How do Foot Orthotic and Bracing Interventions Really Work?

A presentation linking clinical data with laboratory evidence to enhance patient care

Jeff Houck, PT, PhD
Deborah A. Nawoczenski PT, PhD
Ithaca College – Rochester Center
Movement Analysis Laboratory and Center for Foot and Ankle Research
Rochester, NY

Christopher Neville, PT, PhD
Upstate Medical University, Syracuse, NY

Smita Rao PT, PhD
New York University, New York, NY
Session Overview

• What motivated this session?
  – discordance between the severity of foot pathology and functional status
  – competing ideas of how foot orthotics/bracing interventions should be applied may lead to non-optimal management of foot pathologies

• What do we hope to achieve?
  – integration of laboratory based kinematic and kinetic studies, combined with clinical data
  – specific case studies will be used to motivate discussions of best care approaches
Session Evolution

• Discuss the ‘disconnect’ between foot function and foot pathology;

• Present current state of evidence regarding kinematic and kinetic mechanisms underlying orthotic/brace effectiveness;

• Using clinical laboratory data, discuss approaches and controversies of care related to orthotic interventions for selected foot pathologies.
Jeff Houck, PT, PhD
Associate Professor
Department of Physical Therapy
Ithaca College

DISCONNECT BETWEEN FOOT PATHOLOGY AND FUNCTION
Key Points

• The Relationship between Foot Pathology and Patients’ self-reported function
  “Does poor function accompany terrible lookin’ feet?”

• Evidence highlighting the Disconnect between Foot Pathology and Function
Prevalence of flat foot in preschool-aged children.

• Sample
  – 835 children (411 girls and 424 boys) 3- to 6-year-old children

• Methods
  – valgus position of the heel (Laser Scanner) and a poor formation of the arch (Visual)

• Results
  – 54% in 3-year-old children 24% in 6-year-old children

Martin Pfeiffer, Rainer Kotz, Thomas Ledl, Gertrude Hauser, Maria Sluga. *Pediatrics*. August 2006
Footwear in Children

• Sample
  – 2300 children between the ages of four and 13 years

• Method
  • Foot print analysis

• Result
  – Shod: 8.6% compared with Unshod: 2.8%

• Conclusion
  – Flat foot was most common in children who wore closed-toe shoes, less common in those who wore sandals or slippers, and least in the unshod.

(Rao, Joseph et al. JBJS (1995)
Summary (Flexible flatfoot – normal?)

- Flexible flatfoot decreases with maturity
  - MLA reaches peak height @ 12-13 years old (Staheli, 1987)
  - Medial fat pad may play a role (Mickle et al, J Ped Ortho, 2008)
- The overall prevalence of flexible flatfoot in adults is estimated at 8 - 20% depending on measurements used. (Benvenuti, 1995, Badlissi, 2005)
- Shoes worn less than 5-6 years old may influence flexible flatfoot (Rao, 1992, Sachithanada, 1995)
Foot structure

• The poor association of foot structure and function is underscored by the range of foot posture found in non-painful feet.
Runners with extreme High/Low Arch

• Sample
  – 20 High Arch (extremes)
  – 20 Low Arch (extremes)

• Methods
  – Arch Height Index

Fig. 1. Injury profiles by category.

D.S. Williams III et al. / Clinical Biomechanics 16 (2001) 341–347
Summary

• When foot postures are extreme and there is exposure to high loads

  – Foot posture is associated with injury
Is foot pain associated with flatfoot (pes planus) in the Elderly?

