Secular Trend in Emargination of the Japanese Patella, with Special Reference to the Skeletal Gracility of the Earliest Jomon People*

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Abstract The secular trend in emargination of the Japanese patella was studied on a total of 220 specimens ranging from the prehistoric Jomon period to the present age. There was found a significant decrease both in the incidence and in the relative size of the supero-lateral notch of the patella with the progress of civilization. It was suggested that the emarginate patella was due to a deficiency of bone, in relation to the development of the quadriceps femoris muscle. Archaeological evidence indicated that the prehistoric Jomon people improved and broadened their subsistence economy from the Earliest to the Latest stage. The above hypothesis on the causation of emarginate patella gave a satisfactory explanation for the skeletal gracility in association with developed muscularity of the Earliest Jomon people who subsisted entirely on various forms of hunting, fishing, gathering and collecting under narrow circumstances.

INTRODUCTION

The human patella is a triangular sesamoid bone which is embedded in the tendon of insertion of the quadriceps femoris muscle. Since HELLMER's paper (1935) it has widely been accepted that the patella ossifies from several centers, which appear during early childhood and later fuse. When the supero-lateral angle remains unossified, the condition is called "emarginate patella". Although considerable attention has been paid to the general

morphology of the Japanese patella, comparatively little is known of the emargination of this bone, exclusive of the observations of KATO et al. (1960).

Apart from the patella, it has been noticed by MORIMOTO (1971 & 74), H. SUZUKI (1950), M. SUZUKI (1968) and OGATA (1968 & 69) that the skeletons of the prehistoric Jomon people in Japan are relatively thinner and slenderer at the Earliest stage (ca. 8000 to 5500 B.C.) than at the Middle, Late and Latest (ca. 3000 to 300 B.C.). It seems to require explanation for the notable differences in the skeletal gracility or robustness between the earlier and later Jomon peoples.

The purpose of this paper is to give

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data on the secular trend in emargination of the Japanese patella from the prehistoric Jomon period to the present age, and further to discuss the problem of skeletal gracility of the Earliest Jomon people in Japan.

MATERIAL AND METHOD

To assess the secular trend in emargination of the Japanese patella, a total of 220 bones of 168 individuals were examined. As shown in tables 1 and 2, the material used consisted of the patellae ranging over the prehistoric Jomon (ca. 8000 to 300 B.C.), the protohistoric Kofun (ca. 300 to 700 A.D.) and the medieval Kamakura to recent Edo (1192 to 1867 A.D.) periods in addition to the present

age of Japan. The prehistoric, protohistoric and medieval to recent bones were excavated from various archaeological sites in Japan and well kept by the Department of Anatomy, Niigata University School of Medicine, Niigata. The present-day material belonged to the same Department of Anatomy. All the patellae examined were in a fairly good state of preservation and showed little pathological changes.

The supero-lateral angle of the patella might remain unossified (emarginate patella) or might ossify independently (bipartite patella). There seemed to be a certain similarity in form between the emarginate patella and the main mass of bipartite patella unaccompanied by a

Table 1. Number of Japanese individuals examined.

Period (stage)	Male	Female	Total
Jomon (Earliest)	3	3	6
Jomon (Middle to Latest)	42	24	66
Kofun	16	9	25
Kamakura to Edo	23	17	40
Present age	23	8	31
Total	107	61	168

Table 2. Number of Japanese patellae examined.

Period (stage)	Side	Male	Female	Total
Jomon (Earliest)	R	3	2	5
	L	2	2	4
Jomon (Middle to Latest)	R	30	12	42
	L	24	15	39
Kofun	R	9	7	16
	L	12	6	18
Kamakura to Edo	R	20	14	34
	L	12	9	21
Present age	R	14	6	20
	L	18	3	21
Total	R + L	144	76	220

Fig. 1. Measurements of supero-lateral notch of Japanese patella. Posterior surface of right bone is illustrated. A-B, length of notch; C-D, depth of notch. In addition, maximal breadth of patella (E-F) is measured in a horizontal plane.

small marginal accessory bone. Since it was actually difficult to distinguish the emarginate patella from the main mass of bipartite patella, the two types of variation were conveniently placed in the same category as an emarginate patella.

As a result of emargination, there was usually found a notch at the supero-lateral angle of the patella (fig. 1). The chief

dimension of the supero-lateral notch of the patella was its length. The length of the notch was the corresponding chord, the rectilinear distance from one extremity of the mouth of the notch to the other. The maximal breadth of the patella was the distance between the most lateral parts of the patella taken in a horizontal plane. The index of emargination of the patella exhibited an approximation of relative length of the notch, its formula being "100 times the length of the notch/the maximal breadth of the patella".

