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VARIATIONS IN PLANTARIS MUSCLE MORPHOLOGY AND THEIR CLINICAL SIGNIFICANCE: A CASE REPORT

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ABSTRACT

Purpose:- Plantaris is considered a vestigial muscle in humans with a small belly and long thin tendons. It is known to present several anatomical variations in terms of its occurrence, origin, course, relation with surrounding neurovascular structures, and insertion. It may be absent unilaterally or bilaterally. On rare occasion, its double occurrence has been reported also. Usually, the origin of this inconspicuous muscle begins at the lateral supracondylar line of the femur and the knee joint capsule. It continues distally, forming a long and slender tendon. In most cases, it inserts onto the calcaneal tuberosity on the medial side of the Achilles tendon. However, many morphological variations have been discovered during anatomical dissections. **Methods:-** This study was carried out in the Department of *Rachana Sharir*, Postgraduate Institute of Ayurveda, Dr Sarvapalli Radhakrishn Rajasthan Ayurveda University, Jodhpur by Professor Mahendra Kumar Sharma and Dr. Shyoram Sharma in August 2022 to September 2023, on a total of 7 cadavers. The dissection of the thigh, knee, crural, and talocrural region was performed using standard techniques according to a strictly specified protocol. **Results:-** Four different insertion points were observed. The first band (A) was inserted near to the tarsal canal flexor retinaculum. The second band (B) bifurcates into two branches—B1 and B2. B1 is located on the medial side and B2 is located on the lateral side of the calcaneal tuberosity. The third band (C) is inserted into the superior nonarticular calcaneal surface of the calcaneus

anteriorly to the Achilles tendon. **Conclusion:-** Considering the above discussion, though minor differences have been observed between the present study and earlier reports related to plantaris, prior knowledge about such possible variation will definitely supplement the understanding of muscular variation of the posterior crural region.

KEYWORDS: Achilles tendon, Anatomy, Evolution, Plantaris muscle, Plantaris tendon.

INTRODUCTION

Plantaris belongs to a superficial group of flexor muscles of the posterior crural compartment along with gastrocnemius and soleus and thus form the bulk of the calf. The lower leg divides into three fascial compartments; Anterior, Lateral and Posterior.

These compartments are formed and separated via divisions by the anterior and posterior intermuscular septa, and the interosseous membrane. Each compartment contains its distinct set of muscles, vasculature, and innervation: The anterior compartment musculature functions to primarily dorsiflex the foot and ankle, the lateral compartment musculature functions to plantar flex and evert the foot, posterior compartment musculature functions to plantarflex and invert the foot.

The posterior compartment of the leg (often referred to as the "calf") further divides into distinct superficial and deep compartments by the transverse intermuscular septum. The larger, superficial compartment of the lower leg contains the gastrocnemius, soleus (GS) and plantaris muscles.

The deep layer of the leg's posterior compartment contains the popliteus, flexor digitorum longus, flexor hallucis longus, and tibialis posterior muscles. The various muscles of the posterior compartment primarily originate at the two bones of the leg, the tibia, and the fibula. The tibia is a large weight-bearing bone, often referred to as the "shin bone," and articulates with the femoral condyles superiorly and the talus inferiorly. The fibula articulates with the tibia laterally at proximal and distal ends; however, it has no involvement in weight bearing.

Structure and Function

The divisions of the lower leg are made up by intermuscular septa that are extensions of the overlying fascia. Within the posterior compartment of the leg, an additional septum further separates the compartment into two additional layers; superficial and deep. It was

traditionally felt that the fascia overlying specialized organs and tissues within the body are irrelevant and only served to hold in place a particular tissue type. However, current thinking realizes that fascia, such as that of the posterior leg compartment, are not only involved in creating osteofascial compartments for muscles but also provide protective tunnels for neovascular bundles irrespective of limb positions, facilitate venous return, act as protective sheaths, dissipate external pressures, and are clinically significant in the spread or containment of infections.

