Memoirs of the College of Science, University of Kyoto, Series B,
Vol. XXXIII No. 1 (Biology), October 1966

On the Triceps Surae in Primates

by

Hidemi Ishida

Department of Zoology, Faculty of Science, Kyoto University

Abstract

The relative weight and the relative linear measurements of triceps surae are examined chiefly on Japanese macaques and partly on some other species of the primates.

In Japanese macaques, there is no striking age change in the relative weight of the soleus to the gastrocnemius, that is, both muscles grow in parallel with each other. Age change of the relative linear measurements is not significant. Thus one may say that the proportional size of the triceps surae in Japanese macaques is probably determined before birth.

The proportionally longer gastrocnemius and Achilles tendon, broader and heavier soleus are characteristic for man. The monkey has shorter gastrocnemius and narrower and lighter soleus than apes and man. The anthropoid ape has shorter Achilles tendon even as compared with the monkey.

There is no doubt that the relative measurements of the triceps surae of the primates bear a close relation to their postural attitude and their mode of progression.

It is well known that the primates have in general the locomotive organs characteristic of the species corrsponding to their posture and locomotion. Particularly, the triceps surae, which is one of the most characteristic features of the muscular apparatus in a species of the primates and bears a direct relation to his postural attitude and his mode of progression, has been hitherto studied by many investigators. Frey (1913) discussed the phylogeny of the triceps surae in a comparison of the linear measurements of the component part of this muscle, the gastrocnemius, soleus and the tendon of Achilles, for various species of the primates.

Chudzinski (1894), Loth (1911 a, b), William et al. (1930), Seki (1950) and etc., moreover, have made contributions to the anatomy on racial difference of the human triceps surae, by measuring the amount of the muscular mass and the height from the united point between muscle bellies and the Achilles tendon to the distal end of this tendon. Recently, Huttel (1953) and Suzuki (1954) have applied this method to the calf of the living man and made clear the racial differences of this muscle more easily.

On the other hand, some of anatomists and anthropologists have taken notice of the fact that the relative weight of the gastrocnemius to the soleus has a close relation to the relative strength of them, and then to the mode of posture and locomotion. According to the method by which the ratios of the weight between both muscles are quantitatively compared, Endo (1937) reported on the investigation of the new born and adult in man and the rhesus monkey, Tappen (1955) of a gibbon, Theile (1884) and Matsushima (1927) of human adult and Yazaki (1959) of human fetus.

In these works which dealt with the triceps surae, however, the species and the cases of each species which had been examined were very small in number, excluding Frey's material. There is no investigation, moreover, revealing both the relative weight and the linear measurements of this muscle on the same individual, and also the changes of these features with age.

In this study, therefore, the changes of these measurements or proportions with age are examined chiefly on Japanese macaques and partly on some other species, such as the squirrel monkey, rhesus monkey and chimpanzee, and the comparison between these species are observed, with special reference to their mode of habitual posture and of progression.

Material and Method

The materials used in this study are shown in table 1. The majority of them is Japanese macaques (*Macaca fuscata*) belonging to sub-family *Cercopithecinae* of the Old World monkey, while the rhesus monkey (*Macaca mulatta*) from the same genus as Japanese macaques, the dusky lutong (*Trachypithecus obscurus*) from *Colobinae*, another sub-family of Cercopithecoid family, the squirrel monkey (*Saimiri scuirea*) from the New World monkey, and the chimpanzee (*Pan trogrodytis*) from the anthropoid ape, are observed. The comparative data quoted from the literetures, such as Frey's etc., include the prosimian, monkey, ape and man.

Table 1. Materials used in this study.

		Fetus	New Born	Juvenile	Adult	Total
Squirrel monkey	Male	1				1
	Female		1		1	2
Japanese monkey	Male	2	5	4	14	25
	Female		6	2	6	14
Rhesus monkey	Male			1		1
	Female				1	1
Dusky lutong	Male				1	1
Chimpanzee	Female				1	1
Total		3	12	7	24	47

Accoding to the age estimation based upon the dental eruption, Japanese macaques and rhesus monkeys were divided into two age groups; adult and juvenile. The juvenile period of this study corresponds to 2-3 years and the adult over 7 years old. Besides both age groups, there are materials of the new born and fetus. The age group for the chimpanzee and dusky lutong estimated by their period in breeding is adult and that for the squirrel monkey, estimated by her dental condition and by the fact that she was in pregnancy, was adult, although the exact age for them were uncertain. As to the estimation of the duration after or before birth, the writer followed Schultz (1937), in these materials the former being 1-5 days after its birth and the latter 2-3 lunar months.

