### Title

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On the Muscles of the Thigh in Macacus cyclopsis

Part 2. The extensor group of the thigh

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This department, under the supervision of Prof. J. SATOH, has been engaged in the statistical anatomical study of Macacus cyclopsis in which a large number of animals are examined to determine the normal condition (standard type) of the muscles, blood vessels, nerves and other systems of this animal. One of the authors, FUKUDA,* previously in 1960 reported on the study of the flexor muscles of the thigh which had been conducted as a part of this project. In the present report the findings obtained subsequently on the extensor muscles of the thigh will be presented.

MATERIAL AND METHOD

The material consist of 50 bodies of adult Macacus cyclopsis (100 lower limbs) selected from among Professor SATOH's specimen that are preserved in this department. This sample is the same as that used previously by FUKUDA. These animals after capture and strangulation were immediately fixed by injection of 10% formalin into the femoral artery and then preserved in 10% formalin solution.

Gross anatomical inspection of the origin and insertion of the muscles was made and the nerve supply was studied with the use of a loupe or binocular magnifying lenses as necessary.

FINDING AND CONSIDERATIONS

I. Origin and Insertion of the Extensor Muscles of the Thigh (Figures 1, 2, 3)

The extensor group is composed of the sartorius and the so-called quadriceps femoris. The latter is separated into four muscles; the rectus femoris, the vastus medialis, the vastus intermedius and the vastus lateralis.

1) The sartorius

The sartorius is a thin, narrow muscle which lies superficially and

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Fig. 1 Medial side of thigh (muscles of superficial layer)

1. M. sartorius
2. M. rectus femoris
3. M. vastus lateralis
4. M. vastus medialis
5. M. tensor fasciae latae
6. M. iliacus
7. M. pectineus
8. M. adductor longus
9. M. gracilis
10. M. semimebranosus accessorius
11. M. semitendinosus
12. M. gastrocnemius
Fig. 2  Medial side of thigh (muscles of deep layer)

1. M. sartorius
2. M. rectus femoris
3. M. vastus lateralis
4. M. vastus medialis
5. M. vastus intermedius
6. M. tensor fasciae latae
7. M. iliacus
8. M. pectineus
9. M. adductor longus
10. M. gracilis
11. M. semimembranosus prop.
13. M. semitendinosus
14. M. gluteus medius
15. M. gluteus minimus
16. M. gastrocnemius
17. M. popliteus
18. M. adductor magnus
passes obliquely along the ventral surface of the thigh from the upper lateral thigh to the medial surface of the leg.

This muscle arises from the middle of the anterior edge of the ilium, slightly below the anterior superior spine of the ilium. Its origin is covered on the lateral side by the tensor fasciae latae and on the medial side by the iliacus. There always is fusion with the origins of these two muscles. The origin most commonly is muscular (79%), but there are instances in which the medial portion of the origin is tendinous (14%) and others in which the dorsal portion of the origin is tendinous while the ventral part is muscular (60%). In a very rare case, the origin was tendinous (1%).

This muscle runs to the leg where it crosses over the tibial collateral ligament and, after a slight increase in width, inserts by muscle into the medial and anterior surfaces of the upper part of the tibia below the knee joint line.

At the attachment, there may be firm union (32%) or only mild membranous union (53%) or no union (15%) with one part of the common tendon of the gracilis and the semitendinosus which inserts below and dorsal to this muscle. There are cases in which this muscle may be longitudinally separated into two parts in the region of insertion (2%). There was one case in which the terminal end of the insertion of this muscle completely fused with the muscle fibers of the insertion of the gracilis.

The origin of this muscle is reported to be lower in anthropoid ape than in man, being from the anterior edge of the ilium between the iliacus and the gluteus minimus (Hepburn). The area from which it arises is said to be smaller in higher monkeys (Beattie). The origin of this muscle in Macacus cyclops is considerably low and the area from which it arises is quite extensive the average distance from the spina iliaca anterior superior to the most distal point of the origin of this muscle being 4.5 cm. Moreover, the origin of this muscle in Macacus cyclops is muscular in almost all cases and in large the insertion also is muscular (Preuschoft, Ikari, Steffens). In contrast to this, the origin usually is tendinous in many anthropoid apes and man (Raven, Michalis, Frohse, etc.).

There were two cases in which this muscle was longitudinally divided into two parts near the insertion but such division of the muscle may be observed in man. There are reports of longitudinal division of the belly of the muscle into two parts and even separation of the origin into three parts (Ikari) while division along the entire length of the muscle has been reported in Negroes (Macalister).

