Original Research Article

Plantaris a vestigial muscle, its corelation to muscular evolution and its clinical implications

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Abstract

Background: Muscular evolution in human is muscular adaptation from stiff quadrupedal walking to bipedalism. Transforming from pre hominid to hominid bipedals provide insights to mechanics of walking in human. Evolutions of legs in primates are surprising in human locomotion providing stability for walking. Plantaris muscle (PM) is regarded as vestigial muscle due to its weak contribution to calf muscles. Apes and prosimians show plantaris continuing with plantar aponeurosis. The objective of the study was to prevalence of the vestigial muscle plantaris, a corelation to evolution and its clinical implications. **Methods:** Dissection of plantaris muscle done in foetuses and its existence, nerve supply, and insertion recorded. **Result:** Of the 20 legs dissected, 6 legs showed absent plantaris muscle. Nerve supply was fom branch supplying deep crural muscles of leg. **Conclusion:** Review of evolution list shows marsupials which shared common genetic imprint with human had plantaris extending to plantar aponeurosis and with absent soleus muscle. Nerve supply to plantaris indicates that muscle is derived from anlage of the deep posterior crural muscles. Daselar and Anson reports verticalization of human posture lead to receding of insertion of plantaris from plantar aponeurosis to calcaneus. It is also reviewed that LCA of all primates had plantaris inserted to plantar aponeurosis.

Keywords: Plantaris muscle (PM), Plantaris tendon (PT), LCA (Last common ancestor), Prehominid, Primates, Bipedalism.

Introduction

Muscular evolution in human is muscular adaptations made by humans from the early ancestors to modern man. Evolution of human bipedalism was a progression from quadrupedal walking to modern gait. Understanding the nature of locomotion in our pre-bipedal primate ancestor (pre-hominid) and in early hominid bipeds provides insights into basic mechanics of walking in human [1].

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The first hominids (primates with upright bipedal gait) have evolved in Africa 5-6 million years ago [1]. From Aristotles thoughts of De Motu Animalium, Borelli's review on biomechanics in 1600, Muybridges's documentation of gaits in horses, animal movement are areas of research. De la Croix commented on 'pithecoid gait' the gait used by the early ancestors of man [2]. Evolution of the legs in primates is surprising as in human locomotion plantar flexors provide propulsion and stability [3].Plantaris muscle (PM) is regarded as vestigial by its slender diameter and weak contribution to calf muscle. Plantaris muscle is referred to as "Freshman's nerve" because of its long slender white tendon. This slender muscle with its long tendon has more of proprioceptive function than kinaesthetic sense of limb position and muscle contraction. In apes and prosimians, plantaris is attached to plantar

aponeurosis. In American brown bear, plantaris muscle shares the size of gastrocnemius [4]. If human body has a truly vestigial organ, it is suggestive that the organ was once useful probably in non-human ancestors. Evolutionist have identified some muscles being vestigial like auricular muscles, erector pili muscles and plantaris muscle of the leg [4]. One of the problems with the concept of vestigial or functionless muscles is the well-known fact that unused muscles degenerate. People like astronauts exposed to a prolonged weightless environment, to those confined to long bed rest, lose a significant amount of muscle mass in few months. Muscle mass is a matter of 'use it or lose it'. It is unlikely that any muscle that was unused for lifetime would remain as healthy muscle tissue [4]. The plantaris muscle with plantar flexors is concerned with plantar flexion of foot. While evolutionists are concerned about the phylogenecity, surgeons use the muscle for tendon repair [5]. Cruveilheir proposed this muscle to be vestigial in man and suggested that during evolution plantaris muscle lost its attachment to plantar aponeurosis and got inserted to calcaneus as our ancestors assumed the erect posture [5]. In many mammals, like apes and prosimians, the plantaris is attached to the plantar aponeurosis. In most ruminants and horses, the plantaris attaches to the Achilles tendon similar to man [5]. Even though PM is considered vestigial, it serves the function of proprioception as it has more muscle spindle [6]. Evolutional studies suggest that plantaris muscle is a rudimentary muscle it plays minor role in gait biomechanics. However, plantaris muscle seems to have very important proprioceptive role since it has very high density of muscle spindles [7]. The objective of the study was to prevalence of the vestigial muscle plantaris, a corelation to evolution and its clinical implications.

Materials and methods

Plantaris muscle was dissected in 20 limbs of IUD foetuses obtained from Department of O & G at GMC Thrissur during a period of 6 months in the year 2014 - 2015 in the Department of Anatomy. Its existence in the foetuses were recorded. Nerve supply and insertion of the plantaris muscle also noted.

Results

Table 1: Muscle belly position

Fetal no	Sex	Muscle belly right	Muscle belly left
52	m	absent	absent
37	f	9mm	1.5cm
17	m	9mm	1.2 cm
22	m	1cm	1.1cm
33	m	absent	absent
19	m	1.3cm	1cm
51	f	absent	absent
46	m	9mm	9mm
56	m	1.2cm	1cm
35	m	1cm	1cm

Table 1 shows 10 Fetal number accordingly to gender, Out of 7 were male and 2 were female.