The concavity of the notch was measured as follows. The depth of the notch was the maximal distance of the notch from the above-mentioned chord or length. The relation of this depth to the length of the notch was given by "100 times the depth of the notch/the length of the notch"; and it furnished the index of concavity of the notch.

OBSERVATION

The percentages of occurrence of the emarginate patella in Japanese from the prehistoric Jomon period to the present

Table 3. Percentages of occurrence of supero-lateral notch of Japanese patella in different periods, with comparative data from other previous publications.

Period (stage) or population	Male		Female	
	N	Present (%)	N	Present (%)
Jomon (Earliest)	5	5(100.0)	4	4(100.0)
Jomon (Middle to Latest)	54	49(90.7)	26	24(92.3)
Kofun	21	18(85.7)	13	7(53.8)
Kamakura to Edo	32	23(71.9)	23	16(69.6)
Present age	32	22(68.8)	9	3(33.3)
Present Japanese (KATO & HARADA, 1960)	74	16(21.6)	66	14(21.2)
Modern Koreans (ARASE, 1932)	214	137(64.0)	26	16(61.5)

age are given in table 3, with comparative data from other previous publications. It is apparent from this table that the frequencies of occurrence of the emarginate patella in both sexes have a tendency to decrease significantly with the course of times. There is found no significant sexual difference in the incidence of the emarginate patella in every period, with the exception of the protohistoric Kofun.

Table 4 shows the secular trend in the maximal breadth of the Japanese patella from the prehistoric Jomon period to the present age. It is readily seen that the patella is absolutely larger in males than in females. There is found little difference in the maximal breadth of the patella among the different periods.

The secular changes in the length of the notch at the supero-lateral angle of the Japanese patella from the prehistoric

Jomon period to the present age are recorded in table 5. It will be seen from this table that in the Jomon people a significant difference in the means of the length of the notch of the patella exists between the two sexes, whereas little sexual difference in the same length is found in the bones from the protohistoric Kofun, the medieval Kamakura to Edo and the present-day Japanese.

Table 6 represents the distribution of the relative length of the notch of the Japanese patella from the prehistoric Jomon period to the present age. It should be noticed that the relative length of the notch of the Japanese patella exhibits a tendency to decrease significantly with the progress of civilization. No sexual difference in the relative length of the notch of the Japanese patella is present.

In table 7 are collected the results of

Table 4. Distribution of maximal breadth (in mm.) of Japanese patella in different periods.

Period (stage)	Male			Female		
	N	$\bar{X}$	u^2	N	$\bar{X}$	u^2
Jomon (Earliest)	5	44.78	3.41	4	39.83	1.97
Jomon (Middle to Latest)	41	44.40	7.40	19	38.22	3.03
Kofun	18	46.16	14.92	6	41.47	2.60
Kamakura to Edo	23	44.42	9.71	16	39.07	7.31
Present age	22	45.80	5.45	3	36.97	5.41

Table 5. Distribution of length (in mm.) of supero-lateral notch of Japanese patella in different periods.

Period (stage)	Male			Female		
	N	$\bar{X}$	u^2	N	$\bar{X}$	u^2
Jomon (Earliest)	5	17.52	4.59	4	12.48	8.69
Jomon (Middle to Latest)	41	13.30	27.57	19	10.49	12.11
Kofun	18	10.89	8.96	6	10.02	9.79
Kamakura to Edo	23	7.75	10.51	16	7.49	11.95
Present age	22	8.97	10.74	3	7.80	13.39

Table 6. Distribution of relative length of supero-lateral notch of Japanese patella (100 times length of notch/maximal breadth of patelle) in different periods.

Period (stage)	Male			Female		
	N	$\overline{X}$	u^2	N	$\overline{X}$	u^2
Jomon (Earliest)	5	39.16	24.93	4	31.48	69.41
Jomon (Middle to Latest)	41	30.03	153.18	19	27.45	81.04
Kofun	18	23.40	23.66	6	24.22	61.69
Kamakura to Edo	23	17.30	44.42	16	19.24	80.82
Present age	22	19.59	48.17	3	20.77	75.11

Table 7. Distribution of depth (in mm.) of supero-lateral notch of Japanese patella in different periods.

Period (stage)	Male			Female		
	N	$\overline{X}$	u^2	N	$\overline{X}$	u^2
Jomon (Earliest)	5	1.60	0.64	4	1.10	0.07
Jomon (Middle to Latest)	41	1.27	0.79	19	0.91	0.47
Kofun	18	0.76	0.32	6	0.52	0.23
Kamakura to Edo	23	0.70	0.32	16	0.55	0.13
Present age	22	0.75	0.13	3	0.67	0.45

Table 8. Distribution of index of concavity of supero-lateral notch (100 times depth of notch/length of notch) of Japanese patella in different periods.