(Badlissi et al, JAGS, 2005, Benvenuti et al, JAGS, 1995)
Association of IADL and Foot Problems
Benvenuti et al, JAGS, 1995

Summary
• Pes planus is associated with foot pain
• Foot problems mostly limit distance walking activities
• However, associations are weak
Implications

• Foot conditions in the elderly are common, however, pes planus is not closely linked to IADL’s
Case Example

• 67 y.o. female with intermittent pain right foot PTTD

• PMH: bilateral THR, CA survivor

• Function: Walking 1-2 miles with minimal sx’s
Influence on Orthotic/Brace Prescription

• Foot postures vary widely
  – Flexible flatfoot as an example is a normal variant
  – Questions the validity of targeting flatfoot

• Extreme foot postures appear more susceptible therefore orthotic/bracing indicated

• Elderly subjects may prefer exercise/orthotics/bracing in spite of severe deformity
Treatment based on individual pathologies and client preferences NOT on foot structure alone!
Jeff Houck, PT, PhD
Associate Professor
Department of Physical Therapy
Ithaca College

PROPOSED MECHANISMS OF ORTHOTIC/BRACING TREATMENT FOR FOOT PATHOLOGY (KINEMATICS VS. KINETICS)
Basics: Two mechanisms

- **Kinematic**
  - Use braces/orthotics to reposition foot/ankle improving alignment and therefore clinical outcomes

- **Kinetics**
  - Use braces/orthotics to alter the loading in the foot/ankle resulting in improved clinical outcomes
    - Unloading
    - Changes in loading
Review of Important Foot Ligaments

- Spring Ligament
- Long Plantar Ligament
- Lisfranc Ligament
- Plantar fascia
- Deltoid Ligament
Plantarfascia - Windlass Mechanism

• Toe dorsiflexion tightens plantarfascia raising MLA
Radiographs - Static Alignment
Lateral Talo-first metatarsal angle
Forefoot Abduction

Normal

Abnormal
Midtarsal Joint Locking

Subtalar Inversion

Palpated STN

HF Inv/Ev (Degrees)

PTTD

Control

% Stance
Muscle Control
The Relationship Between Ankle, Hindfoot, and Forefoot Position and Posterior Tibial Muscle Excursion

Adolph Samuel Flemister, M.D.\textsuperscript{1}; Christopher Glenn Neville, M.D.\textsuperscript{2,3}; Jeffery Richard Houck, Ph.D.\textsuperscript{3•}
Are all these really happening at once?

80% of the power for walking comes from the ankle?

Significance of other muscle (FDL, FHL, foot intrinsics)?
(Fiolkowski et al, 2003, Hinterman et al, 1994)

Hindfoot Inversion = Boney stability

PASSIVE
Blackwood et al, 2005

Triceps Surae

Spring Ligament & Plantar fascia
Foot Kinematics

• Normal – foot movements
  – Hindfoot inversion
  – Forefoot adduction

• Flatfoot - Abnormal foot motions
  – Hindfoot eversion
  – Forefoot abduction
  – Forefoot dorsiflexion
Subtalar neutral position as an offset for a kinematic model of the foot during walking

Jeff R. Houck *, Josh M. Tome, Deborah A. Nawoczenski

A. Ankle
Dorsiflexion/Plantarflexion

Neville et al, In Press
Center for Foot and Ankle Research
Neville et al, In Press
Center for Foot and Ankle Research
Joint Dynamics

Normal
Abnormal
Frontal Plane

- Tibia/fibula
- Calcaneous

Neville et al, In Press
Center for Foot and Ankle Research
Subluxation of the Talocalcaneal Joint
in Adults Who Have Symptomatic Flatfoot

BY DHEERA ANANTHAKRISNAN, M.D.; RANDAL CHING, PH.D.; ALLAN TENCER, PH.D.;
SIGVARD T. HANSEN, JR., M.D.; AND BRUCE J. SANGEORZAN, M.D.; SEATTLE, WASHINGTON

- Peri-talar subluxation
Midtarsal Joint Locking

Subtalar Inversion

Inversion

Palpated STN

Calcaneus

Calcaneocuboid Axis

Med.

Lat.

Talonavicular Axis

Neutral

Inverted Calcaneus

HF Inv/Ev (Degrees)

PTTD

Control

Foot & Ankle International/Vol. 26, No. 12/December 2005
Dorsiflexion

1st Metatarsal

Plantar Flexion

Rearfoot

Dorsiflexion

1st Metatarsal

PTTD
Control

Palpated STN

% Stance

Dorsiflexion (Degrees)
Although the foot is flat the raising/falling pattern of the arch is unaffected!!!
Hindfoot or 1\textsuperscript{st} Metatarsal?