Furthermore, the insertion of this muscle is said to be more distal in monkeys than in man (Kohlbrugge). In man the insertion is considered to be more distal in Negroes and the Ainu race as compared
with others (Anthony et Hazard, 1983; Shiina, 1953). However, the insertion in Macacus cyclopsis did not seem to be particularly low. Also, the insertion was always muscular in Macacus cyclopsis and there was no case in which it is tendinous as it is in man. Consequently, there is no formation of the so-called Pes anserius.

2) M. rectus femoris

This muscle arises by tendon and in rare instances by muscle (2%) from the under region of Spina iliaca ant.inf. that is from along the border between the acetabulum and the ilium. The medial side of this muscle is adjacent to the iliacus while the lateral side is adjacent to the tensor fasciae latae and the gluteus minimus but fusion is hardly seen at all. The only fusion that occurs is the loose connection of the upper fourth of this muscle with the gluteus minimus (44%) and in a few cases there is union between the tendon of origin of this muscle with the fascia on the lateral side of the iliacus (12%). The origin of this muscle usually is by a single head. However, there are rare instances in which the tendon of origin is separated into two parts (5%); one is a narrow, short but strong tendon from the lower half of the ilium anteroinferior to the origin of the gluteus minimus and the other is a broad, thin tendon from the lateral surface of the ilium. The belly of this muscle is fusiform and descends along the superficial layer of the vastus intermedius and inserts into the middle of the patella after uniting with the tendon of insertion formed by other vastus muscles. The insertion is usually muscular on its upper surface and tendinous on its lower surface. There are a few cases in which the insertion is entirely tendinous (9%).

There was an exceptional case in which the entire muscle except the origin was completely fused with the vastus intermedius and inseparable.

This muscle usually is considered to arise by two heads though there are some instances in which it is by a single head. In anthropoid ape it is said to arise by a single head in some cases and by two heads in others with many individual variations (Sonntag, 1939; Piran, 1957; Hepburn, Preuschoft). In my cases of Macacus cyclopsis the origin as a rule was by a single head as is the condition in Hylobates and Macacus rhesus. There were a few cases in which there was separation of the origin into portions which is considered to be an incomplete form of origin by two heads.

3) M. vastus lateralis

This muscle is the largest among the quadriceps femoris and is located on the lateral side of the rectus femoris. The origin, which usually is tendinous, is from the middle lateral surface of the greater
trochanter with one portion being from the lateral surface of the femur below the greater trochanter. This muscle inserts into the lateral portion of the common tendon of insertion of the other muscles of the quadriceps femoris. The insertion of this muscle is united with the tendon of insertion of the vastus intermedius (78%), but there was no instance in which this fusion occurred at the level of the belly of the muscle. There was a case in which the lower third of the belly of the muscle was firmly adhered to the lateral portion of the rectus femoris. In rare cases, the distal part of this muscle was completely covered by the rectus femoris (6%).

My finding regarding the origin of this muscle in *Macacus cyclopsis* agrees with that for man, *Gorilla* and *Macacus rhesus* (RAVEN, OKUDA). The condition is said to be a little different in *Chimpanzee* and *Hapale* in which no origin is seen from the lateral surface of the crest of the femur (SONNTAG, BEATTIE).

Review of the relation between the origin of this muscle and gluteal muscles shows that there is only a loose attachment with the gluteus minimus. In *Macacus cyclopsis* there is no fasciculus connecting this muscle with the gluteus maximus such as reported to be seen in all human fetus (IKARI, ECKSTEIN). The frequency of attachment of the insertion with the vastus intermedius (78%) is not very different from the frequency in human fetus (74%), but the frequency at which the lower tip of this muscle is covered by the rectus femoris is less than frequency in human fetus (28%).

The adhesion of the belly of this muscle with the rectus femoris seen in some of my cases of *Macacus cyclopsis* has been reported in Negroes and Papuan fetuses (STEFFENS, ECKSTEIN).

4) M. vastus medialis

This muscle usually arises from the area extending from the medial surface of the lesser trochanter to the lateral edge of the greater trochanter. In rare instances, it may arise from the crest of the upper third or upper half of the shaft of the femur (6%).

The medial edge of the origin most frequently is tendinous (61%). The lateral part of origin is covered by the insertion of the gluteus minimus while one part of the medial side is covered by the iliacus with mild fusion with these muscles in rare instances (7%).

In the majority of cases it is united with the origin of the vastus intermedius and inseparable (52%).

This muscle descends between the adductor longus and the rectus femoris. It unites with the lower parts of the other quadriceps to form a very short common tendon which inserts into the medial edge of the patella. However, the ventral side of the lower half of this insertion is muscular in the greater majority of cases (72%). There was one case in which the insertion was muscular on both sides and in several cases the distal portion of this muscle was fused with the insertion of the
rectus femoris and inseparable.

The common tendon of the adductor longus and the anterior portion of the adductor magnus inserts into the middle of the belly of this muscle to form the adductor canal.

