It's All About That Base: Gluteal Function and Activation After Stroke

What to Expect

- Discussion on improvement of walking after stroke
- Review observational gait analysis and problem-solving for individuals with stroke
- Often misunderstood function of our "Base"
- Supine Hip Extensor Manual Muscle Test
- Activities to increase hip muscle activation and improve strength
  - To improve walking ability and quality of life after stroke

Ground Reaction Force Vector
Ground Reaction Force Vectors

Weakness
- Avoid torque demand to the muscle
- Allow other muscles to take over
- Find stability and sacrifice forward progression

Hip Problems in Stroke

Past Retract / Decreased Step

Collapse into flexion during Weight Acceptance

Ground Reaction Force Vector

Lateral Lean During Stance
Contralateral Pelvic Drop

Excess Backward Rotation

Demand Exceeds Capacity

Patient Example

- D. M.
- 49 years old
- Husband, father, businessman
- Owns his own mini-market
- Enjoys soccer
- Wants to walk “better”

“I want to walk better”
Improvement

• “I want to walk better”

• What does the literature say about improvement in walking after stroke?

Classification of Walking Handicap in the Stroke Population

• Muscle strength, proprioception, walking velocity, functional walking ability at home and in the community

• **Gait speed** was best predictor of walking classification, and participation of mobility in home and the community

  – Perry, Garrett, Gronley, Mulroy – 1995

Classification of Walking Handicap in the Stroke Population

- <0.4 m/s - Household
- >0.4 - <0.8 m/s - Limited community
- >0.8 m/s - Community
- Normal = 1.3 m/s

  – Perry, Garrett, Gronley, Mulroy – 1995

Improvements in Gait Speed are Meaningful

• Function and quality of life measures (SIS) were significantly higher for those who transitioned to a higher level of ambulation


How Do We Increase Speed?

• Increase stride length
  – Normal stride is 1.3 meters

• Increase in cadence
  – Normal cadence is 115 steps/minute

What Happens?

• Increases ground reaction forces
• Increases torque demand
• Weight Acceptance
  – Hip Extensors
  – Quadriceps
• Single Limb Support
  – Hip Abductors
  – Plantar flexors
• Swing Limb Advancement
How do Individuals Increase Walking Speed after Stroke?

What do we know about walking after experiencing a stroke?

Scientific Literature

• Use of Cluster Analysis for Gait Pattern Classification of Patients in the Early and Late Recovery Phases Following Stroke
  
Motion Analysis

Fine Wire EMG

EMG Muscle Test
- Firing pattern while walking
- Intensity
- Timing
- Quick stretch
  - Duration
  - Intensity

Isometric Torque Testing
- Hip extensors
- Hip abductors
- Knee extensors
- Knee flexors
- Ankle dorsiflexors
- Ankle plantar flexors

Classification of Gait Patterns after Stroke
Mulroy et al, 2003

Cluster Analysis: Flexed
- 27% Normal Speed
- 18° Knee flex TSt
- 39° Knee flex PSw

Mulroy et al., 2003
Cluster Analysis: Extended

- 20% Normal Speed
- 7° Knee hyperextension
- 18° Knee flexion

- Mulroy et al., 2003

Rehab Admission Strength

Six Month Strength

Cluster Analysis

- Plantar flexors, dorsiflexors weaker in Flexed and Extended groups
- Hip extensors weaker in Flexed
- Knee extensors weaker in Extended

- Mulroy et al., 2003

Cluster Analysis: Summary

- We have distinct groups
- Based on observed gait patterns & speed
- Pattern of weakness differentiates grouping, not spasticity
- Improved gait speed at 6mo related to increased EMG activation and improved strength

- Mulroy et al., 2003

Cluster Analysis: Summary

- We have distinct groups
- Based on observed gait patterns & speed
- Pattern of weakness differentiates grouping, not spasticity
- Improved gait speed at 6mo related to increased EMG activation and improved strength
- Low responders had reduced gluteal and calf EMG

- Mulroy, Gronley, Weiss, Newsam, Perry 2003
“I Want to Walk Better…”

- Transition to a higher functional level
- Increase speed
  - Increased strength key muscles
  - Increased muscle activity key muscles

