The Effect of the Gastrocnemius on the Plantar Fascia

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KEYWORDS

• Gastrocnemius muscle • Plantar fascia • Achilles tendon • Sagittal foot mechanics
• Gastrocnemius tightness • Plantar fasciitis • Ankle dorsiflexion stiffness

KEY POINTS

- The exact role that gastrocnemius tightness has on the plantar fascia has been a topic of discussion for many years and remains incompletely understood.
- The anatomic connection between the gastrocnemius muscle and the plantar fascia is disputable and seems to vary with age.
- The relationship between gastrocnemius tension and the plantar fascia during weight-bearing activities can be explained from a mechanical view of the foot in the sagittal plane.
- Gastrocnemius tightness increases Achilles tendon tension and increases dorsiflexion stiffness of the ankle joint during weight-bearing activities, which also increase plantar fascia tension during weight-bearing.

INTRODUCTION

The gastrocnemius (both the medial and lateral heads) and soleus muscles work through the Achilles tendon in their posterior insertion on the calcaneus.[1] The Achilles tendon is the largest and most powerful tendon of the ankle and its tensional force is transmitted to its insertion by active contraction of the gastrocnemius and/or soleus muscles or by passive tension of the musculotendinous unit of these muscles. Passive tension can occur because of an increase in dorsiflexion of the foot or because of gastrocnemius and/or soleus tightness. The tensional force (active or passive) in the Achilles tendon produces a plantarflexion moment at the ankle joint. In weight-bearing conditions, a plantarflexion moment at the ankle joint can decelerate dorsiflexion movement of the ankle during the stance phase of the gait cycle, accelerate plantarflexion movement of the ankle during the propulsive phase of the gait cycle, and stabilize ankle joint over dorsiflexion moments during weight-bearing, balancing the foot in the sagittal plane.[2,3]

Conflict of Interests: Author declares he has no conflict of interests.
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Foot Ankle Clin N Am 19 (2014) 701–718
http://dx.doi.org/10.1016/j.fcl.2014.08.011 **foot.theclinics.com**
1083-7515/14/$ – see front matter

The plantar fascia is a dense band of connective tissue that originates in the plantar tuberosity of calcaneus and courses along the plantar foot dividing into 5 slips that insert in the base of the proximal phalanges of the toes by the plantar plate and in the plantar skin by superficial extensions of the plantar fascia.[4–6] Hicks[7,8] compared foot function with the engineering structures of an arched beam and a truss, and explained nicely how the foot can work variably as one of these structures during weight bearing conditions. In the truss model, the bones of the foot represent an arch structure with the plantar fascia working at the bottom as a resistive tie. Because of its material properties and mechanical behavior, it is accepted that the plantar fascia can be viewed as a representative tendinous/ligamentous structure in the sole of the foot that plays an important role in foot stability.[9–11] Nowadays, there is a considerable amount of evidence, by means of in vitro studies, of the importance of the plantar fascia as stabilizer of the foot in static[12–17] and simulated dynamic walking conditions.[18,19] All of these studies have pointed to the plantar fascia as a major contributor of 3-plane stability of different tarsal joints,[20] although its contribution to arch stability seems to be more substantial in some feet than others.[21] Additionally, computational models developed have predicted a variable decrease in arch height after plantar fasciotomy in static conditions accompanied by a dramatic increase of tensile forces on plantar ligaments and internal stresses of the foot.[22–25]

ACHILLES–CALCANEUS–PLANTAR SYSTEM

In 1953, Arandes and Viladot, 2 Spanish orthopedic surgeons, published a paper that linked the structures of Achilles tendon and plantar fascia into an independent functional unit named the "Achilles–calcaneus–plantar System" (ACPS; in Spanish, *sistema aquíleo–calcáneo–plantar*). They described a functional connection between the Achilles tendon, the plantar fascia, and short flexors of the foot by means of the posterior trabecular system of calcaneus that would work as a big sesamoid transmitting the force from the Achilles tendon to the intrinsic muscles of the sole of the foot. They stated that "linking these structures (Achilles tendon and plantar aponeurosis and short muscles of the sole) it is found the posterior portion of the calcaneus as a big sesamoid such as the patella with the patellar tendon."[26] This concept of functional connection reinforced early anatomic textbooks that had described an anatomic link from Achilles tendon to the plantar fascia through a continuity of the fibers in the posterior tuberosity of the calcaneus.[27,28] Arandes and Viladot described ACPS as "an independent functional unit that connects both structures."[26]

The authors justified this concept by means of ontogenic and phylogenic anatomic observations. From an ontogenic view, they observed a marked anatomic continuity between Achilles tendon and plantar aponeurosis in histologic sections of embriogenic specimens. This observation has been supported recently in a study of the embryologic development of Achilles tendon in fetuses in which the authors remarked a surprising continuity of fibers between Achilles tendon and plantar fascia through a thickened perichondrium in the posterior part of the main body of the calcaneus.[29] Arandes and Viladot pointed that this continuity would be maintained until the age of 7, when the secondary ossification center appears inside these fibers that connect the Achilles tendon to the plantar fascia. Ultimately, it fuses with the main body of the calcaneus to form the posterior tuberosity at the age of 9 or 10. From a phylogenetic view, they observed that in some animals the gastrocnemius muscle expands from the femur to the metatarsals, but in humans bipedal adaptation would have bent the Achilles tendon in a 90°, fashion putting the calcaneus under the talus. The posterior tuberosity of calcaneus then acquired great importance in the weight-bearing position