The role of the plantar fascia in supporting the arch in progressive collapsing foot deformity

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INTRODUCTION: The osseous structure of the foot has been described as an arch-like triangular structure or truss where the plantar fascia (PF) functions as the tensile element, maintaining the overall length of the arch. The importance of the PF in maintaining the arch has likely been underestimated because only minor abnormalities in its structure are seen on MRI studies in patients with progressive collapsing foot deformity (PCFD). However, the importance of a ligament in preventing deformity may not be correlated with its attenuation in PCFD seen on MRI. We hypothesized that the degenerative elongation of the plantar fascia would be a necessary precursor of arch collapse. The goal of this study was to evaluate the role of the plantar fascia in arch stability in PCFD.

METHODS: We used a validated finite element model of the foot reconstructed from CT scan of a female cadaveric foot weighing 60 kg. The model included 28 bones, 72 ligaments, cartilage, and an encapsulating soft tissue. The collapsed foot model was created by simulated transection of the ligaments and unloading of the posterior tibial tendon. The model was used to assess the impact of isolated PF failure on the development of PCFD, evaluate the capability of the PF when reconstructed to restore foot alignment, and determine the amount of progressive strain that constitutes failure for each ligament. Foot alignment angles were used to evaluate the foot alignment. For comparison, the angles were also evaluated for other ligament tears. The impact of PF failure on force changes in the remaining ligaments was also investigated by quantifying ligament force changes during simulated PF cutting in the foot model.

RESULTS: When compared to the intact and collapsed foot models, we found that the individual release of the PF cannot cause deformity (Figure 1). However, it significantly increased the force in the long (142%) and short plantar (156%), deltoid (45%), and spring ligaments (60%), potentially putting the foot at risk of arch instability over time. Moreover, we found that the PF was the structure most able to restore the arch (Figure 1a). The PF was also found to play a secondary role in reducing hindfoot valgus and forefoot abduction deformities (Figures 1b,1c). Moreover, to produce deformity, a considerable amount of attenuation in the spring (strain= 41%) and interosseous talocalcaneal ligament (strain= 27%), but only a small amount in the plantar fascia (strain= 10%) was needed.

DISCUSSION: In comparing intact to collapsed models of the foot, we found that isolated PF release did not cause arch collapse, but that arch collapse could not occur without elongation of the PF. While the progressive strain in the PF needed to enable arch collapse was small, the PF is a very long ligament, thus even small strain within the PF corresponds to substantial change in overall length of the arch. Chronic degeneration of the PF leading to plantar fasciitis may be an early sign of impending PCFD.

SIGNIFICANCE/CLINICAL RELEVANCE: The results of this study will aid our understanding of the fundamental role played by the plantar fascia in supporting the arch and will provide a new target for early detection and intervention in PCFD prior to the onset of arch collapse

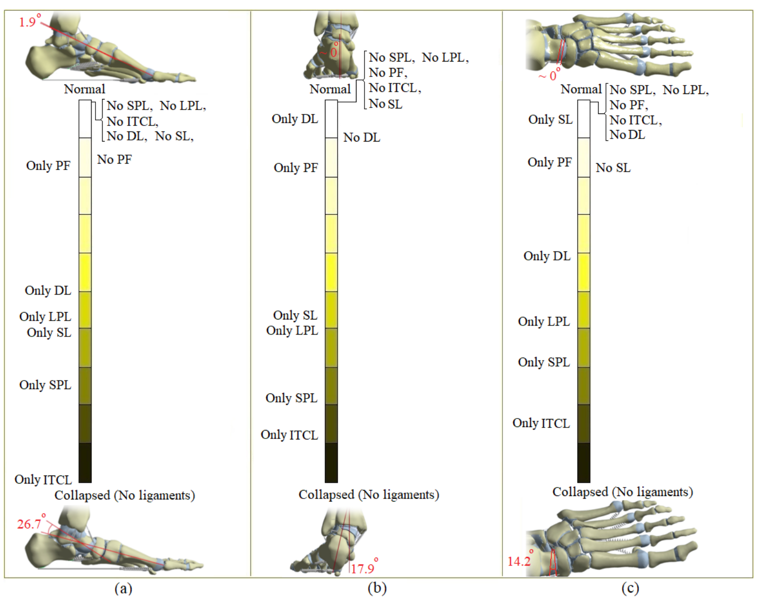

Figure 1. Relative changes in foot alignment angles for each ligament tear scenario within the normal and collapsed foot ranges: (a) Meary's angle (used to evaluate arch collapse), (b) hindfoot alignment angle (used to evaluate hindfoot valgus), (c) talonavicular coverage angle (used to evaluate forefoot abduction). DL, deltoid ligament; ITCL, interosseous talocalcaneal ligament; LPL, long plantar ligament; PF, plantar fascia; SL, spring ligament; SPL, short plantar ligament

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