>83.3</b>	<b>2.15</b>	<b>39</b>	<b>83.2</b>	<b>1.74</b>
Australian Aborigines <sup>1)</sup>	72	85.1**	2.40	40	84.5**	1.75
Alaskan Eskimos <sup>3)</sup>	40	[80.4]**	1.6	40	[80.5]**	2.3
Europeans <sup>3)</sup>	39	[82.9]	2.5	37	[82.8]	1.7
Amerindians (Pecos Pueblo) <sup>3)</sup>	40	[84.2]*	2.1	40	[83.6]	1.8
San <sup>3)</sup>	15	[82.9]	2.3	20	[82.4]	2.5
North Africans (Naqada) <sup>3)</sup>	40	[84.7]**	1.6	40	[83.3]	2.1
<b>Humero-femoral index</b>						
Combined Jōmon	<b>52</b>	<b>69.6</b>	<b>1.86</b>	<b>34</b>	<b>70.0</b>	<b>1.75</b>
Australian Aborigines <sup>1)</sup>	68	72.2**	2.15	41	72.0**	1.45
Alaskan Eskimos <sup>3)</sup>	40	[73.7]**	2.2	40	[72.6]**	2.0
Europeans <sup>3)</sup>	39	[71.8]**	2.5*	37	[72.1]**	1.9
Amerindians (Pecos Pueblo) <sup>3)</sup>	40	[72.1]**	1.8	40	[72.6]**	1.7
San <sup>3)</sup>	14	[69.2]	1.8	15	[68.6]*	2.3
North Africans (Naqada) <sup>3)</sup>	40	[70.9]**	1.7	40	[70.2]	2.4

1) YAMAGUCHI (1967). 2) TRINKAUS (1981). 3) Adapted from TRINKAUS (1981).

\*,\*\* Significantly different from the combined Jōmon at the 0.05 or 0.01 level.

Table 5. Comparison of limb segment indices in the pooled-sex Jōmon, Neanderthal, Upper Palaeolithic, and Mesolithic samples.

	Brachial			Crural			Humero-femoral		
	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s
Combined Jōmon	<b>108</b>	<b>79.6</b>	<b>2.81</b>	<b>96</b>	<b>83.3</b>	<b>1.99</b>	<b>86</b>	<b>69.8</b>	<b>1.82</b>
Neanderthals <sup>1)</sup>	8	74.4**	2.6	9	[78.2]**	1.7	7	[71.5]*	2.2
Upper Palaeolithic <sup>1)</sup>	22	77.4**	2.7	22	[84.5]*	2.6	21	[71.1]	2.9**
European Mesolithic <sup>1)</sup>	39	78.5*	2.7	38	[82.5]	2.6*	28	[69.9]	2.0

1) Adapted from TRINKAUS (1981).

\*,\*\* Significantly different from the combined Jōmon at the 0.05 or 0.01 level.

with higher brachial and crural indices and lower humero-femoral index. They are, on the other hand, much closer to the Upper Palaeolithic and Mesolithic series, though they still differ significantly from these series in one or two indices.

### Summary and Conclusion

There are slight indications for the eastern Jōmon to have relatively shorter distal limb segments than western and central Jōmon, conforming with BERGMANN'S and ALLEN'S rules.

When compared with modern Japanese that may be regarded as representative of the eastern Mongoloid, the Jōmon are characterized by relatively long distal limb segments and considerably short humerus. They share the moderately high crural indices with the Ainu, Europeans, San, Upper Palaeolithic, and European Mesolithic. However, with the relatively long radius and the unproportionally short humerus, their brachial index ranks among the highest in the world. Only the female Yayoi and North Africans share such high brachial indices with the Jōmon.

Notwithstanding the close mutual resemblance in so many osteological characters, even including the crural index, the Jōmon and the Ainu are clearly discriminated in the proportion of the humerus.

The aeneolithic Yayoi is intermediate between the lithic Jōmon and the modern Japanese in the limb segment proportions, but the female Yayoi are much closer to the Jōmon than the male.

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