The Role of Gait Analysis in Patients with Charcot-Marie-Tooth Disease

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Overview

• Utility of Gait Analysis
• Ankle motion – the basics
• CMT ankle
  – Gait characteristics (video, kinematics, kinetics)
  – Case studies based on CMT ankle subtypes
• Discussion

Sources

• Literature
• Our experience of examining 68 patients with CMT with comprehensive motion analysis
• Current study of orthopaedic outcomes (no treatment control group)
• Õunpuu et al., Gait and Posture, 2013.

Charcot-Marie-Tooth (CMT)
(Hereditary Sensory and Motor Neuropathy)

• Most commonly inherited neurological disorder = de-myelination of large peripheral nerves
  • Myelin & axonal subtypes
• Characterized by:
  • distal muscle weakness and imbalance
  • foot and ankle deformities
  • associated gait implications
  • impairment progression at varying rates

Textbook Gait Description

• Foot drop (excessive equinus) in swing
• Steppage (hyper-flexion of knee and hip in swing)
• Circumduction and pelvic hiking in swing

Textbook Clinical Description

• Forefoot equinus and adductus
• Hindfoot varus
• Pes cavus
• Toe deformities – claw toes

(Graystrom, Foot and Ankle 2000)
• Clinical experience:
  – Persons with CMT do not all have the same clinical presentation (impairments)
  – Therefore, there are a variety of gait patterns and deformity…

Background
• The optimal treatment of gait pathology requires a detailed understanding of the pathomechanics during gait
• Visual assessment is limited in providing a full understanding of movement pathology
  – It is just too complicated!

Gait Analysis Is…
• The systematic and objective documentation of gait function in terms of the following:
  – Joint angles (joint kinematics) in 3D
  – Joint moments and powers (joint kinetics) in 3D
  – Muscle activity
• Includes integration of gait analysis data with the impairments such as:
  – Weakness
  – Limited range of motion
  – Bony deformity

The First Step
• Understand the gait analysis data.
  – Know your angle definitions and how they correlate with the clinical exam

Angle Definition – Ankle Sagittal Plane
• The relative angle between perpendicular to the long axis of the shank and the plantar aspect of the foot
• As viewed by an observer looking along an axis perpendicular to the shank-foot plane

Please note: the ankle joint angle definition includes multiple joints (ankle and foot)

Normal Ankle Sagittal Plane Motion

[Graph showing normal ankle plantar-dorsiflexion motion]

0 25 50 75 100 % Gait Cycle
-30 -20 -10 0 10 20 30
Plantar flexor weakness

Plantar flexor weakness

0 25 50 75 100 % Gait Cycle
-30 -20 -10 0 10 20 30
Ankle Plantar-Dorsiflexion

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• Peak ankle dorsiflexion in terminal stance = clinically relevant gait impact
• Three patterns present in CMT:
  – greater than typical
  – within typical range
  – less than typical
The Flail Foot – Compromised Prerequisites of Gait

• Stance phase stability
• Swing phase clearance
• Appropriate prepositioning at initial contact
• Adequate step lengths

Treatment Goals: Address these compromised prerequisites of gait

The Flail Foot

• Clinical Examination Findings
  – Limited passive dorsiflexion range of motion
    • Knee flexed (1 ± 7 degrees)
    • Knee extended (8 ± 7 degrees)
  – Full plantar flexion and forefoot inversion/eversion
  – Strength: (median/maximum/minimum)
    • Plantar Flexors (2/5/2)
    • Dorsiflexors (4/5/0)
    • Forefoot Invertors (5/5/0)
    • Forefoot Evertors (4/5/2)

Flail Foot

• Functional outcome of ankle weakness includes instability in standing and during gait due to limited ability to bear weight over the forefoot

The Flail Foot

• Gait Characteristics
  – Increased and delayed peak dorsiflexion in terminal stance
  – Increased equinus in swing and at initial contact
  – Reduced peak plantar flexor moment and power generation in terminal stance

The Flail Foot

• Treatment Options
  – Brace
  – Surgery to maintain a “braceable position” of foot and ankle if needed

Ankle-foot Orthoses (AFO’s)

• limit excessive dorsiflexion and allow weight bearing on the distal portion of the foot
• will provide more stability for the patient in standing and during gait
• limit excessive equinus and associated clearance problems in swing
Barefoot vs. Hinged AFO

- Reduced excessive plantar flexion in swing
- No change in peak ankle dorsiflexion timing in terminal stance
- No improvement in peak ankle plantar flexor moment in terminal stance

Barefoot vs. Solid AFO

- Reduced excessive plantar flexion in swing
- Reduced excessive dorsiflexion in terminal stance
- Associated reduced excessive knee flexion in stance

Flail Foot TX: Surgery may be needed if foot “unbraceable”

- Posteromedial release
  - Achilles Z lengthen
  - Posterior capsulotomies
  - Abductor Hallucis
  - FHL/FDL
  - TN capsulotomy
  - Plantar fascia release
- Closing cuboid osteotomy
  - (cuneiform too osteopenic to open)

