The Non-Surgical Treatment of Equinus

If the pathology can be treated conservatively, then the equinus deformity must also be simultaneously treated conservatively.

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***Editor's Note:** This is the first in a new series of PM articles dedicated to a practical approach to biomechanics—that is, articles that will present biomechanically-focused information that can be used on a day-to-day basis in podiatric practices.*

Equinus deformity has been associated with over 96% of biomechanically-related foot and ankle pathologies; and although there has been significant advancement in the surgical treatment of equinus, little or no advance has been made in its non-surgical treatment.[1] The treatment of any pathological condition mandates comprehensive treatment of all components of the pathology, and this is particularly important in biomechanical pathologies with an underlying equinus component. With the growing body of evidence-based research regarding the importance of equinus, it is important to have an understanding of the fundamentals of non-surgical equinus therapy.

Equinus deformity has been associated with over 96% of biomechanically-related foot and ankle pathologies.

What is the definition of equinus?

When discussing any component of equinus, the starting point must be standardizing the definition. The lack of a standard definition has led to much confusion. Many of the proposed definitions in the literature are based solely on anecdotal evidence, until DiGiovanni et al provided an evidence-based answer to this long-standing question in their landmark article "Isolated Gastrocnemius Tightness."[2] The study consisted of 34 symptomatic patients with a multitude of common foot or ankle pathologies and 34 control patients without any foot or ankle pathology. Not only did they examine ankle joint dorsiflexion in both groups with the knee extended and knee flexed, they also evaluated the accuracy of clinical evaluation with a goniometer compared to a validated ankle joint dorsiflexion method of measurement.

Clearly, the literature shows questionable reliability of measuring ankle joint dorsiflexion using a goniometer, but this study did provide some validation of the method most commonly employed by clinicians to assess equinus.[3,4] Their conclusion stated, "We have selected < 5° of maximal ankle dorsiflexion with the knee in full extension

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New Concepts and Studies

"New Concepts" is a forum for the presentation of (1) new technologies and products which have been the subject of clinical study, and (2) new studies involving existing products. Readers should be aware that Podiatry Management does not specifically endorse any of the technologies, concepts, or products being discussed.

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as our definition because it allowed us to diagnose the problem in those who were at risk (symptomatic patients) with fairly good reproducibility (76%) and, more importantly, we were able to reliably avoid (in 94% of the cases) unnecessary treatment of those who were not at risk (asymptomatic people)." Regarding the reliability of using a goniometer to measure equinus clinically, they stated, "Clinical examination was

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TABLE 1

Lower Extremity Orthopedic Pathology Related to Equinus	**Reference(s):**
Plantar heel pain/plantar fasciitis	1, 2, 5, 6, 7, 8, 9, 10, 58, 59, 60, 61, 62, 63, 64, 65, 67, 69, 70, 71, 72, 73, 74, 75, 76, 78, 79, 88, 101, 102, 103, 111
Achilles tendonitis/tendonosis	1, 11, 12, 13, 21, 22, 57, 77, 78
Posterior tibial tendon dysfunction/Adult flat foot deformity	2, 10, 14, 15, 16, 17, 18, 19, 20, 35, 36, 57, 78, 79
Muscle strains	23
Stress fractures	22, 24, 48, 88
Shin splints/Medial tibial stress syndrome	22, 24, 25, 46, 88
Iliotibial band syndrome	24, 25
Patellofemoral syndrome	26, 88
Ankle sprains/fractures	27
Diabetic foot ulcers	28, 29, 30, 31, 32, 39, 43, 78, 79, 122, 123, 124
Charcot deformity	33, 34, 37, 38, 39
Metatarsalgia	1, 2, 10, 16, 20, 36, 62, 78
MPJ synovitis/PDS	10
Hallux abducto valgus	1, 2, 16, 20, 40, 52, 66, 78
Hammer toes/Claw toes	20, 44, 78
Lis Franc's/Midfoot arthrosis	35, 53, 78
Hallux limitus/Hallux rigidus	41, 68
Forefoot calluses	1, 20
Morton's neuroma	38, 45, 78
Chronic ankle instability	47, 88
Poor balance/Increased fall rate in elderly	49, 89
Sever's disease	50, 51
Pediatric flatfoot	54, 55
Lateral foot pain	1
Genu recurvatum	38
Low back pain	38
Arch pain	62
Ankle arthrosis	78, 79
Subtalar arthrosis	78
Sesamoiditis	78
Anterior compartment syndrome	88

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demonstrated to be fairly reliable in identifying muscle tightness."

