The Effects of Sectioning the Spring Ligament on Rearfoot Stability and Posterior Tibial Tendon Efficiency

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Posterior tibial tendon insufficiency has been implicated as a cause of adult acquired flatfoot. Multiple theories are debated as to whether or not a flatfoot deformity develops secondary to insufficiency of the posterior tibial tendon or of the ligamentous structures such as the spring ligament complex. This cadaveric study was undertaken in an attempt to determine the effect that sectioning the spring ligament complex has on foot stability, and whether engagement of the posterior tibial tendon would be able to compensate for the loss of the spring ligament complex. A 3-dimensional kinematic system and a custom-loading frame were used to quantify rotation about the talus, navicular, and calcaneus in 5 cadaveric specimens, before and after sectioning the spring ligament complex, while incremental tension was applied to the posterior tibial tendon. This study demonstrated that sectioning the spring ligament complex created instability in the foot for which the posterior tibial tendon was unable to compensate. Sectioning the spring ligament complex also produced significant changes in talar, navicular, and calcaneal rotations. During simulated midstance, the navicular plantarflexed, adducted, and everted; the talar head plantarflexed, adducted, and inverted; and the calcaneus plantarflexed, abducted, and everted, after sectioning the spring ligament complex. The results of this study indicate that the spring ligament complex is the major stabilizer of the arch during midstance and that the posterior tibial tendon is incapable of fully accommodating for its insufficiency, suggesting that the spring ligament complex should be evaluated and, if indicated, repaired in flatfoot reconstruction. Level of Clinical Evidence: 5 (The Journal of Foot & Ankle Surgery 47(3):219–224, 2008)

Key Words: calcaneonavicular ligament, flatfoot surgery, kinematic, pes planus, spring ligament, tibialis posterior

Posterior tibial tendon insufficiency (PTTI) has long been implicated as a cause of adult acquired flatfoot (1–9). Debate exists as to whether PTTI primarily develops and then leads to increased strain on the spring ligament complex (SLC), or whether an attenuated SLC leads to increased strain on the posterior tibial tendon (PTT) and eventually its insufficiency. Studies using cadaveric human lower extremities, as well as observational clinical investigations, have demonstrated the importance of the osseous and ligament structures, as well as the dynamic pull of extrinsic tendons, in maintaining arch height and foot stability (1–20). Some authors have theorized that loss of PTT function leads to progressive arch collapse and, as a result, increased stretch of the medial ligaments of the hindfoot and ankle, including progressive attenuation of the SLC (1–3). Contrary to this theory, it has also been suggested that attenuation of the SLC results in increased strain on the PTT and the development of PTTI (13).

The SLC is composed of multiple fascicles with debate over whether 2 or 3 fascicles exist. Traditionally, it was thought that the inferior calcaneonavicular (ICN) and superomedial calcaneonavicular (SMCN) ligaments comprised the 2 components of the SLC (21, 22). Davis et al (22) found that the SMCN component exhibited histologic properties suggestive of significant load bearing, while the ICN component demonstrated a pure tensile load function. They also stated that the distal aspect of the PTT gave off 2 attachments to the SMCN ligament, further suggesting the intimate relationship of the two structures. Taniguchi et al (23) identified what they termed a “third ligament,” composed of fibers running from the notch between the calcaneal facets to the navic-

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ular tuberosity; and recent magnetic resonance image (MRI) studies also support the presence of 3 distinct ligaments comprising the SLC (24, 25).

When asked in 2003 about how they treated flat foot deformity, orthopedic foot and ankle surgeons indicated that 94% augment the PTT, 70% address equinus if it is present, and 97% perform some type of bony procedure, while only 53% indicated that they repair the SLC, although no explanation was given for the relatively low proportion of surgeons addressing the SLC (26). Thus, the literature indicates that a large proportion of surgeons continue to augment the PTT, despite concern that attenuation of the SLC may be responsible for much, if not all, of the acquired flexible flatfoot (15).