Embryology

Limb development in the human embryo originates from mesenchymal tissue, derived from the lateral plate of the mesoderm, encased within the ectoderm. Outgrowths of the lateral plate mesoderm, referred to as limb buds, arise in the middle of the 4th week in utero under the influence of signaling from mTORC1. The exact morphogenesis of these limb buds is dependent upon several transcription factors, and each limb bud develops a positional value with respect to the proximo-distal, anteroposterior and dorsoventral axes of the fetus. Depending on its position, a slew of specific transcription factors may be expressed, including retinoic acid, fibroblast growth factor, sonic hedgehog, and hoxc6, allowing for the development of the particular upper or lower limb.

Blood Supply and Lymphatics

The posterior compartment of the leg receives vascular supply from the posterior tibial artery. This artery is a continuation of the popliteal artery, with the latter arising from the femoral artery. The posterior tibial artery supplies various muscles of the posterior compartment via its muscular branches and also supplies the tibial bone via the nutrient artery of the tibia. The posterior tibial artery provides a fibular artery as well. The fibular artery not only provides blood supply via muscular branches to specific posterior compartment muscles, but it also provides the nutrient artery of the fibula. The posterior tibial artery continues towards the foot where it divides into the medial and lateral plantar arteries. The posterior tibial artery travels deep to the triceps surae muscle within the intermuscular septum and travels along with the tibial nerve.

Nerves

The tibial nerve provides innervation of the posterior leg compartment. This nerve is the larger branch of the sciatic nerve which divides into the tibial nerve and common fibular (peroneal) nerve at the popliteal fossa. The tibial nerve continues along the length of the leg

and into its terminal branches known as the medial and lateral plantar nerves. Both the common fibular nerve and the tibial nerve innervate various muscles of the posterior leg. The tibial nerve provides the medial sural cutaneous nerve, which unites via the sural communicating branch from the common fibular nerve to create the sural nerve. The sural nerve supplies skin overlying the lateral and posterior leg.

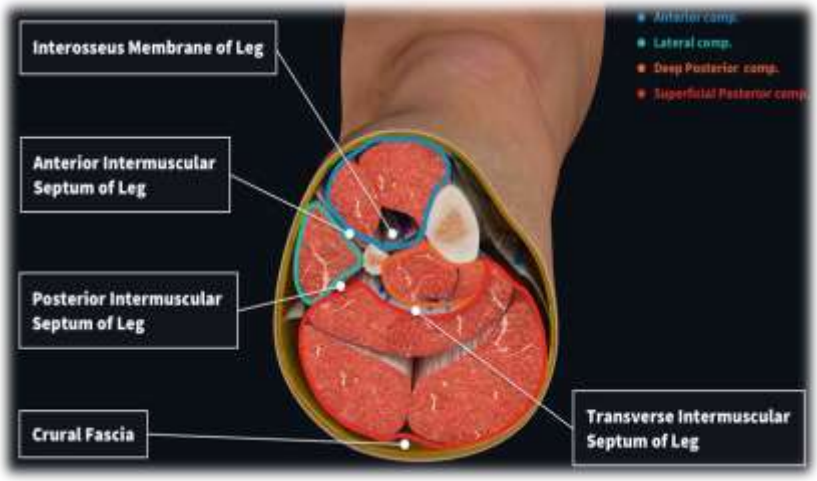


Fig. 1: A Muscles compartment of the leg.

Muscles

Muscles of the posterior compartment are in two subdivisions: A superficial and deep layer.

Superficial posterior muscles

The gastrocnemius muscle is made up of separate lateral and medial heads. The medial is the larger of the two. The medial head originates at the femur and the medial femoral condyle whereas the lateral head originates at the femur and lateral femoral condyle. The gastrocnemius directly overlies the soleus muscle, and together these two muscles blend into a calcaneal (Achilles) tendon (AT), which inserts into the tuberosity of the calcaneus. Between the AT and the overlying superficial fascia is a sub-calcaneal bursa that allows for frictionless motion between skin and tendon.

