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Walking Recovery Post Stroke

Jill Seale, PT, PhD, NCS

- Presenter Disclosure: Financial: Jill Seale has received an honorarium for presenting this course. Non-financial: Jill Seale has no relevant non-financial relationships to disclose.
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Learning Outcomes

After this course, participants will be able to:

- Identify at least four common gait deviations and causative impairments experienced in persons post-stroke.
- Identify at least three appropriate outcome measures when creating an effective strategy for examination and evaluation of gait in persons post-stroke.
- Identify at least three interventions found to be efficacious in the evidence for improving gait post-stroke.
- Identify at least one intervention technique and one orthotic prescription when creating a plan of care for gait recovery in a person with stroke.

Norms

- Cadence: steps per minute (113-116)
- Velocity: 82 m/min or 1.37 m/sec
- BOS: 2-4”
- Toe out: 7°
- Stance phase: 62% of gait cycle
- Swing phase: 38% of gait cycle
- Single limb support: 80% of time
- Double limb support: 20% of time

Q1

Normal Gait

- Weight Acceptance
  - Initial Contact
  - Loading Response
- Single Limb Support
  - Midstance
  - Terminal Stance
- Swing Limb Advancement
  - Preswing
  - Initial Swing
  - Mid Swing
  - Terminal Swing

Why is achieving normal gait important?

Energy Conservation

- This is an essential function of gait that occurs throughout all phases of gait cycle
- Appropriate use of momentum and passive positioning substitutes for muscle activity, allowing selective relaxation, thereby conserves energy
- Any deviation from normal gait pattern will increase energy expenditure
- PLUS, fall risk, overuse injuries, stigma, etc…

Stance versus Swing

Swing phase

- Most commonly identified, described, and addressed
  - Seale J, Utsey C. P*hysiother Therory Prac*, 2019
- Greatly dependent on the stance phase
- Fairly easy to compensate for distal impairments of swing phase
- An orthotic solution often does not completely re-establish swing limb clearance

Swing depends on stance

- Knee flexion in pre swing occurs passively
- What causes this passive knee flexion?
  - Heel rise
- What causes the heel to rise?
  - The plantarflexors stopping the forward progression of the tibia

Q2

Stance phase

- Stability in stance occurs
  - Early in stance via the quadriceps
  - Mid to late stance via the plantarflexors
- Lack of stability
  - Early: leads to immediate knee hyperextension through entire stance phase
  - Late: leads to EITHER slight knee flexion (crouch) throughout stance OR knee extension thrust in mid to terminal stance

Q3

2 Video Examples of Instability in Stance

Current understanding and focus of gait post stroke

- Focus on swing limb dysfunction
- Regarding causative factors, focus on more proximal impairments, little identification of plantarflexor weakness as contributing factor
- Often don't identify weakness in plantarflexors as cause of stance instability
- "Stance phase doesn't bother me… but in swing phase you have to clear the foot" (expert)
- "Control that footdrop…that's always the first priority" (expert)
  - Seale J, Utsey C, Seale J, Utsey C. P*hysiother Therory Prac*, 2019

Gait Examination and Evaluation Post Stroke

- Observational Analysis
- Objective Outcome Measure

Observational analysis

- Advantages
- Disadvantages
- How do we maximize accuracy?
- From qualitative research study:
  - All described systematic approach of observational gait analysis (OGA)
  - Lack of consistency in approach between subjects
  - Expert group only: functional outcome measures, different environments and duel task, energy efficiency, patient autonomy
    - Seale J, Utsey C, unpublished data.

Observational Gait Analysis Tools

- GAIT: Gait Assessment and Intervention Tool ☆
- HGAF: Hemiplegic Gait Analysis Form
- RVGA: Rivermead Visual Gait Assessment
- WGS: Wisconsin Gait Scale
  - Ferrarello F et al, Phys Ther, 2013
- Racho Los Amigos Observational Gait Analysis system

Q5

Examine Both Sub Phases

- **SINGLE LIMB INSTABILITY IN STANCE**
- **IMPAIRED LIMB CLEARANCE IN SWING**

Impairment Examination

- 5 Functional Categories
  - Deformity (ROM)
  - Muscle weakness (MMT)
  - Sensory Loss (Kinesthesia)
  - Pain (VAS)
  - Impaired Motor Control (Fugl Meyer, STREAM)

Review of R1 and R2

- Resistance 1
  - ROM at initial resistance
- Resistance 2
  - ROM at max stretch
- Why is this important?