The triceps surae, after dissecting free from the cadavers fixed in 10% formalin solution and washing for 20-30 hours, was measured in the following measurements: with the gastrocnemius, 1) the distance from its femoral origin to the tendinous insertion on the calcaneus on each head, 2) the distance from the most distal point of the medial and lateral belly of the muscle and the fused point of both the bellies to the tendinous insertion on the calcaneus, 3) the maximum breadth of the muscle belly; and with the soleus, 1) the distance from its origin to the insertion on the calcaneus, 2) the maximum breadth. Besides those, the total length of tibia was measured.

The gastrocnemius and soleus which had been dehydrated in 75% alcohol solution for about 24 hours in order to put them on the same condition, were weighed on the balance, their tendon being removed.

The relative weight and the relative linear measurements calculated from the weights and measurements mentioned above are as follows:

Relative weight

gastrocnemius / crural musculature ×100
soleus / crural musculature ×100
soleus / gastrocnemius ×100

Relative linear measurements

total length of medial gastrocnemius / tibia length ×100
total length of lateral gastrocnemius / tibia length ×100
length of Achilles tendon on united point of bellies of gastrcnemius / tibia length ×100
length of Achilles tendon on medial side / tibia length ×100
length of Achilles tendon on lateral side / tibia length ×100
maximum breadth of gastrocnemius / tibia length ×100
total length of soleus / tibia length
maximum breadth of soleus / tibia length ×100
length of Achilles tendon on medial side / total length of medial gastrocnemius ×100
length of Achilles tendon on lateral side / total length of lateral gastrocnemius ×100
length of Achilles tendon on medial side / length of medial belly of gastrocnemius ×100

length of Achilles tendon on lateral side / length of lateral belly of gastrocnemius ×100

Relative Weight of the Triceps Surae

The relative weight of the triceps surae for the adult forms of Japanese macaques is presented in table 2. There are no statistically significant differences between the right and the left and also between males and females ($P>0.05$). For this reason, further examination will be made upon only the right side of the male.

Table 3 in which the age changes of the relative weights are indicated, makes clear that both ratios of the gastrocnemius and of the soleus to the crural musculature tend to become greater with an advance in age. As a result, there are no striking variations with age in the relative weight of the soleus to the gastrocnemius, that is, both muscles seem to increase in parallel with each other during growth.

Table 2. Relative weights of the triceps surae of adult Japanese macaques.

	Male						Female					
	Right			Left			Right			Left		
	n	x	u^2	n	x	u^2	n	x	u^2	n	x	u^2
Gastrocnemius/ Crural musculature	14	24.02	2.647	14	24.25	2.286	6	24.45	9.333	6	25.00	9.000
Soleus/ Crural musculature	14	10.02	1.647	14	10.05	1.373	6	10.27	2.137	6	10.27	2.916
Soleus/ Gastrocnemius	14	41.17	20.249	14	41.44	17.373	6	42.00	18.489	6	41.08	22.556

Table 3. Age changes of the relative weights of the triceps surae in Japanese macaques.

		Fetus		New Born		Juvenile		Adult	
		R	L	R	L	R	L	R	L
Male	Gastrocnemius/ Crural musc.	21.63	21.55	15.41	16.41	23.04	24.23	24.22	24.25
	Soleus/ Crural musc.	9.01	8.99	8.04	8.15	8.67	9.50	10.02	10.05
	Soleus/ Gastrocnemius	41.66	41.77	50.63	47.66	37.63	39.21	41.17	41.44
Female	Gastrocnemius/ Crural musc.			15.95	16.13	22.39	22.11	24.45	25.00
	Soleus/ Crural musc.			7.98	8.04	10.04	10.07	10.27	10.27
	Soleus/ Gastrocnemius			50.03	49.85	44.84	45.55	42.00	41.08

Table 4. Relative weights of the triceps surae for some species of the primates.