- Foot Flat
  - Dorsiflexion
  - Hindfoot Global (Degrees)
  - Slope Control
  - Slope PTTD

- Foot Flat
  - Dorsiflexion
  - Control
  - PTTD
Collapse of the Midfoot

- Tibia
- Calcaneus
- 1st Metatarsal
Joint Dynamics

Normal
Abnormal

Hindfoot
Plantarflexion

1st Metatarsal
Dorsiflexion
Foot Kinetics

Experiments

• **Early Studies**
  – No muscle activation with weight
  – Assumed stability of midfoot is the result of passive mechanisms

• **More Recent Studies**
  – Power generation from the midfoot
Pressure Patterns
Normal Pressure Patterns

• Center of pressure starts posterior
• Moves anterior and lateral
• Shifts medial during late stance
• Centered over 2\textsuperscript{nd} – 3\textsuperscript{rd} metatarsals during late stance
• Centered under big toe at end of stance
Abnormal Pressure Pattern Associated with Flatfoot

Medial Shift in Pressure
Clinical Goal

• Restore normal pressure patterns?

   Off load pathology or restore load?
Are all these really happening at once?

80% of the power for walking comes from the ankle?

Significance of other muscle (FDL, FHL, foot intrinsics)?
(Fiolkowski et al, 2003, Hinterman et al, 1994)

Hindfoot Inversion = Boney stability

PASSIVE
Blackwood et al, 2005
Ankle Power

- Responsible for 80% of the energy in walking
- Primarily triceps surae
- Strong deforming force on a long lever (foot)
Ankle vs Midfoot Power

- 2 segment models show that there is a significant power generation at the midfoot

Ankle Power
- 2 Segment Foot Model
- 1 Segment Foot Model

Midfoot Power
- Midfoot Power

Power (W/kg)
The power generation at the midfoot emphasizes the role of muscle control

Triceps Surae

Significance of other muscle (FDL, FHL, foot intrinsics)?
(Fiołkowski et al., 2003, Hinterman et al., 1994)

Hindfoot Inversion = Boney stability

Spring Ligament & Plantar fascia

(Oatis & Gage, 2001, Flemister et al, 2007)

PT

MLA

PASSIVE
Blackwood et al, 2005
Midfoot Stability

• **Normal foot** – good alignment may multiply muscle forces, resulting in large power generations at the midfoot for propulsion
  – Power generation at the midfoot is large

• **Flatfoot deformity** – The foot may be more dependent on muscle control because of the loss of alignment (which alters moment arms).
Clinically

• Altering kinetic patterns may be more important for the foot with midfoot stability than controlling kinematics!!
Case Example: PTTD

Gradually decreasing ankle power output = plantarflexor weakness
Why do orthotics work?

• Lessons learned
  – Patients may benefit from developing clinical models that combine kinematics and kinetics.
    • Kinematic correction improves alignment
      – In some cases are we so restrictive that we are sacrificing muscle control?
    • Kinetic changes alter loading
      – Unloading
        » In some cases are we targeting kinematics and causing kinetic changes?
        » In other cases are we targeting kinematics when kinetics would be more effective?
      – Alteration of loading patterns
Acknowledgements

“Working collaboratively to solve patient centered biomechanics problems”

Radiology
Dr. Kwok

Orthopedics
Dr. Baumhauer
Dr. Flemister
Dr. Di Giovanni

Rehabilitation
Dr. Nawoczenski
Dr. Rao

Orthotics
Chris Constantini
Dan Sherwood
Deborah A. Nawoczenski PT, PhD
Ithaca College-Rochester Center
Movement Analysis Laboratory and Center for Foot and Ankle Research