Recent Findings in Kinetics

- Less time in single limb stance on hemi limb
- Step length asymmetry affects forward propulsive force generation

- Balasubramanian et al, 2007

Forward Propulsion Mechanics

- Anterior-posterior GRF
- Force that acts to propel body forward
- Reduced on hemi side
- $F_a = 1/d^*M_a\sin(TLA)_{vop1}$

- Hsiao et al, 2015

Breaking & Forward Propulsion Forces

Walking faster after stroke

- Main power burst in hemi & normal walking:
  - Hip extension moment at LR
  - Hip abduction moment at MSR
  - Ankle plantar moment at TSS/PSw
  - Hip flexion moment at PSw/Sw

- Mutroy, Kautz, Sullivan, 2014
Joint Powers

Lateral Weight Shift

- Control of lateral weight shift is associated with walking speed in individuals post-stroke

- Hsiao, Gray, Creath, Binder-Macleod, Rogers, 2017

Excess Hip Abduction in Stance

Slower Walkers

- Delayed and deficient weight transfer to paretic limb
- More lateral paretic limb placement
- COM further from COP
- Lower hip abductor moment

- Hsiao, Gray, Creath, Binder-Macleod, Rogers, 2017

Improved Gait Speed After Stroke

Mechanics After Treatment

- FES plantarflexors/dorsiflexors
- Fast walking on treadmill
  - Trailing limb angle most important contributor to increasing gait speed
  - Plantar flexion moment (internal) at TSt/PSw

- Hsiao, Knarr, et al. 2015, 2016

- Mulroy, Klassen, Gronley, Eberly, Brown, Sullivan - 2010
Different Strategies to Increase Speed after Stroke

- Forward propulsion asymmetry between legs
- Some increased speed via non-paretic plantar flexor propulsion
- Some increase speed via paretic leg plantar flexor propulsion

– Allen, Kautz, Neptune, 2014

Capacity to Increase Walking Speed After Stroke

- Capacity to increase walking speed is limited by impaired hip and ankle power generation in lower functioning persons post-stroke. Gait and Posture

– Jonkers I, Delp S, Patten C. 2009

Capacity to Increase Walking Speed After Stroke

- Those who were able increased plantar flexor power, and hip flexor power during PSw
- Low functioning patients increased power in the non-hemi limb

– Jonkers, Delp, Patten 2009

Recovery vs. Compensation

- Lower level patients walked faster by improving forward propulsion forces from non-hemi limb
- Higher level patients walked faster by improving forward propulsion forces in both hemi and non-hemi limb.

- Jonkers, Delp, Patten 2009
I Want to Walk Better:

- Transition to a higher functional level
- Increase speed using recovery model
  - Large step
  - Increased hip extensor & abductor moment, EMG & strength
  - Shift body weight medially onto stance limb
    - Increase hip abductor moment
  - Increased forward propulsion forces - hemi side
    - Increased calf EMG & plantar flexion moment
  - Increased hip extension angle at TSt
    - Large step on opposite limb
  - Trailing Limb Posture
    - Increased hip flexion power at PSw/ISw

Influence of Trailing Limb

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San Diego, CA
September 16, 2017

CPTA 2017, San Diego, CA
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Passive Contributions to Moments/Powers - Whittington 2008

Impaired Trailing Limb
- No heel rise
- Small opposite step
- Inadequate hip ext
- Pelvis dropped out
- External rotation hip:
  - Pelvic hike
  - Abduction
  - Lean laterally
  - Contralateral vault

“All About that Base”
- Gluteal “Base” holds pelvis and trunk stable during Weight Acceptance
- Initiating forward progression
- Gluteal base holds pelvis stable in frontal and transverse plane
- Calf “Base” contributes to forward propulsion
- Stable trailing limb positions for passive components of swing

“I want to walk better”
- To return to work in the mini-market
- To be able to play with my daughter
  - Walk farther
  - Walk faster
  - Walk comfortably in confined spaces
  - Quick turns, obstacles, etc

Observational Gait Analysis
Summary of Stride Characteristics

- Velocity: 12 M/min 15% N
- Cadence: 48 Steps/min 42% N
- Stride Length: 0.54M 35% N
Early Mid Stance

