Introduction to Biomechanics for the Podiatric Medical Assistant

By
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Topics

• Equinus
• Forefoot
• Rearfoot
• Foot Typing
• Orthotic Consideration
Basic Foot Biomechanical Concepts

- Remove any deforming force of leg onto the foot
- Rearfoot position perpendicular to ground – normalize STJ axis
- Forefoot parallel to corrected rearfoot position – prevents pronatory moments for compensation

James Amis, MD – Frontiers in Surgery 2016
The Split Second Effect: The Mechanism of How Equinus Can Damage the Human Foot and Ankle

"We are awakening to a new era of understanding the mechanics and function of the human foot and ankle. There is a simple, singular, usually silent, and remote cause for the majority of non-traumatic acquired foot and ankle pathology, and mechanically, it creates cumulative damage to the foot and ankle through leveraged forces. In short and in this author’s opinion, equinus is the primary mechanical common denominator that leads to the majority of acquired non-traumatic foot and ankle problems by indirect leveraged means as well as direct forces along the posterior/plantar chain. There can be no more room for the standard thinking that these resultant foot and ankle problems arise just because we are getting older or we are obese or they are just random, or that an equinus contracture is only a part of the equation. Equinus is the equation."
Conditions Associated with Equinus Documented in the Literature

- Heel Spur Syndrome/Plantar Fasciitis
- Achilles Tendinopathy
- Posterior Tibial Tendon Dysfunction
- Diabetic Foot Ulcers
- Charcot Neuropathy
- Metatarsalgia
- Morton’s Neuroma
- Lesser MTP joint pathologies – PDS, Capsulitis
- Hallux Valgus
- Hammer Digit Syndrome
- Ankle Fracture/Sprains
- Sever’s Disease
- Pediatric Flatfoot Deformity
- Poor Balance/Fall Risk Elderly
- Low Back Pain
- Ankle Arthritis
- STJ Arthritis
- 1st Ray Hypermobility
- Adult Pronus Valgus
- Hallux Valgus
- Sesamoiditis
- Lateral Column Syndromes/Foot Pain
- Freiberg’s Infarction
- Familiarus Callus
- Iliotibial Band Syndrome
- Medial Tibial Stress Syndrome/ Shin Splints
- Patellar Tendonitis/Syndrome
- Chronic Ankle Instability
- Tibial Stress Fractures
- Osteoarthritis Forefoot/Walkfoot
- Muscle Strains
- Gore Resurfacing
- Arch Pain
- Anterior Compartment Syndrome
- Familiarus Nerve Entrapment

Pierre Barouk, MD - Foot Ankle Clin N Am 2014
The Gastrocnemius: Introduction

“Looking for a retraction of the gastrocnemius should be an essential part of the foot and ankle examination for practitioners, not just surgeons. Even though the equinus has been recognized for 50 years as having an influence on the foot, only a few practitioners routinely search for it. The proportion of gastrocnemius tightness is high in the normal population, but it is significantly higher in populations that have foot and ankle problems. Why do we have short gastrocs? The evolution of the human race, especially walking at a certain pace and extending the knee, is probably one of the explanations. In addition to this, there is also the problem of sitting for long periods of time and the frequent use of high-heeled shoes. With this issue of Foot and Ankle Clinics of North America, you will gain a better understanding of how to recognize gastrocnemius tightness (the clinical Silfverskiold test is essential), how to treat it, and understand why it has an influence on many of the current pathologies that we see every day. Attaching some symptoms (calf cramps, lower limb instability, difficulty in walking without a heel, lumbar pain) to gastrocnemius tightness is essential to treating patients in a global manner. I hope you will be convinced of the importance of this, and no longer do without!”
“It has been postulated that epidemiologic factors, such as obesity, sedentary life style, medical comorbidities, shoe wear, concrete floors, advanced age, female gender, and overuse issues, to name a few, are responsible for a variety of foot and ankle pathology. Although these factors might consistently coexist with a variety of foot and ankle problems and seem to have a causal relationship, it is my assertion that they have little if any direct relationship.”

