INTRODUCTION

Partial foot gait...

THOUGHT FOR THE DAY

Learning is about more than simply acquiring new knowledge and insights; it is also critical to unlearn old knowledge that has outlived its relevance. Thus, forgetting is probably at least as important as learning.

Gary Ryan Blair

THOUGHT FOR THE DAY

Irrelevant knowledge
• 120 years ago

Irrelevant knowledge
• 120 years ago
• 60 years ago

13 days in hospital for normal birth
THOUGHT FOR THE DAY

Irrelevant knowledge
- 120 years ago
- 60 years ago
- 30 years ago

4 to 6 weeks plaster for inversion ankle sprain

AGENDA

- Medical evidence
- Normal function
- Abnormal stress
- Controlling stress to create environments that allow healing

PATIENT PRESENTATION

- Apropulsive gait
- Footdrop

Inability to
- Propel foot off the ground
- Advance limb through space during swing phase

Inability to
- Pick foot up during swing

CAUSES

- Footdrop
- Neuro-involved
  - CVA
  - MS
  - SCI
  - Etc

- Footdrop
- Apropulsive gait

- Neuro-involved
  - CVA
  - MS
  - SCI
  - Etc
  - Partial foot amputation
  - Soft tissue dysfunction

PATIENT PRESENTATION

- Apropulsive gait
- Footdrop

Inability to
- Propel foot off the ground
- Advance limb through space during swing phase

Inability to
- Pick foot up during swing
SOFT TISSUE DISRUPTIONS

Common lower quarter soft tissue dysfunctions:
- Achilles (all)
- PTTD
- Ankle sprains including syndesmosis
- Ankle RA
- Plantarfasciitis
- Shin splints
  - (anterior athletic compartment syndrome)
- *Metatarsal stress fractures

COMPENSATORY MECHANISMS

Apropulsion
- Lift foot off floor
- Advance limb
- Concentric trunk rotation
- Contralateral concentric internal hip rotation
- Hip/knee flexion
- Pelvic tilt
- Trunk sway
- Various combinations of
  - Hip hike
  - Trunk sway
  - Circumduction
  - Hip/knee flexion

COMMON ORTHOTIC INTERVENTIONS

Common lower quarter practices
- Immobilize to make it stable
- Immobilize in subtalar neutral
- Immobilize for soft tissue healing
- Immobilize for edema reduction

What evidence exists to substantiate these practices?

EVIDENCE BASIS FOR PRACTICES

Data findings
- Low quality studies
  - Figueiredo et al 2008
  - Low level of confidence
  - Low quality
  - Lack of standard terminology

Data findings

- Low quality studies
- Inconsistent data

Ridgwell et al 2010
- Insufficient details
  - Participants
  - Devices
  - Protocols
- Unable to synthesize outcomes across studies

Immobilization creates stability

There are no consistent data

Questions:

- Would you put our usual orthotic intervention onto someone who was not injured?

Immobilization leads to disuse atrophy of:

- Muscles
- Tendons
- Ligaments
- Vascular systems
- Proprioceptive systems
- Osseous structures
- Articulating surfaces

Immobilization

- Chronic instability

Loss of motion is designated as a primary cause of chronic pain and re-injury


Urso ML. Regulation of muscle atrophy: wasting away from the outside in: an introduction. Medicine and Science in Sports and Exercise 2009 Sep

Immobilization

- Chronic instability
- Less strength with weaker scar

• Inhibits development of structural strength
• Results in a smaller quantity of scar tissue that is less able to resist higher loads


Management and rehabilitation of ligamentous injuries to the ankle
IMMOBILIZATION CREATES STABILITY

Immobilization
- Chronic instability
- Less strength with weaker scar
- Significant impact on outcomes

...using immobilization is frequently linked to muscle atrophy, weakness, and higher rates of re-rupture

IMMOBILIZATION ALLOWS HEALING

Immobilization
- Fiber strands
- Ligament/tendon
- Disruption

Ursu MI. Regulation of muscle atrophy: wasting away from the outside in, an introduction. Medicine and Science in Sports and Exercise. 2009 Sep

Ursu MI. Regulation of muscle atrophy: wasting away from the outside in, an introduction. Medicine and Science in Sports and Exercise. 2009 Sep
IMMOBILIZATION ALLOWS HEALING