Mid Stance

Terminal Stance

Pre Swing

- Low force vector
- Force vector very close to ankle joint center
  - Low plantar flexion internal moment
- COM is not in front of the force vector
- There is no trailing limb angle
- No forward propulsion mechanics
Pre Swing

- Force vector moves forward only after opposite foot makes contact

Terminal Stance

Initial Swing

Pre Swing

SAGITTAL PLANE KINETIC ANALYSIS
PATHOPHYSIOLOGY LAB, RANCHO LOS AMIGOS NATIONAL REHABILITATION CENTER

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Let's Talk About Strength…

DIAGNOSIS: Right Hemisphere Stroke
HISTORY: HTN
LEFT LOWER EXTREMITY:

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</table>

Tone: Mild increase for calf, adductors with quick stretch
Tactile: Normal
Proprioception: Normal: hip & knee, impaired: ankle & toes

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**Strength is Good**

Any Questions?

Jacqueline Perry, MD

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**Treatment Focus for Walking Faster**

1. Load onto a fully outstretched limb & maintain hip stability
   - Inverted ankle
   - Weak gluteals
2. Progress body weight forward during stance
   (forward propulsion mechanics)
   - Weak calf
   - Tight Achilles
   - Weak glut med
3. Attain a trailing limb posture
4. Improved hip/knee flexion during swing

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**All About That Base?**

- Weak hip extensors and abductors:
- Reduced loading forces by past-retract and small ipsilateral step length
- Unwilling to progress body weight forward

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- Weak calf and hip abductors:
- Unwilling to progress onto limb & forward in late stance
- Poor trailing limb sets up for impaired swing mechanics:
  - Hip flexor power generation

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- Hip extensors
- Hip abductors
- Soleus/Gastroc
I Want to Walk Better:

• Transition to a higher functional level
• Increase speed using recovery model
  – Large step
  – Increased hip extensor & abductor moment, EMG & strength
  – Shift body weight medially onto stance limb
    • Increase hip abductor moment
  – Increased forward propulsion forces - hemi side
    • Increased calf EMG & plantar flexion moment
  – Increased hip extension angle at TSt
    • Large step on opposite limb
    • Trailing Limb Posture
  – Increased hip flexion power at PSw/Sw

Is an AFO Indicated?

AFO Design

Rigid (R) Plantar Stop (PS) Dorsi Stop (DS)

Each AFO worn ≥ 2 weeks prior to testing

Conclusion

• All AFOs improved heel first contact and foot clearance in swing.
• Plantar flexion contracture affects performance in an AFO
  – With a contracture: unable to utilize the different brace settings in stance
  – No contracture: an articulating AFO improved gait and a Rigid AFO impeded gait

- Mulroy, Eberly, Gronley, Weiss, Newsam 2010

Conclusion

• Calf EMG intensity did not decrease when walking in a brace
• Anterior Tibialis EMG did not decrease in articulating AFOs
  – Mild decrease in swing in rigid AFO

- Mulroy, Eberly, Gronley, Weiss, Newsam 2010
Why Not Faster Initially in AFO?

- Walking speed improved in 4 of 10 subjects in the AFO
- Changes in speed, stride length and cadence correlated with hip extension strength ($r=0.63$)
- The ability to improve gait speed when wearing an AFO was dependent on hip extension strength

Hip Strength & AFO
- 10 subjects with MCA stroke
- Tested in and out of own AFO

- Walking speed improved in 4 of 10 subjects in the AFO
- Changes in speed, stride length and cadence correlated with hip extension strength ($r=0.63$)
- The ability to improve gait speed when wearing an AFO was dependent on hip extension strength

- With increased stability at the ankle the demand of forward progression of the body weight shifted to the hip
- Only those individuals strong enough to handle the increased torque demands from increased stride length or cadence were able to walk faster in their AFO

Hip Strength & AFO
- With increased stability at the ankle the demand of forward progression of the body weight shifted to the hip
- Only those individuals strong enough to handle the increased torque demands from increased stride length or cadence were able to walk faster in their AFO
AFO

- Dorsi stop recommended to stabilize tibia
- Tibial restraint may create the need to lean forward to allow forward progression
- Increases the demand on the hip extensors