The inseparable fusion of one part of the origin of this muscle with the vastus intermedius such as seen in Macacus cyclopsis may also be found in human fetus of Pauans and Negroes (Steffens, Eckstein). The frequency at which this muscle is seen fused with the tendon of insertion of the rectus femoris in Macacus cyclopsis (74%) is much more higher than in fetus (40%) whereas the frequency of fusion with the vastus intermedius is much higher in human fetus (70%) than in Macacus cyclopsis (44%).

5) M. vastus intermedius

This muscle is located in the lower layer of the rectus femoris at between the vastus medialis and the vastus lateralis. It arises by muscle in general from the anterior surface of the lower femur and inserts into the anterior surface of the capsule of the knee joint by a common tendon with the other vastus muscle. As previously mentioned, there was one case in which this muscle a short distance from its origin fused with the belly of the rectus femoris to become a single muscle which inserted into the anterior surface of the femur with a common tendon being formed with the vastus medialis and the vastus lateralis.

There was no case in which the deep fasciculus of this muscle formed an independent so-called articularis genu that attaches to the capsule of the knee joint. In a few cases, the muscle fibers which attach firmly to the anterior surface of the femur were separated from the vastus intermedius by a thin fascia (10%).

The level at which this muscle arises in Macacus cyclopsis generally is the same as in Macacus rhesus (Howell, Okuda) and Hapale (Beattie) but is slightly higher than in Chimpanzee (Sonntag). The fascia seen at both ends of insertion in Macacus cyclopsis may also be found in Gorilla but in this instance it is a broad, thin, flat tendon (Raven).

The articularis genu, which was incomplete in my cases, is a thin, flat fasciculus in man that arises from the middle of the anterior surface of the shaft of the femur and inserts into the capsule of the knee joint. In Gorilla it may be the same as in man or occasionally absent. It is considered to be absent in Chimpanzee and Macacus rhesus (Raven, Hepburn, Preuschoft, Sonntag, Champneys, Howell). However, Okuda has noted a considerable number of cases in which there was an incomplete trace of the articularis genu in Macacus rhesus (40%). In conclusion, it appears that this fasciculus is not sufficiently independent yet in monkeys.
Fig. 3  Lateral side of thigh
1. M. sartorius
2. M. rectus femoris
3. M. vastus lateralis
6. M. tensor fasciae latae
11. M. semimembranosus prop.
13. M. semitendinosus
16. M. gastrocnemius
18. M. adductor magnus
19. M. quadratus femoris
20. M. gluteus maximus
21. M. biceps femoris
II. Nerve Supply to Extensor Muscles of the Thigh (Figures 4)

This group of muscles is supplied by the femoral nerve. This nerve descends lateralward between the psoas major and the iliacus, and passed downward under the Arcus tendineus of the inguinal region along the lateral side of the femoral vein to the anterior surface of the thigh where it divides into muscular branches, cutaneous nerves and its terminal branch, the saphenous nerve.

After the femoral nerve emerges on the anterior surface of the thigh, the muscular branches that supply the extensor muscles of the thigh immediately separate into medial and lateral groups of nerves, which is centered around the saphenous nerve. The medial group of nerves supplies the pectineus and the sartorius while the lateral group innervates the quadriceps.

1) The nerve located in the middle of medial group of nerves becomes the saphenous nerve, the terminal branch of the femoral nerve which runs to the lower thigh. As this nerve passes through the adductor canal, it first lies on the lateral side of the femoral artery but later crosses over to the other side. This crossing to the other side
occurs most frequently below the tendinous adductor muscle in the vicinity of the area of bifurcation of the popliteal artery (42%). In other cases, it may be even lower at the region of the union of the sartorius with the gracilis at the knee (34%), or sometimes within the tendinous adductor canal (16%) or at a higher level (8%).

Of the small branches which are given off from the saphenous nerve, there is one small branch which is sent off from above the knee joint toward the upper medial side of the capsule of the joint. From this nerve another sub-branch runs to beneath the skin either after piercing the sartorius or without piercing this muscle and supplies the fascia. Another small branch sinks into the deep portion from the medial edge of the knee joint to become the articular branch.

2) The most medial branch of the medial group of nerves supplies the pectineus but the location at which this branch arises is variable. It most frequently separates slightly below the Arcus tendineus (66%) with other instances in which it separates at about the same level (24%) or higher (10%). There was one case in which the separation occurred very high on both sides.

There was no case in which nerve supply to the pectineus was absent. Occasionally, the nerve supply was by the lateral branch (2%) and there was a case in which the supply was by a branch from the medial intermediate branch (1%). In one case the muscular branch to the pectineus sent off a cutaneous branch.

3) The most lateral branch of the medial group enters the sartorius from its lower surface at the level of the upper third of this muscle.