- Fiber strands
- Ligament/tendon
- Disruption
- Immobilization

IMMOBILIZATION ALLOWS EDEMA REDUCTION

- Immobilization helps reduce edema
- There are no data to support this concept

IMMOBILIZATION ALLOWS EDEMA REDUCTION

- Muscle pump function helps reduce edema
  - Normal gait helps reduce edema

PRINCIPLES OF FUNCTION

Foundation principles - the basis upon which rehabilitation decisions are based

Goal: to restore gait deficit patients to the highest possible level of function
- Symmetrical
- Stable
- Safe
- Fluid

- Dynamic
- Propulsive
- Energy efficient
- Pain free
CONCEPT

The foot/ankle complex serves three purposes
- Flexible adapter to the terrain
- Stabilize body during weight-bearing
- Propulsion during gait

PRINCIPLES

Components of functional stability
- Appropriate motion
  - All three planes
- Appropriate amounts
- Appropriate pathways
- Adequate strength
- Adequate proprioception

FUNCTIONAL STABILITY DURING GAIT

Sequential cascade of events leading to functional stability
- Motion of the biomechanical event
- Triggers proprioceptive stretch reflex
- Leading to eccentric muscle activation
- Enabling concentric propulsion
- Creating proximal stability during gait
Conclusion: immobilization leads to instability

NORMAL FUNCTION

Normal function
- Calcaneal ROM (Right posterior view)

AFO IMPLICATIONS

Normal function
- Calcaneal ROM
- Time in STN
AFO IMPLICATIONS

Normal function
- Calcaneal ROM
- Time in STN
- Congruency

Sub-talar neutral
20° Inversion (Swing)
3.0 cm²

Sub-talar neutral
2.79 cm²

10° Eversion (Stance)
3.0 cm²


REACTIVE CHAIN

Normal function
- Calcaneal ROM
- Trigger mechanism
  - ST eversion
  - MF valgus
  - FF abduction
  - RF eversion
  - Medial Tibial rotation

White R: Action of the Subtalar and Ankle Joints, JBJS, 1964

REACTIVE CHAIN

Foot pronation
- Dorsiflexion
- Eversion
- Abduction

Secondary to calcaneal eversion...

Blackwood CB: The Midtarsal Locking Mechanism, Foot Ankle International, 2005 Dec

PROPRIOCEPTION

Sequential cascade of events leading to functional stability
- Motion of the biomechanical event
- Triggers proprioceptive stretch reflex

Gray f: Chain Reaction Seminars, Wynn Marketing, June 2000

Propiroception
- Pacinian Corpuscles
- Ruffini Endings
- Golgi-Mazzoni Corpuscles
- Golgi Ligament Endings
- Golgi Tendon Organs
- Muscle Spindles
- H-reflex
**PROPRIOCEPTION**

**Proprioception**

- Pacinian Corpuscles
  - Distal - fast
- Ruffini Endings
  - Proximal - slow
- Golgi-Mazzoni Corpuscles
  - Compression
- Golgi Ligament Endings
  - Tension/Stretch
- Golgi Tendon Organs
  - Fail-safe system
- Muscle Spindles
  - Change rate
- H-reflex
  - Topical pressure

**Proprioception stretch reflex**

- CNS
- Golgi Ligament Ending
- Spinal Interneuron
- α-motoneuron
- Muscle spindle
- Synergistic groups
- Antagonist groups

**Recent Findings**

- Proprioceptive responses are linked to maintenance of postural stability in entire limb
RECENT FINDINGS

- Lower leg receptors connected to Erector Spinae

- Stability of the trunk is prioritized over other segments by the nervous system

REACTIVE CHAIN

Proprioceptive implications

- Impairment to anatomic structures = impairment to proprioceptive response
  - Neuromuscular conditions
  - Traumatic disruption
  - Immobilization
- Proprioceptive rehabilitation (re-education) occurs ONLY with joint compressive forces and controlled (graded) motion

FUNCTIONAL STABILITY DURING GAIT

Sequential cascade of events leading to functional stability

- Motion of the biomechanical event
- Triggers proprioceptive stretch reflex
- Leading to eccentric muscle activation
- Enabling concentric propulsion