Period (stage)	Male			Female		
	N	$\overline{X}$	u^2	N	$\overline{X}$	u^2
Jomon (Earliest)	5	9.12	22.18	4	8.85	0.51
Jomon (Middle to Latest)	41	9.09	24.18	19	7.87	18.31
Kofun	18	6.83	22.72	6	4.62	11.31
Kamakura to Edo	23	8.63	31.60	16	7.09	11.04
Present age	22	8.68	16.12	3	7.03	25.03

measurements made on the depth of the notch of the Japanese patella in the different periods. It may be seen that the depth of the notch of the Japanese patella shows a tendency to decrease during the advance of times, the decrease being more evident in males than in females. There is found no sexual difference in the means of the depth of the notch.

Table 8 includes the values of index of concavity of the notch of the Japanese

patella in the different periods. It will be seen that there is no significant difference in the index of concavity of the notch of the Japanese patella either between the two sexes or among the different periods.

DISCUSSION

The writer's observation shows that the supero-lateral notch of the patella of varying size is present in approximately two-thirds of the present-day Japanese

males examined. As will be seen in table 3, there is little difference in the frequencies of occurrence of the notch of the patella between the present-day Japanese (MORIMOTO, 1975) and the modern Koreans (ARASE, 1932) males. Tables 3, 5, 6, 7 and 8, however, indicate that in both sexes there is a secular decrease in either the incidence or the size of the notch of the Japanese patella with the progress of civilization, though the notch is invariable in shape between the two sexes as well as among the different periods. No suggested explanation for the above secular decrease has yet been given.

As a possible cause of the emarginate patella, MARTIN-SALLER (1959) suggest that the notch is the marking for the insertion of vastus lateralis muscle into the patella. According to them, the deep type of the notch is met with in three per cent of European specimens, and is commonly bilateral. But BASMAJIAN-GRANT (1971) have pointed out in their textbook of anatomy that the supero-lateral angle of the human patella gives partial attachment not only to the vastus lateralis, but also to the rectus femoris and vastus intermedius muscles. It is, therefore, more correct to say that the margin of the patella to which the tendons of the above-mentioned three heads of quadriceps femoris muscle are partially attached is often marked by a notch of varying size. On the other hand, HELLMER as well as MCKENZIE et al. (1957) clearly demonstrates that the patella always ossifies from several centers, and that the multiple centers of ossification are regarded as a

normal occurrence in this bone. It is natural to suppose that the strong tendinous pull of the quadriceps femoris muscle inhibits the centers of ossification at the supero-lateral angle of the patella. Thus the emargination of the patella is associated with the relative development of the quadriceps femoris muscle and the concomitant suppression of the marginal centers of ossification of the patella. The data reported in this study seem to support the view that both high frequency and large size of the supero-lateral notch of the patella correlate with a muscular development of the lower limbs. It has to be realized here that, as tables 4, 6 and 8 show, there is little difference in the relative size of the notch of the patella between the two sexes in every period. This seems to suggest that the pull where the tendinous attachments are concentrated has a definite inhibiting effect on the marginal ossification centers of the patella without distinction of sex.

As for another possible cause of the emarginate patella, it might be inferred that the ossification centers at the supero-lateral angle of the patella are so sensitive to nutritional changes as in the cartilage cells of the epiphyseal plate of long bones, and that the mitotic activity of the cartilage cells at the ossification centers is diminished by any severe deficiency of nutrition. The results obtained from this study clearly demonstrate that Japanese populations exhibit a significant decrease in both incidence and relative size of the notch of the patella with the progress of civilization. There seems to be little doubt

that the occurrence of the emarginate patella correlate with nutritional status. Most of descriptive literatures on the Japanese archaeology have indicated that the prehistoric Jomon people subsist predominantly on various forms of hunting, fishing, gathering and collecting, whereas the protohistoric Kofun people are basically agriculturalists who cultivate wet-rice and miscellaneous cereals based on the use of iron tools. It may safely be assumed that both high frequency and large size of the supero-lateral notch of the patella among the Jomon people are attributed to the shortage of bony material caused by a dietary deficiency, in association with the developed musculature of the lower limbs.