CLINICAL AND LABORATORY EVIDENCE:
LESSONS FROM PATIENTS WITH HALLUX RIGIDUS
Overview

• Background
  – Etiology and pathology

• Clinical presentation
  – Kinematic and Kinetic Adaptations

• Management Approaches
  – Operative vs. Non Operative

• Lessons Learned
THE “GREAT” TOE

• 8 muscles impact 1st MTP function
  – 6 directly insert on hallux

• 1st MTP dorsiflexion needed approximately 900 times/mile

• Joint forces 80-130% BW during normal walking speeds

• During quiet standing, great toe carries twice the amount of pressure as the other 4 toes combined

Oatis 2004; Hutton 1981
THE “GREAT” TOE

• 1st MTP requirements ‘normal’ function that is coupled with 1st metatarsal motion
  • 45 º normal walking gait\(^1\)
  • 60º standing on toes/heel raise
  • >75º stair climbing\(^2\)

• “Other” demanding activities
  – Running
  – Dancing
  – Squat/Football
  – Baseball pitchers

Nawoczenski JBJS 1999; Darter JOSPT 2001
North Carolina’s Ty Lawson is used to being in control.

As the lead guard in coach Roy Williams’ high-octane attack, the ball rarely leaves Lawson’s hands when he’s on the court.

So it’s no surprise that Lawson felt out of sorts when his still-injured toe forced him into spectator status during UNC’s first-round win against Radford.

“I was real stressed,” Lawson said after the game. “In the beginning when they came back and it was like 13-11, I’m like yelling out there, ‘Come on guys, pick it up!’”
Toe becomes Thumb

• Replantation

Courtesy of University of Rochester Medical Center, Hand and Wrist Surgery
A joint ‘set up’ for pathology

- Activities that require increased dorsiflexion:
  - Decreased joint contact area = increased pressures
  - Increased compression at maximum dorsiflexion

- Activities that require increased co-contraction
  - Increased joint reaction forces

Shereff 1986, Ahn et al., 1997
1st MTP Joint Osteoarthritis

- Affects 35-60% of population over 65 years of age

- Degenerative changes
  - Loss of articular cartilage
  - Joint space narrowing
  - Osteophyte formation

Hallux Rigidus

• Painful and insidious condition

• Affects 1 in 45 people over the age of 50
  – 2nd most common disorder of the 1st MTP joint
  – Women 60-70% of cases
  – Bilateral 50% -80%

Shereff and Baumhauer 1998, Canesco et al., 2008, Zammit et al., 2009
Hallux Rigidus: Patient Profile

• Localized pain
  – Dorsal, plantar, ‘diffuse’

• Marked restriction in 1\textsuperscript{st} MTP dorsiflexion
  • And often plantarflexion

• Activity limitations
  – Stairs, kneeling, walking, running; activities requiring ‘stabilization’: eg. martial arts and golf
Kinematic Alterations Hallux Rigidus

Kinematic Alterations:

✧ Decreased hallux dorsiflexion
  ✧ Increased hallux abduction

✧ Decreased forefoot (1st MT) plantarflexion

✧ Decreased hindfoot dorsiflexion

Kinetic Adaptations Hallux Rigidus

Kinetic Alterations:

• Pressure Changes
  – Increased hallux pressures
  – Increased lateral forefoot loading

• Gait alterations
  – Subtle adaptations to off-load painful joint may be associated with increased hip and knee pain

Interventions: Operative

• Cheilectomy
  • Most common surgical intervention for patients with grades I and II HR

• Goals:
  • Remove osteophytes, loose bodies, and dorsal bone decrease pain
  • Increase range of motion but joint mechanics not necessarily corrected
Surgical Outcomes

• Pain reduction\textsuperscript{1,2}

• Activity limitations persist
  – Not impressive changes in range of motion

• Equivocal as to whether normal kinematics and kinetics can be restored\textsuperscript{3,4}

\textsuperscript{1}Couglin J Bone Jt Surg 2003; \textsuperscript{2}Easley Foot Ankle Int 1999; \textsuperscript{3}Nawoczenski Foot Ankle Int 2008; \textsuperscript{4}Shereff J Bone Jt.
Kinematic Alterations following Cheilectomy Surgery

Significant differences .. but on average, increases of 11 degrees!

