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BIOMECHANICAL EFFECT OF EQUINUS IN PES PLANUS AND PES CAVUS DEFORMITIES

One of the most beneficial perks of having been in podiatric practice for over four decades has been observing how podiatric theories and beliefs have changed over that same period of time. For example, during my podiatry student years at the California College of Podiatric Medicine from 1979-1983, we were taught that Lapidus bunionectomies were bad since they destroyed an important joint of the foot and that 1st metatarsophalangeal joint (MPJ) implants were a much better surgical procedure than 1st MPJ arthrodesis procedures. In addition, we were taught that equinus deformity, where there is lack of ankle joint dorsiflexion, could cause a pes planus deformity and that equinus deformity could also be caused by a pes cavus deformity resulting in a "pseudoequinus" (Whitney AK, Green DR: Pseudoequinus. JAPMA, 72:365-371, 1982).

Equinus deformity, whether caused by gastrocnemius, soleus, Achilles tendon or ankle joint bony abnormalities, causes a restriction in ankle joint dorsiflexion, and is often claimed by some podiatrists as being the "root of all foot evils". It is widely believed within the podiatric and orthopedic medical communities, that equinus deformity, over time, may cause a flattening of the medial longitudinal arch (MLA) and subtalar joint (STJ) pronation. Because of this belief, surgical procedures for flatfoot correction are often combined with lengthening procedures of the gastrocnemius-soleus-Achilles tendon (GSAT) complex in order to raise the MLA, decrease the pronated position of the STJ and improve the functional outcome of flatfoot reconstructive surgeries (Hiller L, Pinney SJ: Surgical treatment of acquired flatfoot deformity: what is the state of practice among academic foot and ankle surgeons in 2002? Foot Ankle Intl, 24:701-705, 2003).

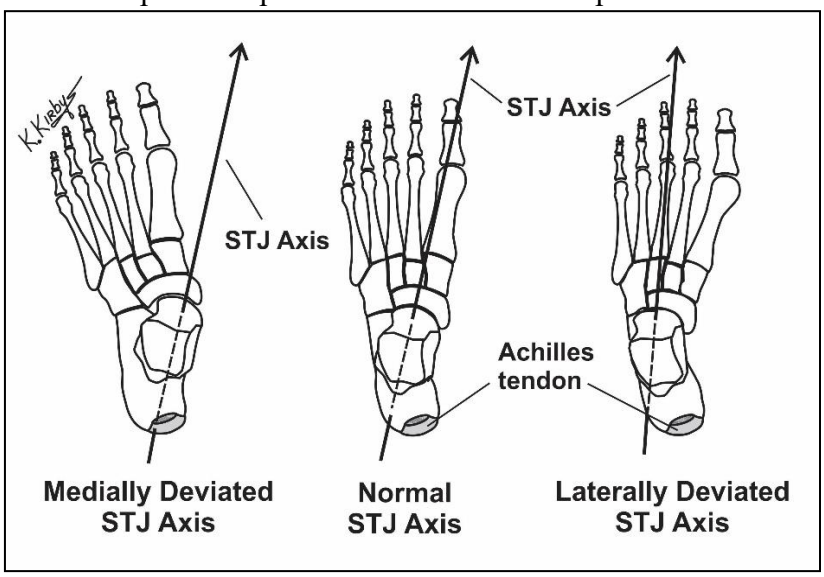

Figure 1. The effect of equinus deformity on the foot is largely determined by the spatial location of the subtalar joint (STJ) axis and the medial arch height of the foot. In a foot with medially-deviated STJ and pes planus deformity (left), Achilles tendon tension will produce only a small amount of STJ supination moment by its actions on the calcaneus but will produce a large STJ pronation moment by plantarflexing the forefoot into the ground. With a normal STJ axis with a normal arch height (middle), Achilles tendon tension will produce a moderate STJ supination moment by its actions on the calcaneus and will produce a moderate STJ pronation moment at the forefoot, resulting in a relatively stable foot that neither excessively pronates nor supinates. In a foot with laterally-deviated STJ axis and pes cavus deformity (right), Achilles tendon tension will produce a large STJ supination moment at the calcaneus and will produce only minimal STJ pronation moment by the increase in ground reaction force under the plantar forefoot caused by the equinus deformity. Therefore, how equinus deformity affects the overall biomechanics of the foot is greatly determined by whether the STJ axis is medially-deviated, is normal, or is in a laterally-deviated position.