A deep calcaneal bursa between the tendon and bone facilitates frictionless gliding of the tendon over the bone. The soleus muscle originates on the posterior surface of the fibula as well as the soleal line on the tibia. As a unit, the gastrocnemius and soleus muscles form the triceps surae.

Deep to the triceps surae lies the plantaris muscle. This muscle originates on the lateral supracondylar line of the femur and inserts onto the tuberosity of the calcaneus adjacent to the AT. The plantaris muscle is commonly a source of grafting material. The triceps surae muscles provide for plantar flexion of the foot. However, the gastrocnemius muscle itself can also facilitate flexion of the knee. The plantaris muscle allows minor plantar flexion as well.

Fig. 2: Muscles of posterior compartment of the leg.

Deep posterior muscle

The most superior muscle of the deep posterior compartment of the lower leg is the popliteus muscle. The popliteus has its origin at the lateral condyle of the femur and inserts onto the posterior tibial surface superior to the soleus muscle. The popliteus muscle facilities unlocking of the knee joint via internal rotation.

The flexor hallucis longus (FHL) originates from the posterior surface of the fibula and inserts into the base of the great toe's distal phalanx. The FHL tendon travels below the sustentaculum tali and is held in place by the annular ligament. The FHL muscle plantarflexes the talocrural joint and the metatarsophalangeal and interphalangeal joints of the great toe.

The flexor digitorum longus (FDL) muscles originate from the posterior surface of the tibia and inserts onto the distal phalanges of the 2nd to 5ith digits in the foot. The FDL muscle crosses both the talocrural joint and metatarsophalangeal joints, serving as an active plantar flexor of both joints. The FDL also plantarflexes the metatarsophalangeal and interphalangeal joints of the 2nd through 5th toes.

An accessory FDL muscle is said to be present in 15% of the population.Finally, the tibialis posterior muscles originate on the interosseous membrane and inserts onto the navicular tuberosity and cuneiform bones of the foot. Its tendon travels through the tarsal tunnel. The

tibialis posterior muscle provides for plantar flexion across the talocrural join and inversion of the subtalar joint.

The three muscles within the superficial posterior compartment include the gastrocnemius, soleus, and plantaris muscles. Together these three muscles form the triceps surae. The gastrocnemius is involved in plantar flexion of the ankle, while the knee is in extension, and also is involved in flexing the leg at the knee joint. The soleus is involved in plantar flexion of the ankle, irrespective of knee position. The plantaris, a muscle that is thought to be absent in 10% of the population, is also involved in plantar flexion of the ankle but plays a limited compared to the other two superficial posterior muscles. The deep posterior compartment muscles include the flexor hallucis longus, flexor digitorum longus, tibialis posterior and popliteus muscles. The flexor hallucis longus is primarily involved with flexing the big toe while also having limited contribution to plantar flexion of the ankle. Additionally, it supports the medial longitudinal arch of the foot. The flexor digitorum longus is involved in flexion of the other four toes of the foot, plantarflexion of the ankle as well, and also maintains the lateral and medial longitudinal arches of the foot. The tibialis posterior is primarily involved in ankle plantar flexion as well as inversion of the foot. The popliteus muscle controls weak flexion of the knee and medial rotation of the tibia. Independent activation, as well as coordination amongst the seven muscles of the posterior leg, is crucial in maintaining balance, facilitating gait, and allowing actions such as stair climbing, jumping, and landing.

Gait is most commonly subdivided into a stance phase and a swing phase (Although additional phases can exist depending on clinical scenario). The stance phase of gait can further divides into a heel strike (Where initial contact is made with the ground), a loading response (where the weight of the body is accepted), a midstance (Where the knee stabilzation occurs), and a terminal stance (Where mass is accelerated forward). During midstance and terminal stance, in particular, the plantar flexors of the ankle play a pivotal role as they eccentrically control dorsiflexion, and concentrically allow acceleration of the foot.