Nawoczenski Foot Ankle Int 2008
Interventions: Non Operative

First line of intervention
• Goals:
  Reduce pain and local inflammation
  Improve function

*Intuitively*....

Prevent further trauma to joint by minimizing
dorsiflexion and decrease loading on the MTP joint
Non Operative Interventions

- Rest, activity modifications
- Protection from excessive dorsiflexion
- Footwear modifications

  Stiff and/or rigid sole designs
Non Operative Management

Foot Orthoses

- Commonly prescribed

- *Little objective evidence to guide prescription for patients with HR!*
Morton’s Extension Inserts

• Characteristic rigid extension of the footplate beneath the great toe
  – ‘over the counter’
  – incorporated into custom designs

• purportedly reduces pain and inflammation by decreasing motion and plantar loading patterns.

*Is this true?*
Hallux Rigidus Study

• 30 patients, Gr. I-III HR
  • 6 wk. intervention with Morton’s Extension (ME) carbon fiber insert
• 18 age, BMI, gender-matched controls

Outcome Measures
• Plantar loading patterns
  – Pedar ® in shoe device
• Self-reported pain and function
  – FFI-R

Nawoczenski et al. Combined Sections Meeting, San Diego 2010
Hallux Rigidus Study

Outcome Measures

• Kinematic Alterations
  – 1st MTP joint, 1st metatarsal, rearfoot
  – Flock of Birds magnetic tracking device (Motion Monitor)
Kinematic Changes

Hallux DF-PF

Small (2 degree) reduction in hallux DF with Morton’s Extension (p=.01) (accompanied by 10% decrease in push off power)
Regional Pressure Distribution: HR (Pre Intervention) vs. Controls
Regional Pressure Distribution:
HR Pre vs. HR Post vs. Controls

Maximum Mean Pressure (MMP) kPa

Foot Region

Hallux | MT1-2 | MT3-5

- Pre Shoe Only
- Control
- Post Shoe + ME
Change in Pressure Distribution
HR Pre to HR Post

 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasil
 brasi
Outcomes Improved!

*All dimensions showed significant change P<.05

62% improved total score!
Lessons Learned

• Only change in motion was seen in hallux DF
  • 2 degrees reduction

• Changes in plantar load distribution
  • Shift of pressures toward the ‘pathological’ joint

And....this was accompanied by improvements in pain and function!
Lessons Learned

- Pressures “normalized” post ME intervention
  - Similar to controls
  - Less drastic ‘gradient’ between medial and lateral forefoot

Challenges approach of off-loading the painful joint and preventing motion!
Lessons Learned

• May be alternative to surgery or extend function until surgery is indicated

• Inexpensive over-the-counter intervention
  – Viable alternative to other conservative treatments
Limitations and Concerns

✧ Short term follow up: 6 weeks
  ✧ Long term effects of increasing pressure medially unknown
Acknowledgements

✧ This project is supported in part by the American Orthopaedic Foot and Ankle Society

✧ Special thanks to Josh Tome, Research Engineer, Judy Baumhauer, MD, and Kristin Morris DPT
Smita Rao, PT, PhD
Assistant Professor
Department of Physical Therapy
New York University

CLINICAL AND LABORATORY EVIDENCE:
LESSONS FROM PATIENTS
WITH MIDFOOT ARTHRITIS
Background

• Arthritis: One of the leading causes of disability

  (CDC, 2007)

• Midfoot Arthritis: High potential for chronic secondary disability
Incidence and Prevalence

• Midfoot Injuries
  – Alarming increase in incidence secondary to motor vehicle trauma.
    \[(Smith \ et\ al.\ 2005)\]
  – As many as 20% are missed or misdiagnosed.
    \[(Goossens\ and\ De\ Stoop\ 1983)\]
Background

• Surgical Management:
  • Challenging!
  • Complex anatomy and function
  • Decreased pain
  • Only modest improvements in function

(Teng and Pinzur, 2002)
• Complications following surgery
  – Non-union, broken screws and wound problems
  – May necessitate further surgery involving revision, arthrodesis, hardware removal
Non-operative Management

• Primary aim of treatment
  – Provide pain relief
  – Often attempted using shoe inserts.