ROM Loss Impact

- Stance
  - PF contracture
  - Knee flexion contracture
  - Hip flexor contracture
- Swing
  - PF contracture
  - Knee flexion contracture

Muscle Weakness

- Weakness and/or insufficient recruitment or activation
- More than MMT grade
  - Muscle endurance
  - Lever length

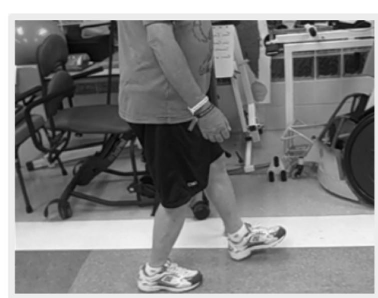
Normal Muscle Activity in Gait

- Key Muscles in Stance
  - Initial Contact and Loading Response
    - Glut max, Glut med, Adductors, Quads
    - All peak by end of loading response
  - Mid and Terminal Stance
    - Gluts and Quads (very early mid stance)
    - Plantarflexors (mid to terminal stance)*
      - *during highest torque demand

Muscle Weakness in Stance

- Quadriceps weakness – hyperextension early in stance (IC or LR); inability to accomplish LR
- Plantarflexor weakness – extensor thrust in MSt to TSt OR excessive ankle DF throughout
- Hip extensor weakness – excessive hip flexion at IC and LR
- Hip abductor weakness- contralateral pelvic drop MSt
- Anterior tibialis – foot slap at LR

PF Weakness in Stance



Stance phase problems in stroke

- More than just decreased weight shift to affected side
- Less time on paretic limb
- Reduced load on paretic limb
- Non-paretic step length is shortened
- Acute and chronic phase: weakness of PFs is primary impairment
- Chronic phase: Weakness of PFs along with PF contracture and/or hypertonicity
- Often not identified, described, or addressed
  - Seale J, Utsey C, *Physio Therory Prac*, 2019

Muscle Weakness in Swing

- Anterior tibialis weakness – flat foot or forefoot IC; decreased foot clearance throughout swing
- Knee flexor weakness – decreased knee flexion in MSw to TSw
- Knee extensor weakness – doesn't achieve full extension at TSw
- Hip flexor weakness – difficulty initiating PSw and ISw (lack of balance between flexors)
- Bottom line: Poor limb clearance

Video Examples

Impaired Motor Control

- In those with upper motor lesion
- Combination of:
  - Muscle weakness
  - Impaired selective control
  - Synergistic patterns
  - Hypertonicity

Objective Outcome Measures

- Gait Speed (the 6th Vital Sign)
  - 10 m walk
    - Middleton A, Fritz SL, Lusardi M, J Aging Phys Act, 2015
- Endurance Measures
  - 2, 6, 12 minute walk
  - Highly correlate with community mobility
- Gait and balance measures
  - Timed Up and Go
  - Berg Balance Test
  - Dynamic Gait Index
  - Functional Gait Assessment

Q4

What about Measures of Participation?

- QOL improves with increases in gait speed
  - Schmid et al
- Relationships between QOL and gait parameters
  - Seale J, Dissertation data
- Determinants of Community Ambulator
- Link to cost and caregiver burden

Walking Recovery Following Stroke

Evidence Based Guidelines

- Intensive, repetitive, mobility task training
- An AFO for individuals with remediable gait impairments
- Circuit training
- Incorporating cardiovascular exercise and strengthening
- NMES
- Treadmill and overground walking with and without BWS
  - Winstein et al, *Stroke*, 2016

Q6, Q10

continuED

Rehabilitate all the Components

- Walking Specific Motor Control
  - Repetitive step training, w/ or w/o PBWS
- Cardiorespiratory Fitness
  - Aerobic conditioning
  - Does not have to be gait specific
- Dynamic Balance Control
  - Progressive balance retraining program, central and peripheral processes of balance
- Muscular Strength/Power
  - Progressive resistance training
  - Need to strengthen paretic and non-paretic side, as well as trunk
  - Make strengthening as task specific as possible
    - Bowden MG, Embry AE, Gregory CM, *Stroke Res Treat*, 2011.

Q7, Q10

continuED

Strength Training

- Moderate evidence to support improvement in gait efficiency – Teasell et al, 2003
- Questionable transference of strength gains to function – Weiss et al, 2000
- Training needs to be specific
- Fair to strong evidence supporting increased strength, gait speed, improved functional outcomes, and improved quality of life (without increase in spasticity)
  - Pak, Patten, 2008

Training Specificity

- Analyze task and find deficits
- Hypothesize causative impairments for identified deficits
- Test out hypotheses to ID causative impairments
- What is the norm, in terms of motor activity, ROM, sensation, etc…?