If the emarginate patella can result from muscular development as well as from starvation, it is possible to explain the reason for the skeletal gracility of the Earliest Jomon people. Probably the large size of the supero-lateral notch of the patella in the Earliest Jomon people relates to a more narrowly based subsistence economy than occurs at the Middle to Latest Jomon stages. ESAKA (1967 & 74) states that in the development of the Japanese tradition of prehistoric Jomon culture there is a very definite chronological trend toward increasingly efficient ecological adaptation. A variety of archaeological sites, according to him, have a tendency to grow larger in the later stages reflecting both an increase in the local population and a more sedentary existence. He also affirms that there is certain evidence for some form of incipient agricul-

ture with taro-yam-and-millet cultivation during the Middle to Latest stage of the Jomon period, though only hunting, fishing and gathering provide the most important food source at the Earliest. It should be understood that the adoption of taro-yam-and-millet agriculture by the Middle to Latest Jomon people previously wholly dependent on a hunting-fishing-gathering economy does not result in a wholesale adoption of farming and the virtual disappearance of early mode of life, but in the formation of a mixed economy in which hunting-fishing-gathering continues to play a very important part. If this is true, there is justification for the belief that those Earliest Jomon people who have more starvation-filled childhood are possessed of the thin and slender skeletons. From the observation on radiopaque transverse lines of arrested growth of HARRIS (1933) in the metatarsal bone of the Earliest Jomon people, H. SUZUKI arrives at the conclusion that these transverse lines are probably resulted from malnutrition. OGATA who has remarked on the skeletal gracility of the Earliest and Early Jomon peoples is of the opinion that the differences in the physical characteristics of the Jomon people between the earlier and later stages is in accord with the changes in their ways of living due to the climatic and geologic alterations. According to him, the climatic and geologic conditions at the Earliest and Early Jomon stages in Japan are unstable and seem to be very hard on the people in those days, whereas the conditions at the Middle to Latest stages are relatively stable and

probably very habitable for them. It is another circumstantial evidence previously afforded by this writer (1971) that the flattened tibia in the Earliest Jomon juvenile is due to the nutritional deficiency which affects the structure of bone and influences the osseous resistance to the stress of habitual posture and locomotion.

Although the skeletons of the Earliest Jomon people are, as already mentioned, thinner and slenderer than those of the Middle to Latest, it is commonly thought that the long bones of the former have considerably developed muscular markings in the form of roughened surfaces and lines. In this regard, the Earliest Jomon people are characterized by the gracility of their skeletons accompanied by the developed muscularity. The preceding discussion may be summarized by saying that their skeletal gracility is attributed not to the flaccidity of muscles, but probably to the shortage of bony material caused by a dietary deficiency.

Much more research is needed in developing both archaeological and physical anthropological techniques of analysing whether or not a prehistoric population has been subjected to acute or chronic malnutrition. So far as the writer is concerned, no study on the emarginate patella in modern adults with known times of childhood starvation has yet been done. Experimental work on laboratory animals has shown that deficiency in either minerals (especially in calcium) or vitamins (including D, C and A) may cause skeletal defects and/or anomalies. But the nutritional factors which act unfavorably

on the developing patella are so little known that no definite theory can be put forward. It may be suggested that this is also a line well worthy of inquiry.

SUMMARY

1. To examine the secular trend in emargination of the Japanese patella, a total of 220 specimens ranging from the prehistoric Jomon period to the present age were investigated.

2. In either sex, there was an observable tendency to decrease in both incidence and relative size of the supero-lateral notch of the Japanese patella with the progress of civilization.

3. The emarginate patella was attributed to the development of the quadriceps femoris muscle, in relation to the deficiency of bony material. Possibly the diet of the prehistoric Jomon people in Japan might help to explain a high grade of emargination of their patellae.

4. The above views on the causation of emarginate patella gave a suggested explanation for the skeletal gracility in association with developed muscularity of the Earliest Jomon people who subsisted entirely on various forms of hunting, fishing, gathering and collecting under narrow circumstances.

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日本人の膝蓋骨切痕の時代的变化
——縄文早期人の長骨の細さに関連して——

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縄文時代から現代人までの男女合計168体220側の膝蓋骨を用いて、その上外側縁に生ずる切痕の時代差を検討した。切痕の出現率および相対長は、時代が進むにつれて減少する。切痕の形には著しい時代差・性差は認められない。

一般に縄文早期人は縄文中後晩期人に比べて骨格はきゃしゃであり、長骨骨幹も細いといわれる。膝蓋骨切痕の出現率・相対長は前者が後者より大きく、両者の差は他の1時代分の差にほぼ匹敵する。膝蓋骨切痕の形成度が大腿四頭筋の発達と生長期の栄養不良とをある程度反映すると仮定すれば、縄文早期人は骨格筋をよく使用したにもかかわらず、生長期に栄養不足に見舞われがちであったので、その四肢長骨が細いと説明できよう。