“The singular and real association of each of these epidemiologic factors is a contracture of the gastrocnemius muscle, which is camouflaged in this list. Most every other cause of these foot and ankle problems is likely mediated by contributing to the degree and/or rate of an already contracting gastrocnemius. These problems promote gastrocnemius tightness, which in time causes incremental damage to the foot and/or ankle.”
Hill JAPMA 1995

- 209 NP over 6 weeks
- 26 deleted – primary complaint did not fit into study guidelines (Nail, VP, etc.)
- 6 of remaining 174 had normal AJ DF
- 168 Equinus – 3 Gastroc/165 GS
- 9 to 85 y/o – Mean = 48.2 y/o
- Equinus = < 3º AJ DF with KE
- Findings – 96.5% of patients with foot or ankle pathology exhibited Equinus

Hill JAPMA 1995

- “The podiatric physician should look beyond the specific complaint to diagnose the underlying cause. Frequently, ankle Equinus deformity will be at the root of the patient’s foot problem.”
- “Gastrocsoleus stretching was found to be an effective modality in treating a wide range of podiatric complaints where ankle Equinus is an underlying etiologic factor.”
Hill JAPMA 1995

• “Treating apparent biomechanical problems that have an underlying equinus deformity with rigid functional orthoses is a major reason for unsuccessful orthotic treatment.”
• “Equinus patients who receive orthoses as their sole treatment may not be capable of accepting orthotic control.”
• “A rigid orthotic will prevent the foot from pronating. The result is arch irritation from excess friction against orthoses.”

Anatomy of Triceps Surae
Triceps Surae Anatomy

- **Achilles Tendon** – strongest, thickest, largest tendon in the body (15 cm)
  - Insertion posterior middle 1/3 of calcaneus with a retrocalcaneal bursa between the two at proximal 1/3 of the calcaneus
  - Course – superficial posterior compartment
  - Achilles fibers spiral laterally about 90°
  - Gastroc fibers insert principally laterally on calcaneus
  - Soleus fibers insert principally medially on calcaneus
  - Tendon Sheath – allows sliding
  - Paratenon – deep to tendon sheath, protects and nourishes tendon
  - Blood supply – myotendinous junction, paratenon, calcaneal periosteum (zone of hypovascularity 4-5 cm cephalad from insertion)

Triceps Surae Anatomy

  - Origin - posterior aspect femur condyles (medial larger head larger and muscle fibers descend further distally) and posterior knee capsule – arches over Popliteal vessels and Tibial nerve
  - Aponeurosis – anterior to muscle
  - Tibial nerve
  - Sural branches of the Popliteal artery
  - Action – Supplies power for propulsion, PF AJ, Knee flexion
Triceps Surae Anatomy

- **Soleus Muscle** — crosses AJ, STJ
  - Origin — head and proximal 1/3 of posterior fibula, middle 1/3 of medial border of the tibia, the soleal line and the interosseous membrane
  - Aponeurosis — posterior to muscle
  - Tibial nerve
  - Posterior Tibial artery, Peroneal artery, Sural artery
  - Action — 80% Type 1 slow twitch fibers that provide stabilization of the leg on the foot, AJ PF

- **Plantaris Muscle** — absent 7% of the time
  - Origin — medial and above the lateral head of Gastroc at lateral condyle of femur coursing lateral to medial
  - Insertion — medial to achilles in central 1/3 posterior aspect calcaneus

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Defining & Evaluating Equinus
Clinical Examination for Equinus

Incorrect Clinical Examination for Equinus
Silfverskold Test to Evaluate Equinus

Morales-Munoz et al. FAI 2016
Gastrocnemius Proximal Release in the Treatment of Mechanical Metatarsalgia: A Prospective Study of 78 Cases

Figure 1. (A) Anatomic landmarks to measure ankle dorsiflexion. (B) Measurement with knee extended. (C) Measurement with knee flexed.
### DiGiovanni et al JBJS 2002