What is the frequency of equinus?

Hill looked at the frequency of equinus by examining 206 new patients over a six-week period of time.[1] 29 of the patients' primary complaints did not meet the study criteria, and they were excluded from the study. Of the remaining 174 patients, six were found to have normal ankle joint dorsiflexion (normal ≥ 3° ankle joint dorsiflexion with the knee extended). The primary finding of the study was that 96.5% of the patients with foot or ankle pathology exhibited equinus.

What are the biomechanics of equinus?

Several studies have demonstrated that during stance phase, a maximum of 8 to 10° of dorsiflexion above 90° must occur at the ankle just before heel-off, with the knee in full extension for normal gait.[42,114,115] Contracture of the gastroc-soleal complex has been shown to restrict the normal advancement of the tibia over the foot during mid-stance, resulting in proximal and distal compensation.[8,36,114,116] During mid-stance, as the tibia is moving over the foot, the knee is fully extended resulting in more limitation of ankle joint range of motion than when the knee is flexed.[117] Specifically, Johnson and Christensen demonstrated that, with loading of the Achilles tendon, there was a dampening of the pull of the peroneus longus tendon which failed to lock the midtarsal joint by everting the medial cuneiform into the central column of the foot, resulting in dorsiflexion of the first metatarsal and first cuneiform and plantarflexion of the navicula and talus.[118] This is the one of the distal compensations associated with equinus, others being pronation of the rearfoot, early heel-off, and abducted gait pattern.[118] Proximal compensation that may occur includes: lumbar lordosis, hip flexion, and genu recurvatum.[39]

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What pathologies are associated with equinus?

The extremely high frequency of equinus presence, in conjunction with biomechanically related foot and ankle pathologies, is another concept that must be fully appreciated. Table 1 shows lower extremity pathologies that have been linked with equinus in the literature with the reference.

Does stretching the Gastrocsoleal muscle increase ankle joint range-of-motion?

Konrad and Tilp examined the changes of the muscle tendon unit with static stretching of the Gastroc-soleal complex.[80] The study consisted of 49 police cadets, with 25 assigned to a stretching group and 24 to the control group. The stretching group stretched five-times per week for six weeks using the standing wall push stretch. The stretch was held for 30 seconds per leg, alternating legs for four stretches of each leg, totaling 120 seconds of stretching per leg. This time period of 4 x 30 second static stretches has been shown by Ryan, et al. to decrease muscle-tendon stiffness.[81]

Range of motion was measured with an electric goniometer, with the patient standing with the foot at a right angle to the leg. The patient then stepped back with one leg to maximally dorsiflex the ankle while keeping the heel on the ground and the back knee fully extended, the front knee flexed, and the foot in neutral position to avoid pronation. The range of motion was the difference between the maximal dorsiflexion position and neutral position. Ankle joint range-of-motion pre-stretch averaged

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30.9° ± 5.3° for the stretching group and 32.1° ± 7.7° for the control group. After six-weeks of stretching, the results were 36.3° ± 6.1° and 31.8° ± 7.0°, respectively. The increase in dorsiflexion of 5.4°seen in the stretching group was statistically significant. This result was similar to those of other studies. Mahieu, et al. showed less of an increase in dorsiflexion at 2.6°, while Guissard, Duchateau, and Nakamura, et al. both had results with more dorsiflexion after static stretching at 7.6° and 6.7°.[82,83,84]

Macklin, et al. examined 13 runners who had ≤ 6° of ankle joint dorsiflexion with the knee extended and a foot posture index of ≤ +8 or ≥ -8 (which prevented extreme planus or cavus deformities).[85] Using a ramp, the participants stretched both legs for four minutes in the morning and evening. Ankle joint dorsiflexion was measured at four and eight weeks. Ankle joint dorsiflexion increased by 11° on the left and 10° on the right. This was a 200% increase in ankle joint dorsiflexion.