		Sruirrel monkey (1)	Rhesus monkey (1)	Japanese monkey (14)	Duskey lutong (1)	Chimpanzee (1)
Right	Gastrocnemius/ Crural muscnlature	23.70	23.74	24.02	26.79	25.09
	Soleus/ Crural muscrlature	13.33	10.75	10.02	10.78	18.82
	Soleus/ Gastrocnemius	56.24	45.28	41.17	40.24	75.00
Left	Gastrocnemius/ Crural musculature	23.49	23.75	24.25	28.00	23.59
	Soleus/ Gural musculature	13.49	10.61	10.27	10.65	18.36
	Soleus/ Gastrocnemius	57.43	44.69	42.00	38.00	77.83

As seen in table 4, the ratios of the gastrocnemius to the crural musculature for all species compared here are limited within the narrow range from 20.41% for man and to 26.79% for the dusky lutong 23.70% for the squirrel monkey, 23.74% for the rhesus monkey, 24.02% for the Japanese macaque and 25.09% for the chimpanzee. On the contrary, there are considerable specific differences in the ratio of the soleus to the crural musculature, for instande, the ratio for man is 34.60% against the ratio of around 10% for Japanese macaques, the rhesus monkey and dusky lutong. Chimpanzee and squirrel monkey, with the ratio of 18.82% and 13.33% respectively, occupy an intermediate position between man and Japanese macaques. The facts mentioned above show that the specific differences of the relative weight of the soleus to the gastrocnemius are due to the weight of the soleus rather than to that of the gastrocnemius. As a matter of course, there are significant specific disparities in this ratio, which is the greatest in man (169.50%) and decreases gradually in the order of gibbon (76.40), chimpanzee (75.00%), squirrel monkey (56.24%), rhesus monkey (45.30%), Japanese macaque (41.20%), reaching its minimum in the dusky lutong (40.20%). There are little variations among three species having smaller percentages.

From the above result, it is noted that the large soleus of the upright human contrasts markedly with that of the quadrupedal monkey and that the brachiating gibbon has relatively large soleus, which approaches the monkey rather than man.

Relative Linear Measurements of the Triceps Surae

There is neither bilateral nor sexual difference in all the proportions of the relative linear measurements concerning the triceps surae for Japanese macaques ($P>0.05$), as exhibited in table 5. Thus the discussion hereafter will be made upon only the right side of the male.

Table 5. Relative linear measurements of the triceps surae of adult Japanese macaques.

	Male						Female					
	Right			Left			Right			Left		
	n	x	u^2	n	x	u^2	n	x	u^2	n	x	u^2
Med. Gastro. Total Lg. / Tibia Lg.	14	113.60	12.08	14	112.71	4.17	6	112.72	6.22	6	14.13	16.56
Lat. Gastroc. Total Lg. / Tibia Lg.	14	112.83	10.81	14	111.31	5.20	6	111.80	4.30	6	13.01	16.99
Ach. tend. Lg. on Fusion Point / Tibia Lg.	14	54.53	8.34	14	54.88	11.34	6	56.68	7.80	6	55.20	9.46
Med. Ach. tend. Lg. / Tibia Lg.	14	46.83	7.77	14	46.81	17.34	6	45.76	3.80	6	45.49	3.14
Lat. Ach. tenc. Lg. / Tibia Lg.	14	40.14	10.82	14	38.95	26.65	6	38.39	3.80	6	37.82	4.25
Gastroc. Max. Breadth/ Tibia Lg.	14	22.60	3.14	14	22.38	4.69	6	22.04	19.98	6	22.32	28.56
Soleus Total Lg. / Tibia Lg.	14	92.45	12.77	14	92.09	14.90	6	94.42	21.67	6	94.82	11.44
Soleus Total Lg. / Tibia Lg.	14	18.08	3.86	14	18.71	0.89	6	17.41	22.67	6	17.52	20.81
Med. Ach. tend. Lg. / Med. Gastroc. Belly Lg.	14	41.07	6.30	14	41.38	13.18	6	40.63	4.47	6	39.93	6.22
Lat. Ach. tend. Lg. / Lat. Gastroc. Belly Lg.	14	36.22	6.44	14	34.74	18.59	6	34.64	2.47	6	33.51	3.33
Med. Ach. tend. Lg. / Med. Gastroc. Belly Lg.	14	69.81	51.56	14	71.37	121.16	6	68.68	45.90	6	66.72	45.23
Lat. Ach. tend. Lg. / Lat. Gastroc. Belly Lg.	14	56.49	61.40	14	53.71	178.64	6	52.40	17.72	6	50.30	13.38