Flail Foot TX: Pre vs. Post

The Cavo-varus Foot
The Cavovarus Foot

Compromised Prerequisites of Gait

- Stance phase stability
- Appropriate prepositioning at initial contact
- Pain

Treatment Goals: Position foot to improve stability and reduce pain

The Cavovarus Foot

Clinical Examination Findings

- Limited passive dorsiflexion range of motion
  - Knee flexed (2 ± 6 degrees)
  - Knee extended (9 ± 7 degrees)
- Full plantar flexion
- Variable forefoot inversion/eversion
- Strength: (median/maximum/minimum)
  - Plantar Flexors (4/5/2)
  - Dorsiflexors (5/5/4)
  - Forefoot Invertors (5/5/3)
  - Forefoot Evertors (5/5/3)

Clinical findings:

- Bilateral plantar flexor weakness (2/5)
- Bilateral claw toes
- Bilateral cavus
- Bilateral normal passive ROM

The Cavovarus Foot

Gait Characteristics

- Delayed peak dorsiflexion in terminal stance
- Reduced peak plantar flexor moment and power in terminal stance

Foot Pressures

- Increased lateral weight bearing
- Reduced toe contact

Cavovarus Foot Treatment Considerations

- Cavus: Imbalance between peroneus longus (plantarflexes 1st ray) & anterior tibialis (dorsiflexes 1st ray)
- Varus: Imbalance between posterior tibialis (inverts hindfoot) & peroneus brevis (everts hindfoot)
**Cavovarus Treatment: Non Op**

- Plantar fascia stretch
- Strengthening exercises: dorsiflexors & evertors
- Bracing

**Barefoot vs. Solid AFO**

- Reduced excessive peak dorsiflexion in terminal stance
- Reduced plantar flexion range of motion
- Maintained peak plantar flexor moment in terminal stance
- Reduced peak power generation in terminal stance

**Cavovarus Treatment: Surgical**

- Soft tissue release
  - Plantar fascia
- Soft tissue lengthening
  - Posterior tibialis
- Tendon transfers – to balance/delay recurrence
  - Peroneus longus to brevis
  - EHL to neck of 1st MT
  - Anterior tibialis laterally

**Cavus Component – TX Note**

- The implications of plantar fascia release on “available” plantar flexor length in combination with weakness need to be considered to prevent excessive peak dorsiflexion post treatment
- Consider peak dorsiflexion in terminal stance pre tx to predict outcome

**Cavovarus Treatment: Surgical**

- Osteotomy – if fixed
  - Dorsiflexing 1st ray osteotomy
  - Calcaneal osteotomy
  - Cuboid osteotomy
- Arthrodesis – if severe/reccurred

**Foot Pressure Changes**

- Pre
- Post
Treatment Outcomes Experience

- Through gait analysis we know that outcomes vary

Equinus Ankle and Cavo-varus Foot (toe walker)

The Toe Walker

Compromised Prerequisites of Gait

- Stance phase stability
- Appropriate prepositioning at initial contact
- Swing phase clearance

Treatment Goals: Plantar grade foot

The Toe Walker

- Clinical Examination Findings
  - Limited passive dorsiflexion range of motion
    - Knee flexed (-2 ± 9 degrees)
    - Knee extended (-2 ± 13 degrees)
  - Full plantar flexion and forefoot inversion/eversion
  - Strength: (median/maximum/minimum)
    - Plantar flexors (5/5/2)
    - Dorsiflexors (5/5/2)
    - Forefoot invertors (5/5/3)
    - Forefoot evertors (5/5/4)

The Toe Walker

- Gait Characteristics
  - Increased equinus in stance and wing
  - Absence of dorsiflexor moment in loading
  - Reduced power generation in terminal stance

The Toe Walker

- Treatment Options
  - Leave alone – increased body weight and weakness
  - Stretching casts/night bracing/day bracing
  - Soft tissue: plantar fascia vs. plantar flexor
  - Dorsiflexing osteotomy
  - Clinicians must consider implications of
    - reducing plantar flexor contracture by lengthening a weak muscle which is likely to weaken more over time
    - reducing cavus deformity with implications on “available” plantar flexor length

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Tx Outcomes

• Bilateral plantar fascia release
• Relaxed standing

Pre vs. Post

Pre Surgery - 2000
Post Surgery - 2014

Gait Findings – Pre vs. Post

• Increased dorsiflexion in stance and swing
• Addition of dorsiflexor moment in loading response
• Maintained power generation terminal stance

Summary

• Determine prerequisites of typical gait that are compromised
• Describe clinical and radiographic findings and associated gait issues
• Define treatment options with clear indications and outcome hypotheses
• Current Options:
  – Therapies
  – Bracing
  – Surgical Intervention

Principles

• Consider treatment when pre-requisites of gait are compromised
• Provide support when strength/stability issues are present
• Correct anatomical deformity to improve biomechanical function
• Progressive pathology – document progression objectively using motion analysis to provide basis for treatment

Thank You