The muscle takes origin from lower part of lateral supracondylar line and oblique popliteal ligament. It becomes tendinous approximately at the level of origin of soleus from tibia in the proximal part of lower leg and the long thin tendon then passes downwards between medial head of gastrocnemius and soleus and is further continued along medial aspect of Achilles tendon. Finally, it gets inserted either independently or in association with Achilles tendon

into calcaneus. Due to structural resemblance of its slender tendon with nerve, it is often described as a ‘freshman’s nerve’.

It is regarded as a weak flexor of the knee and acts with gastrocnemius and soleus, thereby assisting in plantar flexion of the ankle. Due to the presence of high-density muscle spindles, it carries proprioceptive function for larger more powerful plantar flexors. Clinically, both the muscle belly and its tendon can be palpated respectively in the popliteal fossa and along the medial aspect of the Achilles tendon near its insertion. It has been reported that the nerve to plantaris arises from the tibial nerve as an independent branch or via the nerve to the lateral head of gastrocnemius.

Plantaris muscle has been observed to present frequent variations in terms of its occurrence, origin, course, relation with surrounding neurovascular structures, and insertion. A cadaveric study evaluated the incidence of muscle. The muscle was found to be present in all 14 legs but had different morphology of insertion having dorsal and ventral belly of the muscle. The muscle may be absent in 10% of cases. On rare occasions, it's unilateral and bilateral double presence. The aim of our study is to present a report of bilateral variation of plantaris muscle in the lower limb.

CASE REPORT

During routine dissection of lower limb involving popliteal region and posterior crural region of an approximately 65year-old male and female cadaver for final year m.d scholar showed the following unusual findings: Plantaris muscle was observed to be arising by two heads. One head (lateral) was thicker and arising from lower part of the lateral supracondylar line deep to the lateral head of the gastrocnemius and the other head (medial) was comparatively smaller and originated from the lower and medial aspect of the oblique popliteal ligament deep to the medial head of gastrocnemius (Figure 3). Very few fibers from the lateral head were seen to have connected with the lateral head of the gastrocnemius. After origin, the lateral head was directed downwards and medially and found to join soon with a medial head which was directed downwards and laterally to form a common slender tendon. The tendon was seen passing downwards deep to both heads of the gastrocnemius and soleus. The tendon was further followed throughout its course to locate its distal attachment. Finally, it was seen along the medial border of the tendocalcaneus to be inserted into the flexor retinaculum of ankle.

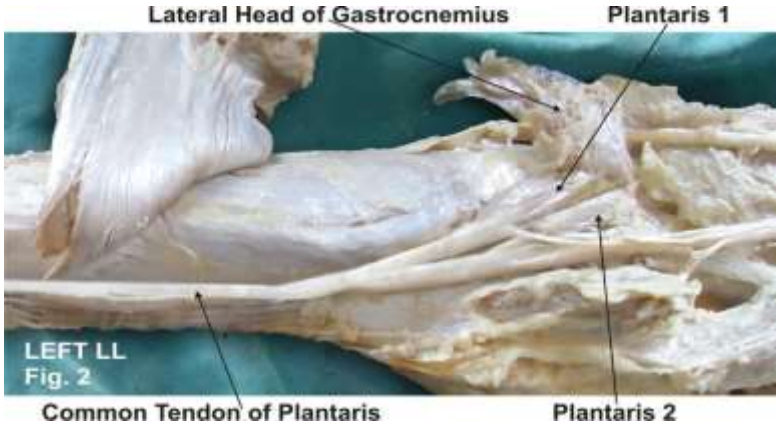


Fig. 3: Plantaris muscle origion variation.

One head of the plantaris muscle originated from the lower part of the lateral supracondylar line of the femur superior to the origin of the lateral head of gastrocnemius while the other head of the plantaris muscle originated from the oblique popliteal ligament.