On the age changes of the relative linear measurements, the following results were obtained. Generally, there are no marked changes with age in most of the proportions. In detail, the proportions of the length of medial and lateral heads of the gastrocnemius to the tibia length, as well as the proportions of the Achilles tendon to the tibia length, show the tendency to decrease slightly with age. The proportions of the maximum breadth of the gastrocnemius and of the soleus to the tibia length change remarkably little during growth. The proportions of the Achilles tendon length to both the length of the medial and lateral heads of the gastrocnemius do not seem to increase nor decrease significantly, while this proportion concerning medial head appears to decrease as opposed to that for lateral head's change. The same tendency as the above is presented in the proportion of the Achilles tendon length to the muscle belly length on the medial and the lateral sides of the gastrocnemius.

In the proportion of the Achilles tendon length to the tibia length and to the gastrocnemius, the medial side always exceeds the opposite side from fetus to the adult forms.

Table 6. Age changes of the relative linear measurements of the triceps surae in Japanese macaques.

	Right				Left			
	Fetus	New Born	Juvenile	Adult	Fetus	New Born	Juvenile	Adult
Male								
Med. Gastroc. Total Lg. / Tibia Lg.	122.86	120.44	117.62	113.60	120.00	119.08	114.17	112.71
Lat. Gastroc. Total Lg. / Tibio Lg.	122.86	120.81	117.02	112.83	120.00	119.08	113.29	111.31
Ach. tend. Lg. on Fusion Point / Tibia Lg.	57.29	56.19	56.38	54.53	57.14	56.67	54.87	54.88
Med. Ach. tend. Lg. / Tibia Lg.	51.43	50.44	47.86	46.83	51.43	50.82	45.46	46.81
Lat. Ach. tend. Lg. / Tibia Lg.	42.86	47.22	41.12	40.14	45.71	46.19	40.02	38.95
Gastroc. Max. Breadth/ Tibia Lg.	22.85	21.69	22.40	22.60	25.71	21.30	22.20	22.38
Soleus Total Lg. / Tibia Lg.	102.86	103.19	98.82	92.45	102.86	104.24	98.92	92.09
Soleus Max. Breadth/ Tibia Lg.	17.14	16.32	18.86	18.04	17.14	15.14	18.66	18.71
Med. Ach. tend. Lg. / Med. Gastroc Total Lg.	41.86	41.89	40.71	41.07	42.86	42.42	39.95	41.38
Lat. Ach. tend. Lg. / Lat. Gastroc. Total Lg.	34.88	39.10	35.18	36.22	38.10	38.68	35.34	34.74
Med. Ach. tend. Lg. / Med. Gastroc. Belly Lg.	72.00	72.38	69.64	69.81	75.00	74.03	67.53	71.37
Lat. Ach. tend. Lg. / Lat. Gastroc. Belly Lg.	53.75	64.41	56.74	56.49	61.54	63.12	56.28	53.71
Female								
Med. Gastroc. Total Lg. / Tibial Lg.		123.29	122.28	112.72		122.97	119.57	114.13
Lat. Gastroc. Total Lg. / Tibia Lg.		134.63	120.65	111.80		122.64	119.02	113.01
Ach. tend. Lg. on Fusion Point / TibiaLg		62.32	59.78	56.68		61.08	61.96	55.20
Med. Ach. tend. Lg. / Tibia Lg.		53.49	45.11	45.76		50.97	46.20	45.49
Lat. Ach. tend. Lg. / Tibia Lg.		47.79	37.50	38.39		46.52	39.67	37.82
Gastroc. Max. Breadth/ Tibia Lg.		21.63	22.39	22.04		22.63	20.66	22.32
Soleus Total Lg. / Tibia Lg.		104.15	99.46	94.42		103.49	97.28	94.82
Soleus. Max. Breadth/ Tibia Lg.		15.56	15.22	17.41		15.88	15.22	17.52
Med. Ach. tend. Lg. / Med. Gastroc. Total Lg.		43.40	36.90	40.63		41.48	38.33	39.93
Lat. Ach. tend. Lg. / Lat. Gastroc. Total Lg.		38.87	30.77	34.64		37.96	33.39	33.51
Med. Ach. tend. Lg. / Med. Gastroc. Belly Lg.		76.77	58.45	68.68		72.05	63.08	66.72
Lat. Ach. tend. Lg. / Lat. Gastroc. Belly Lg.		63.62	45.13	52.40		61.39	50.26	50.53