#### Patient Group vs Control Group

<table>
<thead>
<tr>
<th></th>
<th>Patient Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td># Patients</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Males</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Females</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Average Age and Range</td>
<td>47 (21 to 76)</td>
<td>45 (28 to 63)</td>
</tr>
<tr>
<td>Average Weight and Range</td>
<td>183 lbs. (104 to 345)</td>
<td>171 lbs. (120 to 260)</td>
</tr>
</tbody>
</table>

#### Primary Diagnosis in Patient Group and Number of Patients

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metatarsalgia</td>
<td>7</td>
</tr>
<tr>
<td>Morton’s Foot</td>
<td>13</td>
</tr>
<tr>
<td>Idiopathic Lis Franc Arthrosis</td>
<td>1</td>
</tr>
<tr>
<td>Posterior Tibial Tendon Insufficiency</td>
<td>9</td>
</tr>
<tr>
<td>Plantar Fasciitis</td>
<td>3</td>
</tr>
<tr>
<td>Stress Fracture 5th Metatarsa</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Purpose

Frequency of Equinus in symptomatic patient group and control group, and determine the reliability of clinical evaluation of Equinus.

![Equinus Frequency Chart](chart.png)
Examines two possible definitions of Equinus and confirmation of clinical diagnosis with Equinometer

DiGiovanni et al JBJS 2002

“We have selected < 5° of maximal ankle dorsiflexion with the knee in full extension 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).”
Biomechanics of Equinus

Equinus Compensation - Proximally

• Lumbar Lordosis
• Hip Flexion
• Genu Recurvatum
• Hamstring Contracture
Equinus Compensation - Distally

- **Uncompensated Equinus**
  - No Heel Contact
  - Toe Walker

- **Partially Compensated Equinus**
  - Heel Contact Tibia < 10°
  - Increased FF Pressures Early Heel Off

- **Fully Compensated Equinus**
  - Heel Contact Tibia > 10°
  - Pronated Foot Normal Heel Off

GSC During Gait

- **Stance phase** - maximum AJ dorsiflexion of 8 to 10° is required just before HO when the knee is close to full extension (stretching Gastrocnemius muscle) and hindfoot is normally supinated to create a rigid lever for propulsion
  - Jordan – JAPMA 1979
  - Mann - Biomechanics of the Foot and Ankle 1999
GSC During Gait

- Gastrocnemius muscle tightness limits normal advancement of the tibia relative to the foot during the midstance phase of gait
  - Subotnick – JAPMA 1971

James Amis, MD – Frontiers in Surgery 2016
The Split Second Effect: The Mechanism of How Equinus Can Damage the Human Foot and Ankle

Split Second Effect – Ankle Joint Dorsiflexion

1. Starts the last ⅓ of midstance when swing phase foot starts to pass the stance foot
2. Ends as stance heel lifts just prior to 3rd Rocker beginning
3. Lasts approximately 120ms (1/10th second)
4. Leveraged & direct forces act upon foot & ankle or “start up” gait (limping) develops
5. “Start up” limp gait ⇒ Rest & lack of calf tension ⇒ Worsen calf tightness (Law of Davis)
6. 1000’s steps/per over period of years ⇒ “occult, unrecognized, overuse of imbalance” ⇒ damage to foot & ankle
James Amis, MD – Frontiers in Surgery 2016
The Split Second Effect: The Mechanism of How Equinus Can Damage the Human Foot and Ankle

“It appears that merely being human places us at risk of developing acquired non-traumatic foot and ankle problems. This damage is mediated through our unique anatomy and the gastrocnemius that tightens for a number of reasons (5).”
“The isolated gastrocnemius contracture must be addressed as the definitive treatment for many if not the majority of non-traumatic acquired foot and ankle pathology. While treating the obvious foot or ankle problem is advisable and can be of great benefit to the patient, it must be considered only as adjunctive and palliative.”
Forefoot Varus