• Custom-molded three-quarter insert (3Q)
  – Most common recommendation

•Patients continue to report pain.
Patient Presentation

• Radiographic:
  – Joint space reduction
  – Osteophytes
  – ‘Dorsal bossing’

• Clinical:
  – Pain on dorsum, localized to TMT region
  – Aggravated by walking
  – Stair descent
Self-reported Function

• Foot Function Index – Revised (FFI-R)
  – Pain
  – Stiffness
  – Disability
  – Activity Limitation
  – Social

(Budiman-Mak, E et al., 2006)
Full Length Carbon Graphite Orthoses (FL) as an Alternative

• Promising results from retrospective analysis:

• 63% reported a significant decrease (greater than 50%) in pain within four weeks of using the full length carbon foot plate (FL)
Outcomes

• Clinical Outcome Measures:
  – FFI-R
  – VAS

• Lab / Biomechanical Outcome Measures:
  – Kinematics
  – Plantar loading
Results – 4 weeks

Significant symptomatic improvement after 4 week intervention with the FL

Pain Subscale
Stiffness
Disability Subscale
Activity Subscale
Psychosocial Subscale
Total Score
Pre 41 36 44 39 32 38
Post 31 32 36 30 28 31
Ctrl 18 17 18 17 17 17
Kinematic changes

- At baseline, patients with MFA show a stiffening strategy.
- Instability is evident only in high demand activities

Kinematic changes

• Kinematic changes accompanying orthoses were counter intuitive!

Load distribution changes

• Regional loading changed with orthoses

*(Rao et al., J Orthop Sports Phys Ther 2009)*
Lessons learned

• Disconnect between foot pathology and function – low arched foot structure may be non-specific clinical finding
  – INSTABILITY is a subtle but potentially important impairment in patients with early arthritis

• Orthoses may work by effecting load distribution (big effect size) and altering motion (small effect size)
Limitations and Caveats

- Larger sample sizes, longer term follow-up and clinical trial design indicated
- Homogenous sample = interesting, in and of itself, but may not be generalizeable to men (different BMI range) and activity demands.
Acknowledgements

AOFAS Research Grant
Arthritis Foundation

Josh Tome, engineer extraordinaire!
CLINICAL AND LABORATORY EVIDENCE: LESSONS FROM PATIENTS WITH POSTERIOR TIBIAL TENDON DYSFUNCTION
• Who gets this problem?
  – Recent prevalence data: 3.3% of women over 40 (~2.3 million cases in US)
    • All experienced pain, experienced loss of function, and had evidence of foot deformity but all were undiagnosed  

Kohls-Gatzoulis, J. 2009

– ~80% of published samples are women
What is the treatment?

• Surgical
  • Extensive attention on numerous surgical options

• Orthoses
  – Numerous devices and styles available – no head-to-head comparisons.  
    Imhauser et al. 2002
  • Biomechanical improvement in foot kinematics with UCBL

• 18 of 20 subjects (90%) demonstrated improvement in symptoms with Arizona AFO.  
  Augustin et al. 2003
Staging - Posterior Tibial Tendon Dysfunction

• **Stage I**
  – No foot deformity

• **Stage II**
  – Flexible Foot deformity
    • ligament damage
    • tendon elongation
  – Decreased function of muscle
    • Inability to heel raise

• **Stage III**
  – Fixed foot deformity
  – Loss of muscle function

*Johnson, KA et al. 1989*
Why correct flatfoot kinematics in subjects with Stage II PTTD?

- Unload the Posterior Tibialis Tendon
- Unload Supportive Ligaments
- Improve Muscle Function (heel rise)
How can we Unload the Posterior Tibialis Tendon?