- Weiss et al. 1999

Testing Hip Extensor Strength

- Difficulty attaining prone
- Tight hip flexors
- Hemi shoulder pain

Supine Hip Extensor Manual Muscle Test


Jacquelin Perry, MD

- Test Creator
- Polio Clinic
  - spinal fusions
  - hip flexion contracture
  - large abdomen
  - pulmonary problems
Purpose
To identify a valid and reliable supine testing technique for hip extensors that differentiates 4 levels of strength

Subjects
• Validation and definition
  N = 44 (polio, GB, OA, cauda equina)
  Mean age 52
• Reliability
  N = 16 (post polio syndrome)
  Mean age 51

Validation & Definition
• Supine test performed
• Grade assigned
• Grades confirmed by video
• Maximum isometric torque

Supine Test
• Feet over edge
• Press downward
• Tester lifts heel

Grade 5 (Normal)
• Hip locks in neutral
Grade 4 (Good)
- Unable to lock hip
- Strong resistance
- Requires more than 30° before locking hip

Grade 3 (Fair)
- Greater hip flexion:
  - Fiber length, lever arm
  - Mechanical advantage
  - Increases force production

Grade 2 (Poor)
- Slight resistance

Biomechanical Rationale

Biomechanical Rationale

- Waters 1974

Hip extensor torque
Data Analysis

- One-way ANOVA
- Torque between subjects grouped by muscle test grades

Isometric Torque

* (p < .01)

Normalized Torque

Relative Strength

Supine Hip Extensor Manual Muscle Test

- Valid
- Reliable
- Accurately differentiates 4 grades similar to prone test

Clinical Relevance

- Convenient clinical assessment
- Avoids difficulties associated with prone positioning
What We’ve Learned:

- Lift limb higher & hold for several seconds
- Downgrade if need more than 30° to lock hip
- Fold arms across chest

Now What?

- We understand what is needed for improved walking after stroke
- We understand the impact of gluteal weakness in stroke
- We know how to test for weakness
- What should we do to treat?

Treatment Focus #1

- Load fully onto an outstretched limb
  - Inverted ankle
  - Weak gluteals

Best Hip Extensor & Abductor EMG?

- Fine Wire EMG
- Traditional exercises
- Functional activities:
  - Lower Gluteus Max
  - Add Magnus
  - Biceps Femoris
  - Semimembranosus
  - Upper Gluteus Max
  - Gluteus Medius

Traditional Extension Strengthening
Lower Glut Max: Low vs High Fugyl-Meyer

Hip Exercise Summary
- Supine hip abduction poor EMG
- Prone hip abduction better
- Prone hip extension excellent EMG
- Higher functioning – similar to non-stroke population
- Lower functioning –
  - Weight bearing
  - Functionally based
  - Goal oriented

Hip EMG on Stairs
- Increased lower glut max ascending stairs
- Prolonged glut med ascending stairs
- Prolonged upper glut max ascending stairs
- Decreased EMG descending stairs
  - Perry 1975
Key Concept

- **Forward lean** is key to activating gluteals
- To turn off hamstrings: clams, kneel walk, sit to stand, step up

How to Modify Weight-Bearing and Functional Exercises

- Glut Max EMG - 22% MVC
- Glut Max EMG - 60% MVC
- Glut Max EMG - 108% MVC

Principles of Recovery

- Prime System with Aerobic Exercise
- High Intensity, High Challenge
- Forced Use Paradigm
- Task Specificity
- Targeted with External Focus
- Positive & Empowering Feedback

Hip Hike

Hip Hike?

Glut Med Step-Hike

Weight-Bearing, Functional, Targeted

How Do We Shift Weight Onto Hemi Limb?

PVC Cage for Narrow Base

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Over Ground Narrow Base

- Constraining movement reveals motor capability in chronic stroke: an initial study. *Clinical Rehab* 2017
  - Improved hip & knee flexion during swing
  - Improved step width
  - Improved paretic step length

- Martinez, Mintz, Ecsedy, Fisher 2017

What About the Calf?

Modified Heel Rise EMG

- Soleus EMG 55% MVC
- Soleus EMG 105% MVC

Calf Strengthening
Questions?

Walt Weiss
wweiss@dhs.lacounty.gov
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