Another interesting finding from this study was that the F-scan results of peak plantar pressures (PPPs) beneath the 1st and 2nd metatarsal phalangeal joints (MPJs) on both feet, and the 5th MPJ on the right foot were increased with increased ankle joint dorsiflexion. This is contrary to what historically has been described in the literature as reducing PPPs with increased ankle joint dorsiflexion.[86,87,88] Stance time and heel contact time were both reduced. The authors from this study felt that this surprising finding was mostly likely the result of re-establishing normal foot mechanics. The authors' opinion about this quandary was, "The increased pressures which are now applied for a shorter period of time over a greater and more even distribution within the foot may be less harmful to the foot." They concluded, "These results also strongly indicate that this specific non-invasive stretching regime could be considered before resorting to more invasive options."

The elderly population's ability to stretch to increase ankle joint dorsiflexion is an interesting question that has been answered by Johnson, et al. in their article "Effect of a Static Calf Muscle-Tendon Unit Stretching Program on Ankle Dorsiflexion Range of Motion of Older Women."[90] This study consisted of 13 subjects with an average age of 83.8 ± 4.7 years. The pre-stretching ankle joint dorsiflexion averaged -11.1° ± 4.6°, which corresponds to reported skeletal muscle changes that occur with age, including a decreased muscle cross-sectional area due to fat and connective tissue changes within the muscle.[91,92,93] Gajdosik, et al. had a similar finding for changes in the gastroc-soleal complex when they examined muscle stiffness in young, middle-aged, and elderly women showing significantly decreased ankle joint dorsiflexion with age.[94]

Johnson, et al. utilized the runner's (wall) stretching method for four stretches per limb, held for 60 seconds each, done daily for five of seven days for a total of six weeks. Ankle joint dorsiflexion was then measured three days after the last stretch and averaged 1.2° ± 3.0°, a statistically significant increase of 12.3° ± 4.4°. This was significantly more than Gajdosik, et al. found. They showed an increase of 5.1° after eight weeks of a stretching program consisting of 10 repetitions per leg held for 15 seconds each done daily three times per week. This difference most likely represents the difference between the frequencies of the stretching programs (three times per week vs. five times per week).

How long should stretching be done each day and for how many weeks?

Radford, et al. in their meta-analysis review examined this question based on five trails that met their inclusion criteria of randomized or quasi-randomized static stretching compared to a control group but not using the contralateral leg as the control, excluding cross-over studies and studies with spastic equinus.[95] Stretching techniques varied from weight-bearing to non-weight bearing with the knee flexed or extended. Studies using devices to assist stretching were included, but studies with modalities designed to assist the muscle's physiological ability to stretch were excluded. Any outcome to evaluate ankle joint dorsiflexion, weight-bearing (standing, walking, or running) or non-weight-bearing was included. The findings revealed stretching for ≤ 15 minutes increased ankle joint dorsiflexion 2.07°, ≥15 minutes but ≤ 30 minutes re-

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sulted in an increase of 3.3°, and ≥ 30 minutes averaging an increase of 2.49°.

The authors stated, "Calf muscle stretching provides a small and statistically significant increase in ankle dorsiflexion. However, it is unclear whether the change is clinically important." What is to be made from this conclusion? Certainly, it shows that 30 minutes per day of stretching is adequate to increase ankle joint dorsiflexion, but the multiple variables of measurement and stretching modalities put the total amount of actual increase in ankle joint dorsiflexion in question. Inherently, one would postulate that as the time of stretching per day increased, the resultant amount of ankle joint dorsiflexion would also increase accordingly.

Others studies have utilized stretching programs consisting of 30 seconds per day per leg,[105,108,109] one minute per day per leg,[108,109] one minute 20 seconds per day per leg,[97] two minutes per day per leg,[80,81,105,106,107,109] two and a half minutes per day per leg,[88,94] three minutes per day per leg,[99,101,104] four minutes per day per leg,[90,101] five minutes per day per leg,[96,105] eight minutes per day per leg,[85] 10

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Figure 1: This photo shows improper techniques of the runner's stretch with the back heel off the ground, preventing a full stretch of the gastroc-soleal complex.