HF
Inversion

FF
Adduction

The Relationship Between Ankle, Hindfoot, and Forefoot Position and Posterior Tibial Muscle Excursion

Adolph Samuel Flemister, M.D.¹; Christopher Glenn Neville, M.D.²,³; Jeffery Richard Houck, Ph.D.³
How can we Unload the Spring Ligament?

Sectioning of the Spring Ligament and subsequent plantar flexion of the talus

FIGURE 2 Interaction line plot for talar sagittal plane rotation demonstrating plantarflexion. Notice minimal change in rotation with increasing PTT tension.

Jennings, M J Foot and Ankle Surgery, 2008
Altered Foot Kinematics are focus for correction with orthotic devices…

However, altered movement strategies at proximal joints and changes in muscle control may play a role in the clinical success of an orthosis
Positive Effects – Off the Shelf Brace

**FIGURE 1.** (A) Changes in frontal plane hindfoot motion with air bladder inflation. Positive values indicate hindfoot inversion. (B) Schematic representation of how air bladder inflation influences hindfoot kinematics in subjects with posterior tibial tendon dysfunction.
Is there Something better?

Neville et al, JOSPT, 2009
Need head-to-head comparisons of various brace designs!
Rearfoot control is achieved but effects are small in the presence of gross amounts of eversion. A custom, jointed ankle design is the most successful.
Raising the MLA is a benefit of Custom Designs with the Jointed design allowing continued ankle movement
Forefoot Abduction is poorly controlled with current AFO designs. New design options should be explored.
Mechanisms

• Small corrections in kinematics in the presence of gross deviations....
Where are we Now?

• A jointed ankle design preserves ankle movement and may improve muscle function to control foot kinematics – HF inversion and raising the MLA.
• FF Abduction is poorly controlled!
• A solid ankle design alters proximal joint movement.
Alternative or Additive Mechanism

- Changes in Kinetics...
  - Reduced Ankle power – Lift-off instead of Push-off

Mueller, 1994

Neptune, 2001
Ankle Joint Power Without Brace

-1
-0.5
0
0.5
1
1.5
0 10 20 30 40 50 60 70 80 90 100
Stance (%)
Power Generation (W/kg)

Shoe
Custom Jointed
Custom Solid

Ankle Joint Power

Power Generation (W/kg)

Stance (%)
• Hip Strategy
• Greater knee/hip flexion

Lessons Learned

• Correction of foot kinematics is small in the presence of gross deviations.
• Jointed ankle designs may preserve muscle control.
• Need to improve control of forefoot abduction
• Altered movement patterns at proximal joints may also be an effect of solid ankle designs.
ESTABLISHING THE RATIONALE FOR NON-SPECIFIC FLATFOOT DEFORMITY

Deborah A. Nawoczenski PT, PhD
Ithaca College – Rochester Center
Movement Analysis Laboratory and Center for Foot and Ankle Research
Rochester, NY
Christopher Neville, PT, PhD
Upstate Medical University, Syracuse, NY

Multi-Modal Interventions
• Part I (Nawoczenski)
  – Perspective
  – Orthotic Effectiveness: Review of Mechanisms
  – Considerations for passive and active approaches

• Part II (Neville)
  – Background and Motivation for Multi-Modal Intervention
    • Distal and Proximal
  – Considerations for the non-specific flatfoot
Perspective: The Last Quarter Century

• The Orthotic “Boom”
  – The “80s” and the running revolution
  – The “Root” approach
    • mechanical relationship between the subtalar joint (STJ) and the midtarsal joint
    • a "criteria defining a normal foot“
    • casting feet in a non-weight-bearing "STJ-neutral" position was a method of standardizing and comparing one foot to another
Perspective:
The Last Quarter Century

• The Orthotic “Boom”
  – Emergence of new materials for the orthotic industry.
    • thermoformable plastics, acrylcs, and urethanes
  – Proliferation of orthotic fabrication laboratories
  – Proliferation of continuing education seminars