Table 7. Relative linear measurements of the triceps surae for some species of the primates.

	Right				Left			
	Squirrel(1) monkey	Rhesus(1) monkey	Japanese monkey(14)	Dusky lutong(1)	Squirrel monkey(1)	Rhesus monkey(1)	Japanese monkey(14)	Dusky lutong(1)
Med. Gastroc. Total Lg. / Tibia Length	113.75	107.64	113.60	114.48	113.75	108.24	112.71	114.48
Lat. Gastroc. Total Lg. / Tibia Length	116.25	107.06	112.83	114.48	116.25	107.65	111.31	114.48
Ach. tend. Lg. on Fusion Point / Tibia Length	57.53	44.71	54.53	54.48	60.00	47.06	54.88	54.48
Med. Ach. teng. Lg. / Tibia Length	55.00	38.24	46.83	42.76	53.75	45.88	46.81	41.38
Lat. Ach. tend. Lg. / Tibia Length	40.00	28.24	40.14	25.52	38.75	36.47	38.95	24.14
Gastroc. Max. Breadth/ Tibia Length	17.50		22.60		15.00		22.38	
Soleus Total Lg. / Tibia Length	96.25	91.76	92.45	99.31	93.75	92.35	92.09	100.00
Soleus Max. Bredth/ Tibia Length	11.25		18.04	13.79	11.25		18.71	13.79
Med. Ach. tend. Length/Med. Gastroc. Total Length	48.35	35.52	41.07	37.35	47.25	42.39	41.38	36.15
Lat. Ach. tend. Length/Lat. Gastroc. Total Length	34.41	26.37	36.22	22.29	33.33	33.88	34.74	21.08
Med. Ach. tend. Length/ Med. Gastroc. Belly Length	93.61	55.08	69.81	59.62	89.58	73.58	71.37	56.60
Lat. Ach. tend. Length/ Lat. Gastroc. Belly Length	52.46	35.82	56.49	28.68	50.00	51.24	53.71	26.71

In brief, there is no striking age change of the relative linear measurements and the majority of the proportions for the fetus is similar to those for adult forms, with the exceptions of the proportions of the total length of the gastrocnemius and of the Achilles tendon to the tibia length manifest diminution during growth.

A comparison of the relative linear measurements for various species of the primates is shown in table 7. There is no considerable specific disparities in the proportion of the gastrocnemius length on both sides to the tibia length, that of medial side is 114.48% for the dusky lutong, 113.75% the sbuirrel monkey, 113.60% for the Japanese macaque and 107.64% for the rhesus monkey. These proportions for the prosimian, the platyrrhine and catarrhine monkeys, examined by Frey (1919), fall within the range from 110% to 120%, which significantly differ from the range, between 120% and 135%, for the anthropoid ape and man.