Figure 2: This photo shows improper techniques of the runner's stretch with the back knee bent, preventing stretching of the gastrocnemius component of the gastroc-soleal complex.

Figure 3: This photo shows improper techniques of the runner's stretch with the front knee straight, preventing full stretching of the rear leg gastroc-soleal complex.

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minutes per day per leg,[83,98] 30 minutes per day per leg,[102] and during sleeping hours via a night splint.[60,70,100,101,103,111]

Young, et al. in their paper, "Interventions for increasing ankle joint dorsiflexion: a systematic review and meta-analysis," reviewed 23 studies and the most common duration for stretching was six weeks.[110] This was also the time period used in several of the aforementioned studies. I have found 8 to 12 weeks to be the most common time period to achieve deformity correction of +5° ankle joint dorsiflexion with the knee extended. Based on the literature, a minimum of six weeks should be anticipated when initiating therapy.

Is foot position important when stretching?

Johnson, et al. in "The Effect of Subtalar Joint Position on Dorsiflexion of the Ankle/Rearfoot Versus Midfoot/Forefoot During Gastrocnemius Stretching" evaluated the effect of subtalar (STJ) position on ankle/rear-foot and the mid-foot passive range of motion with stretching of the gastrocnemius muscle.[88] The study consisted of 27 participants with a mean age of 31. 3 years with a chronic lower extremity pathology and ankle joint dorsiflexion of ≤ 10°. The participants stretched five 30-second stretches for a total of 20 stretches in pronation and supination on each lower extremity in a randomly determined sequence. Pre-stretching ankle joint dorsiflexion with the knee extended values were 4.6° ± 2.9° left and 4.6° ± 4.1° right.

This is an excellent opportunity to discuss unilateral vs. bilateral stretching. As this study and others such as Macklin, et al. have shown that there is a consistency between right and left sides for ankle joint dorsiflexion regardless of unilaterality or bilaterality of pathology.[85]

Based on the literature, a minimum of six weeks should be anticipated when initiating therapy.

Additionally, Manel, et al. demonstrated no statistical difference of the pennation angles between right and left leg muscles, and Abellaneda, et al. showed no difference in medial gastrocnemius fascicle length between the right (53.3° ± 1.3 mm) and left (51.8° ± 1.4 mm) legs.[112,113] This data suggests that stretching of the gastrocsoleal complex should be done bilaterally and preferably at the same time. There were several significant findings from Johnson et al.'s study, but the most important was statistically significant increase in midfoot/forefoot dorsiflexion when stretching in pronation compared to supination.

The other pertinent findings were statistically significant, with more extension of the knee and increased normalized vertical ground reaction force when stretching in supination compared to pronation. This knee extension finding is a very important concept. When the subtalar joint supinates, the tibia externally rotates; conversely when the subtalar joint pronates, the tibia internally rotates.[119] This external rotation of the tibia that is required for full knee extension has been termed the "screw home mechanism."[120,121] Johnson, et al. concluded, "Clinicians may want to consider STJ position during gastrocnemius stretching to either facilitate or limit recruitment of dorsiflexion motion at the midfoot/forefoot."

The three difficulties with manual stretching are technique, consistency, and compliance.

What are the limitations with current modalities of conservative therapy for equinus?

The three difficulties with manual stretching are technique, consistency, and compliance. The runner's stretch or wall stretch is not as easy as it would initially appear.

Runner's stretch potential errors:

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1) Back heel must stay down on the ground (Figure 1)
2) Back knee must stay fully extended (Figure 2)
3) Front knee is bent (Figure 3)
4) Back should remain straight
5) Body weight should be forward
6) Foot must be supinated—this is critical and the most difficult factor to perform correctly (Figures 4, 5)

Consistency is involved with the need to stretch for at least six weeks according to much of the literature described above. Stretching every day or five days per week for six weeks can lead to a lack of consistency from the patient. The time to stretch daily certainly has been wide-ranging in the liter-

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Figure 4: This photo shows the incorrect position of the subtalar joint in pronation, allowing dorsiflexion to occur through the mid-foot and internal rotation of the tibia, which prevents full knee extension and suboptimal stretching of the gastrocnemius muscle.