Fig. 4: Plantaris muscle inseration.

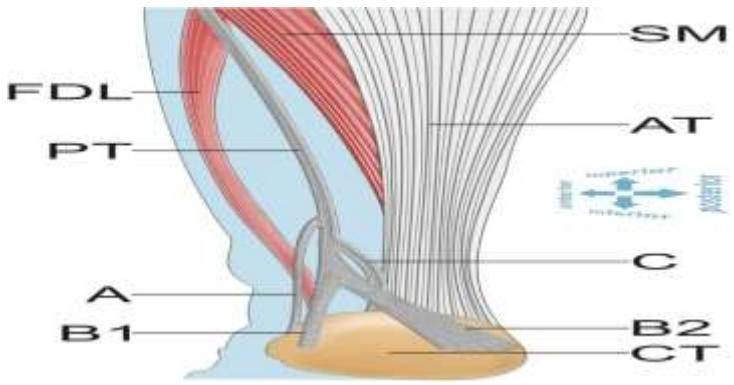
DISCUSSION

Plantaris muscle is known as vestigial muscle in human as its distal attachment has shifted secondarily well short of plantar aponeurosis to calcaneus due to the process of evolution for erect posture and bipedal locomotion1. Embryologically, it is considered as a derivative of the deeper portion of the lateral head of gastrocnemius and often represented as the third head of gastrocnemius or ‘gastrocnemius tertius’.

Our observation regarding the connection of a few fibers of the lateral head of this muscle with the lateral head of gastrocnemius thus could support the embryological explanations advocated by McMurrich. Anatomical variations of the muscle are not uncommon. The lower part of the lateral supracondylar line and posterior surface of lateral condyle of femur have been considered bilaterally as bicipital origin of the muscle. Tendon of such muscle was seen

to be merged with calcanean tendon. A distinct anomalous muscle on medial side of right leg was documented as second plantaris due to its morphological resemblance 8. Sawant SP et al 7 has described a rare variation of the muscle with presence of two heads taking origin from lower part of lateral supracondylar line and oblique popliteal ligament similar to our observations. The muscle with bilateral existence of two separate bellies was reported by Rana et al 9. In all previous reports, plantaris tendon was observed to pass between gastrocnemius and soleus. However, we observed a rare course of common tendon passing deep to both heads of gastrocnemius and soleus. Surgical intervention without knowledge of such deep seated plantaris tendon may lead to inadvertent damage to surrounding structures. Multiple variable insertions along with some rare variety including iliotibial band, lateral patellar retinaculum, iliotibial tract or as split attachments on posteromedial side of calcaneus have been described. Other than its usual bony insertion to the calcaneus, additional muscle with its tendon may be inserted into the crural fascia also. In this regard, we followed the common tendon to be fused finally with the flexor retinaculum which was also found in 28.84% of cases in a study done previously in adult Indians.

Despite of its vestigial nature, documentation of anatomical variation of plantaris muscle is clinically important. Variations in terms of its distinct interdigitations with the lateral head of gastrocnemius or having a strong fibrous extension to the patella may be responsible for patellofemoral pain syndrome. The muscle may get injured during surgical procedures because of its superficial attachment with the fascia of the leg and its long tendon resembling to nerve. Its tendon may also get entrapped between the tibial nerve and its branch to the soleus and produce compression neuropathy. Injury to the plantaris muscle and its tendon or associated tears of the gastrocnemius, soleus and anterior cruciate ligament may be regarded as an important cause of ‘Tennis leg’. Rupture of its tendon may be presented as non-specific lower leg pain.



CONCLUSION

Considering the above discussion, though minor differences have been observed between present study and earlier reports related to plantaris, prior knowledge about such possible variation will definitely supplement the understanding of muscular variation of posterior crural region

Conflicts of interest

The authors declare that they have no conflicts of interest.

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