So what would task specific ther-ex look like?

- Ther ex would match the key characteristics of the task:
  - Type of contraction
  - Range of motion
  - Training to fit demand: load, repetition, lever arm

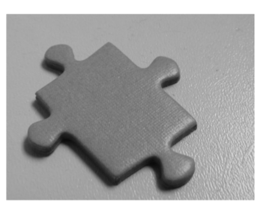


Image by LoggaWiggler from Pixabay

How do we usually strengthen plantarflexors?

Images courtesy of Physiotec

Plantarflexor Strengthening for Improving Gait – Video Example

PBWSTT

- Recent study in acute stroke (< 1 mo)
  - Trialed 4 speeds (.5, 1.0, 1.5, 2.0)
  - Fastest speed – longer stride lengths, increased between-limb symmetry, greater muscle activation, higher RPE
    - Burnfield JM, Human Movement Sci, 2016
- Partial Body Weight Support Treadmill training
  - Facilitate walking recovery and induce activity-dependent plasticity
  - Increase strength, endurance, walking function while minimizing risk of overuse injuries
  - Enables higher repetition of stepping than could be achieved over ground
    - Bayona et al 2005; Krakauer, 2006; Barbeau and Visintin, 2003; Sullivan et al, 2002
  - Still many questions on dose, who responds best, when intervention is best

High Intensity Dynamic Step Training

- Continuous stepping practice
- Multiple, variable environments
- Cardio training at 70-80% HR reserve or 15-17 RPE
- 40- 1 h training sessions over 10 weeks
- Limited BWS, reduced as quickly as possible
- Session included forward treadmill walking, variable walking on treadmill (skill-dependent treadmill training), over ground training, and stair climbing
- Primary focus to increase speed to reach aerobic target intensities as quickly as possible
  - Leddy AL et al, JNPT, 2016

Q8

Circuit Training (CT)

- What is it?
  - *A mode of task-specific exercise using a series of systematically progressed workstations to encourage* ***greater intensity of practice*** *and* ***repetition****.*
    Blennerhassett, 2004

Circuit Training (CT)

- Acute Stroke Rehabilitation
  - Blennerhassett, 2004
    - Single blinded randomized control trial (RCT); N=30
    - Mobility circuit training (CT) vs. Upper Extremity (UE) CT
    - 1 hour/day, 5 days/week for 4 weeks
    - Outcomes: TUG, Step Test, 6 Minute Walk Test (6MWT), Jebsen-Taylor, Motor Assessment Scale
  - Rose, 2010
    - Non-blinded RCT; N=182
    - Inpatient (IP) CT group vs. Conventional IP physical therapy
    - 90 minutes/day, 5 days/week for a 3 month period
    - Outcomes: Gait speed, Gait endurance, Berg Balance, Fugl-Meyer

Circuit Training (CT)

- Chronic Stroke Rehabilitation
  - Pang, 2005
    - Single blinded RCT; N=63
    - Mobility CT vs. Upper extremity CT
    - 1 hour/day, 3 days/week for 19 weeks
    - Outcomes: Berg Balance, 6MWT, VO2 max, knee extension strength, femur bone mineral density (BMD), & Physical Activity Scale
  - Mudge, 2009
    - Single blinded RCT; N=58
    - Individuals at least 6 months post-stroke
    - Experimental group: 12 sessions of CT & Control group: educational classes
    - Outcomes: Step Activity, 6MWT, Gait Speed, Activity Specific Balance Confidence Scale (ABC)

Variable Intensive Early Walking

- Stepping practice at high cardiovascular intensity (70-80% heart rate reserve)
- VARIABLE contexts (tasks or environments)
- 10 minute increments of:
  - Speed-dependent treadmill training
  - Skill dependent treadmill training
  - Overground training
  - Stair climbing
- Challenging: difficulty was progressed and only decreased when participants were not successful for 3-5 consecutive stepping attempts
  - Horby TG et al, Neurorehabil Neuro Rep, 2015

Q8

A Biomechanics Driven Exercise Prescription

- Most important muscle groups for forward propulsion have not been targeted for strengthening
- Strength training focuses on slow and heavy resistance – DOES NOT improve fast muscle contractions needed for walking
- Propose strength training with resistance exercises that target POWER generation
  - Plyometric and ballistic resistance exercises