Figure 5: This photo shows the correct position of the subtalar joint in supination that allows external rotation of the tibia and therefore full knee extension, locking of the midtarsal joint to prevent dorsiflexion occurring through the midfoot.

Figure 6: This photo shows that even with the leg fully extended, it is difficult to get the patient to fully extend their knee, and if the tibia is not externally rotated via subtalar supination, then physically it is all but impossible to put the knee into full extension.

Figure 7: This photo shows the knee bent while wearing a night splint, resulting in sub-optimal gastrocsoleal stretching.

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ature, but Radford, et al. showed that most dorsiflexion resulted in 15 to 30 minutes of stretching daily per leg. Getting a patient to stretch for a total of 30 to 60 minutes per day (stretching each leg 15 to 30 minutes) can lead to poor compliance.

Night splints have been used for decades as an alternative to manual stretching but, like manual stretching, night splints have limitations that can result in sub-optimal results.

1) Night splints do not go above the knee, and therefore do not lock the knee into full extension even when the patient is using it with the leg extended. It is uncomfortable to fully extend the knee while dorsiflexing the ankle. Additionally, the knee cannot be fully extended unless the tibia is externally rotated, which requires the subtalar joint to be supinated via the Windlass mechanism. (Figure 6)

Figure 8: EQ/IQ brace showing extension of the leg component to go above the knee to maintain the knee in full extension to adequately stretch the gastroc-soleal complex.

2) Night splints have traditionally been used during sleep. Most adults sleep on their sides with their knees bent; this results in the gastrocnemius not being stretched. Night splints also have a reputation for disturbing patient sleep, resulting in poor compliance. (Figure 7)

The EQ/IQ equinus brace is one of the most significant improvements in the conservative management of equinus deformity in decades.

3) Dorsal night splints allow the forefoot to plantarflex relative to the rear-foot reducing the corrective force to dorsiflex the ankle.

Innovative conservative management of equinus deformity

The EQ/IQ equinus brace is one of the most significant improvements in the conservative management of equinus deformity in decades. This brace has several features to provide the optimal setting for stretching of the gastroc-soleal complex.

Figure 9: EQ/IQ equinus brace, showing toe wedge to dorsiflex the hallux, lock the midtarsal joint, supinate the subtalar joint, and externally rotate the tibia that allows for full knee extension.

1) The brace extends above the knee, allowing the knee to be locked and maintained in full extension to fully stretch the gastroc-soleal complex. (Figure 8)

2) The Windlass mechanism is engaged by placing a wedge beneath the hallux to dorsiflex it, resulting in stretching of the plantar fascia, locking of the midtarsal joint, supination of the subtalar joint, external rotation of the tibia,

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and full extension of the knee. (Figure 9)

3) The amount of ankle joint dorsiflexion is controllable for a more predictable outcome, with adjustments at 0°, 10° and 20°. It is recommended for the treating physician to determine ankle setting and adjust it upon follow-up examinations. (Figure 10)

It is recommended to use the brace one hour per day simultaneously stretching both legs at the same time. The patient's ankle joint dorsiflexion should be evaluated monthly. Stretching should be continued for at least six weeks at minimum or until full correction is achieved. This may require 8 to 12 weeks. For athletic or functionally high demand patients, maintenance therapy should be considered for prevention of re-contracture. This consists of brace use once weekly for one hour, with periodic follow-up visits to confirm maintenance of correction.

Figure 10: EQ/IQ equinus brace showing ankle joint adjustments of 0°, 10°, 20°.

Conclusion

Equinus is associated with the majority of biomechanically-related lower extremity pathologies. The comprehensive treatment of any pathology with an underlying equinus component mandates stretching of the gastroc-soleal complex. If the pathology can be treated conservatively, then the equinus deformity must also be simultaneously treated conservatively. The historical conservative treatments for equinus have limitations. The EQ/IQ brace provides a solution for the conservative treatment of equinus by addressing these limitations. **PM**

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