MUSCLE FUNCTION

Muscle function

- Eccentric precedes
- Concentric

Soleus

- Origin

GRAY'S: Deep Institute, June 2000
Soleus
• Origin
• Insertion
• Directional bias

Soleus
• Origin
• Insertion
• EMG

Soleus closed chain function
• Eccentric function
  – Sagittal
  – Frontal

Soleus closed chain function
• Eccentric function
MUSCLE FUNCTION

Soleus closed chain function
- **Eccentric** function
  - Sagittal
  - Frontal
  - Transverse

AFO IMPLICATIONS

Pop quiz:
Does immobilization create
a. Stability
b. Instability

PRINCIPLES

1. How do normal stresses occur during gait
2. How do abnormal stresses occur
3. How to minimize abnormal stresses to allow healing

**PTTD**
OVERVIEW

Common PTTD concurrent conditions
• Obesity
• Diabetes
• Hypertension
• Previous trauma
• Tight calf group

NORMAL FUNCTION

Normal function
• Calcaneal ROM (Right posterior view)

PATHOPHYSIOLOGY

Injury mechanism
• Gravity/ground
  – All three planes
  – Stretched plantar ligaments
• Abnormal stress on Posterior Tibialis tendon
• Acquired adult flat foot deformity

REACTIVE CHAIN

Normal function
• Calcaneal ROM
• Trigger mechanism

PTTD STAGES

• Stage I
  – Pain/Swelling along PTT, no X-ray signs.
  – Medial Pain
  – Mild edema
  – Flexible calcaneal eversion

OVERVIEW

A rose by any other name...
• Posterior Tibialis Tendon Dysfunction
• Posterior Tibialis Tendon Insufficiency
• Adult acquired flatfoot
PTTD STAGES

• Stage I
• Stage II
  – Increased pain w decreased medial arch height
  – Abduction of FF on RF (too many toes sign)
  – Progressive heel valgus
  – Inability to do single heel rise
  – X-ray shows subluxed TN joint

• Stage III
  – Rigid non reducible flatfoot
  – RF decreased mobility
  – Pain laterally
  – Possible ruptured PT tendon
  – X-ray shows arthritic changes in tarsal joints

• Stage IV
  – End stage, severe flatfoot
  – Rigid fixed deformity
  – Ruptured PT tendon
  – X-ray shows valgus collapse of Talus

FUNCTIONAL PHYSIOLOGY

• Lateral column
  – Calcaneal control
• Medial column
  – Talar control

• Talus
• Navicular
• Cuneiform
• Posterior tibialis
FUNCTIONAL PHYSIOLOGY

PT Insertions
- Calcaneous
- Talus
- Navicular
- Cuneiform

FUNCTIONAL PHYSIOLOGY

Injury mechanism
- Stretched plantar ligaments
- Abnormal stress on Posterior Tibialis tendon

FUNCTIONAL PHYSIOLOGY

Injury mechanism
- Stretched plantar ligaments
- Abnormal stress on Posterior Tibialis tendon
- Acquired adult flat foot deformity
  - Rearfoot eversion, forefoot abduction

“The abnormal kinematics ... implicate a failure of compensatory muscle and secondary ligamentous support ... with stage II PTTD”

TRADITIONAL MANAGEMENT

Traditional
- 6 to 8 weeks in cam walker
TRADITIONAL MANAGEMENT

Traditional
- 6 to 8 weeks in cam walker
- Progress to gauntlet style AFO

PRINCIPLES

1. How do normal stresses occur during gait
2. How do abnormal stresses occur
3. How to minimize abnormal stresses to allow healing

Injury mechanism
- Gravity/ground
- All three planes
- Abnormal stress on soft tissue
- Transverse plane dominant

Atrophy: loss of
- Muscle mass
- Muscle strength
- Restricted ROM
- Shortened ligaments
- Hypertrophic scarring

On one year follow-up, one of 21 patients was resolved
90% “success” = diminished pain

**PRINCIPLES**

1. How do normal stresses occur during gait?
2. How do abnormal stresses occur?
3. How to minimize abnormal stresses to allow healing?

**AFO IMPLICATIONS**

Hypothetical concept for orthotic intervention that would allow faster/better healing of soft tissue.