As mentioned earlier, however, there also seems to be a belief that equinus deformity is caused by a higher-arched foot shape, or pes cavus deformity. In these individuals, the equinus deformity coexists with a higher-than-normal MLA which may suffer from symptoms related to over-supination of the STJ such as peroneal tendinopathy, chronic lateral instability or lateral column pain.

The question then becomes if equinus truly causes over-pronation of the STJ and flattening of the MLA in all feet, then why do those feet with a pes cavus and an equinus deformity not develop arch-flattening over time? The critical podiatric physician, when presented with this biomechanical contradiction and inconsistency, should then realize that there may be more to the biomechanics of equinus than what is currently widely believed by many podiatrists.

Since most of the cases of equinus deformity are due to some "tightness" in either the gastrocnemius or soleus muscles or in the Achilles tendon, then the following

biomechanical discussion will focus on equinus deformity caused by "tightness" in the GSAT complex. Tension within the Achilles tendon, originating either from GSAT passive length, or from active contractile activity of the gastrocnemius and/or soleus muscles, will cause an ankle joint plantarflexion moment. In addition, this same increase in Achilles tendon tension force will cause an increase in STJ supination moment since the STJ axis exits posteriorly from the lateral aspect of the posterior calcaneus, with the Achilles tendon insertion being positioned medial to the STJ axis.

Previous research has shown that the STJ axis has a variable spatial location and can be medially deviated from normal causing increased STJ pronation moments, or can be laterally deviated from normal, causing increased STJ supination moments (Fig. 1). This same inter-individual variability in STJ axis spatial location will result in the variable biomechanical effects that equinus deformity has on feet with different STJ axis locations. In the pes planus deformity with a medially-deviated STJ axis, the reduced supination moment arm of the Achilles tendon will reduce the STJ supination moment from Achilles tendon tension. Alternatively, in the pes cavus deformity with a laterally-deviated STJ axis, the increased supination moment arm of the Achilles tendon will increase the STJ supination moment from Achilles tendon tension (Kirby KA: Subtalar joint axis location and rotational equilibrium theory of foot function. JAPMA, 91:465-488, 2001).

One of the factors that complicates the biomechanical analysis of the GSAT complex is that gastrocnemius-soleus contractile activity and Achilles tendon tension tend to also increase the ground reaction force (GRF) under the plantar forefoot which also contributes to the magnitudes of pronation and supination moments acting across the STJ. For example, during bipedal standing in a relaxed position, an individual will typically position their center of mass (CoM) anterior to their ankle joint axis to maintain balance by using tonic activity in the gastrocnemius/soleus muscles to exert an ankle joint plantarflexion moment. This ankle joint plantarflexion moment during standing caused by contractile activity and tension in the GSAT complex will also result in an increase in GRF plantar to forefoot which will, in turn, cause a variable amount of STJ pronation/supination moments, depending on the STJ axis location relative to the plantar forefoot.

This variability in STJ axis location means that in pes planus deformity, where the STJ axis is significantly medially deviated, any increase in GRF acting on the plantar forefoot will also cause a large increase in STJ pronation moment. Alternatively, in feet with pes cavus and a laterally deviated STJ axis, any increase in GRF acting on the plantar forefoot will cause very little increase in STJ pronation moment and may, in fact, cause an increase in STJ supination moment (Fig 1). Therefore, the STJ axis spatial location has a significant effect on both the STJ pronation/supination moments from the Achilles tendon acting on the posterior calcaneus and from the STJ moments resulting from increased magnitudes of GRF acting on the plantar forefoot due to increased Achilles tendon tension from gastrocnemius/soleus contractile activity.

Therefore, by using this biomechanical analysis to more coherently explain the effects of Achilles tendon tension on both the ankle and STJ, it is likely that the deformity we call "equinus", may indeed have a variable effect on the moments acting across the STJ axis during weightbearing activities. In other words, pes planus deformities, with their significantly medially-deviated STJ axes, will tend to become more pronated and have increased tendency to have increased flattening of the MLA over time when equinus deformity is also present. In addition, pes cavus deformities, with their significantly laterally-deviated STJ axes, will *not* tend to become more pronated and will *not* have a tendency to have increased flattening of the MLA over time when equinus deformity is present. Certainly, having a logical biomechanical explanation for the variable effects that equinus deformity may have on the wide range of foot structures seen within the human population, is a much more intellectually-mature method by which to consider the complicated biomechanics of equinus deformity rather taking the simplistic view that "equinus is the root of all foot evils".

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