A multi-billion dollar industry $$$
Orthotic Effectiveness

• Pain
  – 50-90% symptom relief
• Function
• Kinematics
  – Static and dynamic alignment
  – Movement alterations
    • Small and non-systematic
    • Peak foot eversion, eversion velocity and total rearfoot motion, coupling changes, dynamic arch height changes
    • Maximum foot inversion during 2\textsuperscript{nd} part of stance

Orthotic Effectiveness

• Kinetics
  – Muscle Activation
    • Intensity, duration and/or frequency of EMG
      – Unclear if increase or decrease in EMG is beneficial or detrimental
        » Eg. Increased activation of certain muscles that may not be as fatigue-resistant
  – Moment arm changes
    • Potential to optimize muscle activation/response
  – Modifications in loading
    • Alterations in pressures or pressure distributions
    • Changes in vertical loading rates and magnitudes

Orthotic Effectiveness

• Proprioception
  – Minimize variability
  – “Preferred movement path”

• Alteration of proximal alignment and loading
  – Knee unloader with ‘neutral aligned’ orthosis
  – Knee adduction moment changes

(Gross and Hilstrom, 2009, Hilstrom et al., 2005, Eslami 2009- Mundermann and Nigg 2000)
Evidence from Presentations
Orthotic effectiveness in unexpected ways!

• Pressure patterns may be the desired outcome rather than modifying range of motion

• Optimal alignment (via arch restoration) may not be beneficial in some patient groups such as midfoot arthritis
  – Suggesting an alteration in joint forces/contacts

• Orthoses may enhance stability
  – Effectiveness may be realized during some activities (e.g. stairs) rather than walking
What is true....

• Subject specific and highly variable results

(Mundermann 2006, Murley 2009)
Do We Need Orthotics at All? Some say ‘no’!

- Using the footwear and barefoot running craze that supports nothing rigid on the foot
  – Scan report and download


- Review injury patterns with shoes

Kerrigan 2009
68 runners
“Neutral” shoe (semi-curved, dual density. Board last, Rearfoot:Forefoot height 24:12 mm
Revisiting Clinical Management of Non Specific Flatfoot Deformity:

Is there an answer somewhere between distal and proximal control?
• Video – standing, correct hip rotation, then orthotics, stand with hip rotation again – do they improve

• Standing – sitting – can they restore the arch
  – Are you working on increased plantarflexion of the 1st metatarsal.
‘Traditional’ approach may not be enough to prevent progression of the deformity or disease process.

Is this 23 yo foot flat foot predestined to be this 56 yo foot with PTTD?
Videos and Stills of Bad Feet
Altering Foot Structure - Distal

- Correction of flatfoot deformity unloads soft tissue structures
Alterning foot Structure - Proximal

• Coupling between the tibia and rearfoot

Nawoczenski, DA et al. 1998
Bellchamber et al. 2000
Hip control and rearfoot motion

• Predictors of maximum rearfoot position
  – Max hip rotation
  – Point in stance where peak hip internal rotation occurred

Snyder, KR et al. 2009
Knutzen, KM et al. 1994
Orthotics and Muscle Control

• Interplay between foot structure and muscle control

Nawoczenski, DA et al. 1998
Kulig, et al, 2005
Orthotics and Muscle Control

- Changes in foot structure may
  - Alter muscle lines of pull
  - Alter muscle’s mechanical effect by changing moment arms.
Interplay between Orthotics and Muscle Activation

• Should we strive for both alignment and muscle activation in our orthotic prescription process?

• Preserve what exists in the foot and not over-restrict motion...and focus on muscle activation and control
Other thoughts

• Are there ways to select foot types that may respond to ‘active’ intervention and improve foot function while still preserving the integrity of static structures?
  – At earlier ages!!

*Not just orthotic intervention – but multi-modal intervention*
Revisit Orthotic Intervention Strategies

• Issues surrounding orthotic management
  – Stress on soft tissues
  – Muscle activity changing foot mechanics
    • Foot and ankle muscle activation
    • Activation of muscles proximal to the foot and ankle
Interplay between Orthotics and Muscle Activation

• Influence of orthotics in changing muscle moment arms
ROUND TABLE DISCUSSION