In the proportion of the Achilles tendon length on the medial side to the tibia length, the highest percentage is 60.02% for man, 55.00% for the squirrel monkey, which follows next. Gibbon falls within the same range from 40% to 50%, as that for the dusky lutong and Japanese macaques, while the great apes, such as the chimpanzee (17%), gorilla (22%) and orang (38%), have a much shorter Achilles tendon relative to the tibia length. On the lateral side, man has the greatest percentage of 66%, as well as on the medial side, The dusky lutong has the least of 25.52%. Among the anthropoid apes, the gibbon and orang with the percentage of around 50% differ from the chimpanzee and gorilla whose ratio is 38%. Japanese macaques, the rhesus monkey and squirrel monkey show the similar percentage of 40% to that on the medial side. The proportionally longer Achilles tendon for man is again revealed in the proportion of the Achilles tendon length to the length of the gastrocnemius, the percentage on the medial side being the greatest for man (48.50%), and the least for the rhesus monkey (35.53%). The squirrel monkey is the only species who rivals man and shows 48.35%, although this proportion is nearly constant for Japanese macaques (41.07%) and the dusky lutong (37.35%). The length of the Achilles tendon for the monkey is longer on the medial side than on the lateral side, differing from that for the anthropoid ape and man reversely. As a result, the specific difference observed on the lateral side is more pronounced. The proportion of the Achilles tendon length to the length of muscle belly of the gastrocnemius shows the same result as observed in the above proportions.

There is no remarkable specific difference in the proportion of the soleus length to the tibia length, which falls between 90% and 100%, while the dusky lutong (99.31%) and squirrel monkey (96.25%) have a much longer soleus than Japanese macaques (92.45%) and the rhesus monkey (91.76%). The squirrel monkey and dusky lutong have narrower soleus relative to the tibia length, with the percentage of 11.25% and 13.79% respectively, than the great ape (24–25%), and man (47.00%) whose percentage reaches its maximum. Japanese macaques (18.04%) and the orang (18%) occupy an intermediate position between the squirrel monkey and the dusky lutong on the one hand and the great ape and man on the other.

In summary, the monkey has shorter gastrocnemius and narrower soleus than the ape and man, the latter having the longest gastrocnemius and the broadest soleus among the primates. The proportionally longer Achilles tendon is one of the most characteristic features for man, although the great ape has short Achilles tendon even as compared with the monkey. In comparison with the length of this tendon on the lateral side, that on the medial side is longer in the monkey, but shorter in the anthropoid ape and man.

Discussion

On the triceps surae of Japanese macaques, as other species of the primates examined in this study, the relative weight and relative linear measurements show no statistically significant differences between the right and the left side and also between the male and the female.

There has been hitherto no detailed mention of the age changes of the relative weight and the relative linear measurements of this muscle. From this study it is indicated that in the relative weight, the ratios of the gastrocnemius and of the soleus to the crural musculature increase slighty in parallel with each other during growth, and as a result, the ratio of the soleus to the gastrocnemius, which varies considerably according to the species of the primates including man, changes little with age. There is no striking age change of the relative linear measurements, with the exceptions of the proportions of the length of the gastrocnemius, the soleus and the Achilles tendon to the tibia length which decrease with age. Consequently, it may be concluded that the components of the triceps surae in Japanese macaques grow with age in preserving the proportion characteristic of their species from the fetal life to adulthood.

A comparison of the relative linear measurements of this muscle for various species of the primates reveals that the monkey has shorter gastrocnemius and narrower soleus than the ape and man. The great ape has short Achilles tendon even as compared with the monkey. Judging from the relative weight of the soleus, the large soleus for man contrasts markedly with that for the monkey, and the anthropoid ape stands between man and the monkey, approaching the latter rather than the former. Here it must be mentioned that the relative weight of the soleus to the gastrocnemius increases with age in man and the squirrel monkey, but does not show any change in Japanese macaques. From the above mentioned discussion, it is confirmed that the human soleus grows more markedly than the gastrcnemius, especially in its breadth rather in its length, while the soleus of Japanese macaques increases in parallel with the gastrocnemius, in preserving the same proportion of its width to its length from the prenatal to the adult form.

The differences of the measurements of the triceps surae for the monkey, ape and man are closely related to the differences of their posture and the mode of progression. As analyzed by Haxton (1947), when the lower limbs act as propulsive strut in upright posture and erect bipedal gait in man, the one-joint muscle soleus must be powerful to flex the planta, as is the gastrocnemius. But if the gastrocnemius were proportionally large and powerful its contraction would throw a considerable strain on the knee extensor at a time when the latter was being actively used for propulsion. From this reason it is more efficient that man should have a one-joint ankle flexor, the soleus, with a reduction in size of the two-joint gastrocnemius and plantaris. In the quadrupedal monkey, when the hind limbs are used as a propulsive lever, the chief power of progression is applied by the biceps femoris and at the same time to prevent passive extension of the knee and ankle joints, the powerful hamstrings and the gastrocnemius must act. Hence, the relatively larger gastrocnemius for the monkey seems to be reasonable.