Uncompensated Forefoot Varus

Compensated Forefoot Varus
Forefoot Valgus

Rearfoot Varus
Rearfoot Varus

Foot Typing
Here’s the Secret!
STEP 1 - EXAMINE ARCH HEIGHT

Arch?
STEP 2 - EXAMINE TOE SIGN

"Peek-a-Boo" Hallux

False Toe Sign

Too-Many-Toes - (laterally)
STEP 3 - EXAMINE GAIT

Narrow Gait
Propels from 1st MTH

Toe-Out Gait
Propels off Medial Hallux

Toe-In Gait
Propels from 1st and 2nd MTH

Neutral Gait
Causes Medial Joint Break-down at Heel Rise

Abducted Gait
Pivots at 5th MTH in Propulsion

Causes Pivots at 5th Met Eate

STEP 4 - CALLUS INDICATORS

1st & 5th MTH
Medial Hallux

CALLUS DENSITY MAY VARY IN RELATION TO ACTIVITY LEVEL AND BODY WEIGHT

1st & 2nd MTH
2nd MTH
2nd & 5th MTH
Large Central Met
**John Wayne**

**HOW TO WALK LIKE JOHN WAYNE**

1. Pull on your cowboy boots that have at least two-inch-high Cuban heels.
2. The boot heel height will make you roll your hips slightly as you walk.
3. For that exaggerated Duke swagger, be sure to move slowly and thoughtfully.
4. Get your hands across your body as you walk.
5. Practice, practice, practice.

**NEUTRAL FOOT**

- False Toe Sign
- Moderately Inverted Heel Alignment
- Poor Shock Attenuation
- Restricted STJ Pronation
- Propels off Medial Hallux

**Orthotic Features**
- Neutral RF Posting
- Medium Arch
- Standard Depth

**Possible Clinical Symptoms**
- Retrocalcaneal Bursitis
- Lateral Hip Pain
- Haglund’s Deformity
- Lower Back Pain
- Iliotibial Band Syndrome
- Pinch Callus Medial Hallux
Chandelier Shaker!

SEVERE PES CAVUS

Propels forcefully from 1st Metatarsal

KEY ORTHOTIC FEATURES
- Lateral Forefoot Posting
- 1st MTH Cut-Out
- Deep Lateral Heel Cup Correction

POSSIBLE CLINICAL SYMPTOMS
- Lateral Ankle Instability
- Peroneal Tendonitis
- Heel Pain
- 5th Metatarsal Base Pressure
- Lower Back Pain
- Sesamoiditis, HAV, Hammer Toes
- Knee Recurvatum

LAGGED INVERTED HEEL ALIGNMENT

LARGE EXTERNAL TIBIAL/FIBULAR ROTATION

PEEK-A-BOO MALLEOLUS TOE SIGN

CALLUSES

FOOT PROGRESSION ANGLE

VALGUS FOREFOOT ALIGNMENT
Runway Model!
Patellofemoral Pain Syndrome

MODERATE PES PLANUS

KEY ORTHOTIC FEATURES
- Deep Heel Cup
- Medial RF Posting
- Moderate Medial Skive
- Medial Flare

POSSIBLE CLINICAL SYMPTOMS
- Plantar Fasciitis
- Metatarsalgia
- Functional Hallux Limitus
- Patellofemoral Pain Syndrome
- Posterior Tibial Tendonitis
- Neuromas
- Dorsal Bunions

• Neutral Toe Out
• Pronation through Midstance
• Midtarsal Joint Instability
"Are the shoes I wear important? Of all the other orthotics I have had, no one has ever talked to me about shoes."

"Yes...and here's the good news! I am going to tell you the exact model to get!"
Rigid Cavovarus Foot Type

Mild Pes Planus Foot Type

Neutral Foot Type

Mod. Pes Planus Foot Type

Abductovarus Foot Type

Severe Pes Planovalgus Foot Type

Please note that not everyone understands the medical interpretation of "mild" or "severe and / or initial or later" stages. When you encounter these stages, it is best to treat them based on the most common part. However, when you have a doubt, you should seek the advice of a healthcare provider who can guide you through the correct treatment.

Think Chandelier

Think Wayne

Think Flintstone

Think Runway Model

Think Fail!
Why Proper Equinus Treatment Results In Improved Orthotic Outcomes

The Orthotic/Equinus War
The Orthotic/Equinus War

Shoe-Equinus Relationship
Shoe Drop
??? Questions ???

DO GOOD
wherever you are.

#PayItForward #GiveItUpForGood