4) The lateral group of nerves pass between the rectus femoris and the vastus medialis to supply the quadriceps femoris. Of these nerves, the most lateral branch enters the origin and the upper third or middle third of the rectus femoris from its dorsal surface.

5) The most medial branch enters the upper third of the vastus medialis.

6) The intermediate branch supplies the medial deep portion of the origin and middle second of the vastus lateralis, and the lateral side of the origin and upper third of the vastus intermedius. This branch subdivides into many small branches with many variations in its condition.

7) The various branches of the femoral nerve, except for the branch to the pectineus, supply the extensor group in different combinations
and with intercommunications between the branches. The most lateral branch of the medial group which supplies the sartorius is in particular highly variable. That is, the most lateral branch of the medial group may be an independent branch (53%), or form a common trunk with the medial and intermediate branches (32%). In other cases there may be common trunk formation of the most lateral branch with the lateral branch (12%), or with the most medial branch of the lateral group (2%) or with the lateral branch and intermediate branch (1%).

8) There are no common branches to the vastus medialis or the vastus lateralis from the most lateral branch of the lateral group of nerves supplying the rectus femoris. However, there are many common branches to the vastus intermedius.

The distribution of the femoral nerve in Macacus cyclopsis is generally the same as described for Macacus rhesus (Howell and Straus). The femoral nerve in Chimpanzee is divided into anterior and posterior branches and it is reported that a part of the anterior branch may supply the gracilis (Sonntag). The former corresponds to the medial group of nerves in my cases while the latter corresponds to the lateral group of nerve but such an exceptional state of distribution was not seen in any of my cases of Macacus cyclopsis.

The saphenous nerve which is the continuation of the main trunk of the femoral nerve accompanies the great saphenous vein downward in man. Due to the absence of the great saphenous vein in Macacus cyclopsis, it descends with the saphenous artery, which is one of the terminal branches of the femoral artery, along the medial side of the knee joint to the lower leg.

The sartorius in Chimpanzee is supplied by the main branch of the saphenous nerve. Even the lower part of this muscle may be innervated by a small branch from the saphenous nerve which is different from the condition in man (Hepburn, Champneys). In Macacus cyclopsis, the upper part of this muscle is only occasionally supplied by the saphenous nerve and the lower part is not supplied by the saphenous nerve at all as in man. Even when a small branch enters this muscle, it penetrates to become cutaneous and in no case does it terminate as a muscular branch.

It is reported that in Gorilla, a branch is frequently given off from the muscular branch to the sartorius that sinks into the deep portion between the iliacus and the rectus femoris and then presumably goes to the hip joint (Raven). Such a branch was not seen in Macacus cyclopsis. However, one articular branch to the knee joint was a small branch from the saphenous nerve. According to Omori the articular branch to the knee joint from the saphenous nerve in monkey only supplies the tibial half of the knee. The articular branch from the branch to the vastus intermedius noted by him in monkey could not be
seen in the study of *Macacus cyclopsis*.

The nerve supply to the articularis genu in *Gorilla* is provided as in man by a branch that penetrates the lower part of the vastus intermedius of this muscle (RAVEN). In my cases in which there were fasciculi which were presumed to be the articularis genu, there was no such small branch supplying this fasciculus.

**SUMMARY**

A total of 100 lower limbs from 50 bodies of *Macacus cyclopsis* were used in a statistical, gross anatomical study of the origin, insertion and nerve supply of the sartorius, and the quadriceps femoris which comprise the extensor group of the thigh. In addition, comparison was made with the findings reported for other primates.

1) **M. sartorius**

This muscle which usually arises by muscle from the middle of the anterior edge of the iliac, lies superficially and runs obliquely along the anterior surface of the thigh to the leg where it attaches to the medio-anterior surface of the upper part of the tibia. There are varying degrees of fusion or union with the tensor fasciae latae and the iliacus in the region of origin and with the common tendon of the gracilis and the semitendinosus in the part of insertion. In rare instances, the belly of the muscle in the region of insertion may be longitudinally divided into two parts.

The nerve supply is by the most lateral sub-branch among the lateral branch of the femoral nerve.

2) **M. quadriceps femoris**

This muscle consists of the rectus femoris, the vastus lateralis, the vastus medialis and the vastus intermedius. The rectus femoris arises from the iliac along the posterosuperior rim of the acetabulum while the other three arise from the femur. These muscles form a common tendon by which insertion to the patella is accomplished.

Exceptional cases include those in which there were two tendons of origin of the rectus femoris and one case in which the belly of the rectus femoris was completely fused with the vastus intermedius to form a single muscle which directly inserted into the anterior surface of the femur. There were several cases in which a fasciculus given off from the deep layer of the vastus intermedius attached to the capsule of the knee joint and this suggested the so-called articularis genu.

The nerve supply is by the lateral branch of the femoral nerve.

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