In the chimpanzee, the soleus with considerable size indicates the increased importance of plantar flexion for progression in semi-erect postural attitude, in spite of thier quadrupedal gait. And in gibbon, the action of the gastrocnemius in flexion of the knee joint is important in the normal locomotion, as in the quadrupeds. This would give the gibbon the large gastrocnemius. On the other hand, the brachiating gibbon is able to walk and run bipedally more easily than any other apes. For this reason, the gibbon has larger soleus in relation to the gastrocnemius than the monkey but smaller one than man.

It should be also very valuable that man has the proportionally longest Achilles tendon and the great ape the shortest as already pointed out by Frey (1913). Since the Achilles tendon, as is the soleus, is possibly very important for steadying the leg on the foot in the standing position, the great ape may not require long tendon part but do the powerful muscle belly part.

Finaly, stricter analysis of the relation between the locomotive apparatus and the postural and locomotive mode of the primates, should be developed by the more detailed anatomical observations on abundant materials and the comparative studies on the function of this muscle during progression.

I should like to express my gratitude to the Japan Monkey Centre for affording me an opportunity for investigating materials in this study.

References

Chudzinsky, T., 1894. Quelques observations sur le muscle jumeau de la jambe. Bull. Soc. Anthrop., Paris, 5: 468-499.

Endo, M., 1938. Kompar-anatomia studo pri la pezo de muskoloj. Mittelungen der Medizinisohen Gesellschaft zu Tokyo, 52: 584-594. (in Japanese)

Frey, H., 1913. Der Musculus triceps surae in der Primatenreihe. Morphl. Jahrb., 47: 1-191.

Haxton, H.A., 1947. Muscles of the pelvic limb. A study of the differences between bipeds and quadrupeds. Anat. Rec., 98: 337-346.

Huttel, W., 1953. Contribution a l'anthropologie du noir d'Afrique. I-II. Acta Trop., 10: 134-140.

Loth, E. 1911 a. Anthropologische Beobachtungen am Muskelsystem der Neger. Korresp. -Bl. d. Ges. Anthrop. Ethnol. & Urgesch., 42: 117.

Loth, E. 1911 b., Über die Notewendigkeit eines einheitlichen Systeems bei der Bearbeitung der Rassenweichteile. Verh. Ges. d. Naturf. & Ärzte, 83: 469.

Matsushima, H., 1927. On the weight of muscles in Japanese. Acta Medica, 1: (in Japanese)

Schultz, A.H., 1937. Fetal growth and develoment of the rhesus monkey. Carnegie Inst. Wash. Contrib. Embryol., 26: 71-101.

Seki, N.. 1950. Messung des Skeletes und der Muskeln, die zur Fersenhebung dienen. Acta Anat. Nippon, 25: 55-59. (in Japanese)

Suzuki, M., 1954. Anthropological observation of the calf of the living Japanese. Bulletin of Shinshu University, 4: 73-78. (in Japanese with English summary)

Tappen, N.C., 1955. Relative weights of some functionary important muscles of the thigh, hip and leg in a gibbon and in man. Am. J. Phys. Anthrop., n.s. 13: 415-420.

Theile, F.W.. 1884. Gewichtsbestimmungen zur Entwicklung des Muskelsystems und des Skellettes beim Menschen. Verh. K. -Leopold- Carol. Dt. Akad. Naturforsch., 46: 134-471.

William, G.D., G.E. Grim, J.T. Wimp & T.F. Whayne, 1930. Calf muscles in American whites and negroes. Am. J. Phys. Anthrop., 14: 45-58.

Yazaki, H., 1959. On the weight of muscles of the lower extremities in Japanese fetuses. Anthrop. Reports, 25: 1-30. (in Japanese with English summary)