- Support function as closely as possible:
  - Avoid immobilization
  - Avoid pathological ROM
  - Allow normal functional biomechanics
  - Facilitate stretch reflex
  - Augment muscle function

**AFOs**

**Treatment Goals**

- Facilitate normal foot biomechanics
- Augment eccentric function of PTT in 1st rocker
- Allow controlled motion & proximal support in 2nd rocker
- Augment concentric function of PTT in 3rd rocker

**LOCAL CONTROL**

**Management goals**

- Limit abnormal foot motion with foot orthotic
  - FOS prefab foot orthotic shell
  - Custom FO
  - Hybrid UCB

**GLOBAL SUPPORT**

**Management goals**

- Limit foot motion
- Provide dynamic support for disrupted soft tissue
  - ToeOFF® family
    - Ypsilon
    - ToeOFF
    - Blue Rocker

**GLOBAL SUPPORT**

**Floor Reaction Composite AFO for muscle augmentation**

- Decelerate forefoot to ground at initial contact
- Stabilize in midstance
- Load potential energy late midstance
- Reflect energy for propulsion
GLOBAL SUPPORT

Management goals
- Limit foot motion
- Provide dynamic support for disrupted soft tissue
- Used in combination

Floor Reaction Composite AFO

FUNCTIONAL PHYSIOLOGY

1st rocker
- FO – decelerate
- ERC AFO – decelerate
  - Ankle plantarflexion
  - Ankle eversion

1st rocker
- FO – decelerate
- Calcaneal eversion
- Midfoot pronation
- Forefoot abduction
- Medial tibial rotation

FUNCTIONAL PHYSIOLOGY

1st rocker
- FO – decelerate
- ERC AFO – decelerate
- Ankle plantarflexion
- Ankle eversion

1st rocker
- FO
- Earlier supination

FUNCTIONAL PHYSIOLOGY

1st rocker
- ERC AFO – load potential energy

2nd rocker
- Stable

FUNCTIONAL PHYSIOLOGY

2nd rocker
-ERC AFO – load potential energy

3rd rocker
- FO
- Earlier supination
**FUNCTIONAL PHYSIOLOGY**

1st rocker
2nd rocker
3rd rocker
- FO
- ERC AFO
  - Energy reflection

**FOOTWEAR**

Shoe considerations
- Firm counter
- Stable Shank
- Rocker toe

**FOOTWEAR**

Possible shoe modification
- Medial buttress
- III+ and IV

**FOOT ORTHOTICS**

Grade I
- Pre-Fab – Allard FOS
- Controls calcaneal eversion in 1st rocker
- Support’s mid foot in 2nd rocker

**FOOT ORTHOTICS**

Grades II & III
- Custom FO
- UCB hybrid design
- Flexible Spectracarb
  - Optional XPE liner
  - Lateral trim line includes 5th MTH
  - Medial trim line proximal to 1st MTH

**FOOT ORTHOTICS**

Grades III+ & IV
- Multi density foot orthotic
- Deep heel cup for transverse plane control
- Accommodative materials
  - Tri-lam using combinations of Plastazote, Poron, & thermo sky
  - For support and shock absorption
  - Used with Blue Rocker

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**ANTICIPATED OUTCOMES**

**PTTD**
- Pain free ambulation <14 days
- Out of ERC-AFO < 90 days, maintain in FO
- Intermittent prophylactic ERC use thereafter for high-stress activity

**Achilles**
- Pain free ambulation <1 day
- Out of ERC-AFO < 30 days, maintain in FO
- Intermittent prophylactic ERC use thereafter for high-stress activity

**Shin splits**
- Pain free ambulation <4 days
- Out of ERC-AFO < 6 days, maintain in FO

**Shoe CUSTOMIZATION SUMMARY**

**Anticipated Outcomes**

**INTRODUCTION**

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  - Integrated closed chain function
  - Gray Institute

**Primary text references**
- Perry
  - Gait Analysis, 1992, 2010
- Gage
  - The Identification and Treatment of Gait Problems in Cerebral Palsy, 2009
- Enoka
  - Neuromechanics of Human Movement, 2009
- Newman
  - Kinesiology of the Musculoskeletal System, 2002
INTRODUCTION

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THANK YOU!