Previous investigation has determined that sectioning multiple stabilizers of the arch, such as the SLC and plantar fascia, leads to a flatfoot in a cadaver model (19). To date, however, no study has determined whether or not SLC insufficiency alone leads to the development of a flatfoot and PTTI. Because of the continued debate over the contribution of the SLC to the stability of the medial longitudinal arch, this cadaveric study was undertaken in an attempt to determine the effect that sectioning the SLC would have on foot stability and whether the PTT would be capable of providing adequate compensation to maintain medial arch stability.

Materials and Methods

Preparation of Specimens

Five fresh-frozen cadaveric left feet were obtained from the University of Washington, and inspected for evidence of previous surgery and gross deformities. The feet were visually inspected for flatfoot deformity by uniformly loading the specimens in simulated weight bearing to 350 N, the applied axial load equivalent to approximately one-half average body weight as stated in previous studies (10, 12, 17), on a loading frame and visually monitoring the medial longitudinal arch height. The specimens had been covered by moist towels to limit thermal injury, and stored at $-10°$ C before testing. The extremities were fully thawed at room temperature for 12 hours before the experiment. Skin, subcutaneous fat, and superficial fascia, as well as deep fascia and muscle, were removed or debulked from the fibular and tibial shafts and the remaining tendons of the extrinsic pedal musculature. The tibialis anterior and long extensor tendons were not prepared since they are inactive during midstance. The Achilles tendon, peroneus longus and brevis, long flexors, and posterior tibial tendons were all trapped using a running Krakow stitch with 80-pound woven Dacron cord (Western Filament, Inc., Grand Junction, CO). A loading frame (Bioconcepts Inc., Seattle, WA) was prepared and each specimen placed in a plantigrade position with the tibia at 90º to the foot. A 0.5-inch, threaded, acrylic rod was placed into the tibial medullary canal to act as an axial-load transfer device for simulated weight bearing. The axial rod and the tendons were secured to individual cylinders (Bimba, Bimba Manufacturing Company, Monee, IL).

Specimen Loading and Measurements

As previously described, we chose to apply an axial compression load of 350 N to simulate midstance. Simulated maximal muscle forces for the triceps surae, peroneus longus and brevis, flexor digitorum longus, flexor hallucis longus, and posterior tibial muscles were calculated according to the relative work percentages described in the study reported by Silver et al (27). The total physiologic tension of the tendons for these muscles equaled the axial load, due to the inactivity of the extensor tendons during midstance. The PTT was loaded at 0%, 50%, 100%, and 150% of its calculated strength before and after sectioning the SLC to determine if the increased pull of the tendon affected foot position and arch stability. All other tendons were loaded to their calculated strength for each measurement. Thereafter, without removing the specimen from the loading frame, the SLC was sectioned. We performed preliminary trials on 3 cadavers to confirm that only the SLC components were transected via inserting a #15-blade scalpel parallel and just proximal to the superior border of the PTT, rotating the blade 90°, and then sectioning the SLC from plantarlateral to dorsalmedial. After sectioning the SLC, the specimen was cyclically reloaded with an increased axial load of 525 N (1.5 times the axial compression load) 100 times at a rate of 50 cycles per minute to simulate ambulation. The positions and rotations of the talus, navicular, and calcaneus were measured and recorded using 3-dimensional (3-D) kinematic sensors (3 Space Fastrak®, McDonnell Douglas Electronics, Colchester, VT) that were secured in the talar neck, navicular tuberosity, and posterior calcaneus with titanium Kirschner wires (Figure 1).

Statistical Analysis

Analysis of variance (ANOVA) was used to determine significant differences ($P < .05$) between each step of PTT loading and also between pre- and postsectioning of the SLC. Post hoc testing was performed using Scheffe's multiple comparisons test with significance being defined at $P < .05$. All statistical analyses were performed on a personal computer using StatView 4.0 software (SPSS Inc., Chicago, IL).