Fig 1: Plantaris muscle

Of the 20 legs dissected, 6 legs showed absent plantaris muscle, Figure 1 and 2. No variation in origin of plantaris muscle was noted. Insertion of plantaris muscle was to calcaneal bone by Tendo Achillis. No continuation of plantaris muscle as plantar aponeurosis was noted. No insertion to calcaneus as separate tendon was noted. Nerve supply was by the branch supplying to deep crural muscles (Tibial branch of sciatic nerve).

Fig 2: Six legs showed absent plantaris muscle

Discussion

Inconstancy of the muscle has lead to unclear theories about evolutional development of PM. In the nineteenth century, the first research studies conducted strongly suggested that the plantaris muscle is a rudimentary muscle that plays a minor role in gait biomechanics. The bipedal posture transition caused the migration of insertion from plantar aponeurosis to calcaneus [7]. In this study also, even after random dissection of 20 limbs, absence of PM was noticed and the insertion of all PM identified was to calcaneus.

PM is considered by anatomists and embryologists a derivative of a deeper portion of the lateral head of the gastrocnemius and is often called "gastrocnemius tertius" which represents the third head of gastrocnemius due to its origin, which is often connected to the lateral head of gastrocnemius [4].

This study also shows that lateral head of gastrocnemius and PM are closely linked.In primitive mammalian form, the distal portion of PM presented a fibrous cap as it passed smoothly over the posterior end of the calcaneal bone to enter the plantar sole and blend with the plantar aponeurosis [5, 8]. Such peculiarities were not noted in the present foetal study.In a review of list of evolution of flexor muscles of foot, Lewis points out that marsupials possessing primitive condition of mammals have plantaris, two heads of gastrocnemius and no soleus [8]. The plantaris is associated with large fabella and expands into plantar aponeurosis [8]. Here in this study absence of soleus was not noted and no expansion to plantar aponeurosis noted signifying that these changes occurred during the course of evolution.Argot suggests plantaris as large muscle in terrestrial marsupials [9].

The study on PM of marsupials was considered as both humans and marsupials share common genetic imprinting mechanism which had been active for about 150 million years despite the difference in reproduction strategies between marsupials and humans as suggested by Professor Geoffrey [10]. The nerve trunks to the PM arose from the nerve group of the deep posterior crural muscles rather than from the nerve groups of the superficial crural muscles and thus PM may be derived from anlage of the deep posterior crural muscles [11]. In this study also the nerve supply to PM was branch from that to deep posterior crural muscles.Loth recognized the considerable variation among primates in specific aspects of plantar aponeurosis attachments and their relationship to the plantaris muscle often categorized as belonging to the triceps surae muscles [5]. While reports demonstrate that the plantar aponeurosis is not a uniquely human structure, the degree to which it differs in humans from those of other animals particularly other primates, remains unclear [5]. In the process of verticalization of human posture, the heel came in contact with the ground and the foot acquired the position of 90° in relation to the lower limb, plantar aponeurosis gradually developed insertion on the lower side of calcaneus as emphasized by Daseler and Anson [5]. The plantaris muscle was primitively continuous with the plantar aponeurosis. It originated from femur just above the lateral condyle under cover of gastrocnemius muscle. The plantaris muscle unambiguously predicts that the last common ancestors (LCA) of all primates most likely had a plantaris that blended with the plantar aponeurosis [12]. This favours that evolution has occurred while attaining bipedalism and migration of plantaris happened from plantar aponeurosis to calcaneus. The

likelihood of this anatomy dropped to 31.2% in the LCA of haplorhines, with the presence of a plantaris that was bound to or inserted into the calcaneal bone being more likely [12]. The plantaris was most likely to insert into the calcaneus for the catarrhine LCA (75.3%), the LCA of all apes (88.3%), great apes (79.7%), and African apes (83.1%). Finally the LCA of *Pan* and *Homo* probably had a plantaris that inserted into the calcaneus (2:98.0%) [12].

Clinical aspects

The tensile structure of PT (plantaris tendon) was also appreciated for atrioventricular valve repair where it was noticed that replacement of the papillary muscle, chordae or both with Plantaris tendon could be performed [13]. In cases where PT is considered a graft source, it appeared useful in confirming that the muscle will make a good graft [14]. Clinically plantaris muscle is involved in differential diagnosis of posterior leg pain, plantaris muscle rupture, non-insertional Achilles tendinopathy and popliteal artery compression syndrome. Different surgical specialties have recognized plantaris muscle tendon as a good graft [7]. Clinical studies show that removing PM result in an improvement of the Achilles tendon structure, accompanied by improved clinical VISA-A scores, i.e. a quantitative index of pain and function in patients with Achilles tendinopathy [15]. By simple harvesting technique, it is used as a potential donor of graft for various reconstructions [15].

Conclusion

Nerve supply to plantaris indicates that muscle is derived from anlage of the deep posterior crural muscles. Daselar and Anson reports verticalization of human posture lead to receding of insertion of plantaris from plantar aponeurosis to calcaneus. It is also reviewed that LCA of all primates had plantaris inserted to plantar aponeurosis.

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