Williams G et al, *Arch Phys Med Rehabil*, 2019

Locomotor Function CPG

- Strong evidence for walking training at moderate to high intensities or virtual reality-based training for those greater than 6 months post to improve walking speed or distance
- Weak evidence for strength training, circuit training or cycling training at moderate to high intensities and VR based balance training to improve walking speed or distance
- Strong evidence suggests that body weight supported treadmill training, robotic assisted training, or sitting/standing balance training without VR SHOULD NOT be performed to improve walking speed or distance
  - Horby et al, *JNPT*, 2020

FES for Ambulation

- Primary use is for providing dorsiflexion assist for patients who present with decreased foot clearance (AKA drop foot) during swing phase of gait
- In persons with stroke, is isolated foot drop common? NO
- Can this address stance phase problems? NO

FES for Ambulation post Stroke

- Faster walking speeds than walking training alone or no intervention
  - Robbins et al, Arch Phys Med Rehabil, 2006
- Evidence inconclusive
  - Roche et al, Physical Therapy Reviews, 2009
- Further walking distance compared with walking training alone or no intervention
  - Pereira et al, Topics in Stroke Rehabilitation, 2012
- FES appears to moderately improve activity compared with no intervention and training alone
  - Howlett et al, Arch Phys Med Rehabil, 2015

More Recently

- Long term f/u comparing FES to AFO in persons with chronic stroke
- AFO provided "to adequately alleviate foot drop" only
- Results : FES proved "noninferior" to AFOs for all primary measures
  - Bethoux et al, *Neurorehabilitation and Neuro Repair*, 2015

User experiences, preferences and choices

- Qualitative study in persons with stroke
- Preference for FES for "primary tool for managing foot drop"
- But…"different experiences of both tools led to frequent choices to supplement FES with different types of AFOs"
  - Bulley C, Shiels J, Wilkie K, Salisbury L, Physiotherapy, 2011

Orthotic Impact on Gait

- Improve quality of gait, improve gait speed, and reduce energy expenditure during ambulation
  - Nolan K, Savalia K, Lequerica A, et al. PM R, 2009; Cruz, T, Dhaher, Y. Gait Posture, 2009; Simons, C, Van Asseldonk E, Van der Kooij H, et al. Clin Biomech, 2009; Leung, J, Moseley, A. Physiother,2003; Gok H, Kucukdeveci A, Altinkaynak H, et al. Clin Rehabil, 2003; Cakar E, Durmus O, Tekin L, et al. Eur J Phys Rehabil Med, 2010.
- Immediate improvements in functional ambulation categories
  - Tyson SF, Kent RM. Arch Phys Med Rehabil. 2013
- Immediate improvements in gait speed, quality, and endurance
  - Hale J, Seale J, Olivier G, Jennings J, DiBello T. 2012; from unpublished data. Hale J, Seale J, Jennings J, DiBello T. J Prosth Orthot. 2013
- Increased step or stride length
  - Tyson SF, Kent RM. Arch Phys Med Rehabil. 2013

Q9

Orthotic Impact on Balance and Other Function

- Immediate improvements in balance
  - Hale J, Seale J, Olivier G, Jennings J, DiBello T. 2012; from unpublished data. Hale J, Seale J, Jennings J, DiBello T. J Prosth Orthot. 2013
- Decreased fall risk
  - Cakar E, Durmus O, Tekin L, et al. Eur J Phys Rehabil Med, 2010; Hale J, Seale J, Olivier G, Jennings J, DiBello T. 2012; from unpublished data; Hale J, Seale J, Jennings J, DiBello T. J Prosth Orthot. 2013; Wang RY, Lin PY, Lee CC, Yang YR. Am J Phys med Rehabil. 2007.
- Not detrimental to stair climbing and sit<>stand
  - Tyson SF, Kent RM. Arch Phys Med Rehabil. 2013
- Less postural sway, improved weight distribution symmetry
  - Wang RY, Lin PY, Lee CC, Yang YR. Am J Phys med Rehabil. 2007.
- No data on impact on quality of life or participation

Q9

Orthotic Design

- Must accommodate any lost ROM and/or spasticity at ankle
- With PF weakness, device needs sufficient stiffness to substitute for plantarflexors

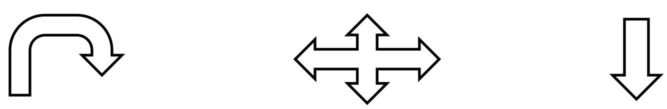
Assistive Device Selection

continued

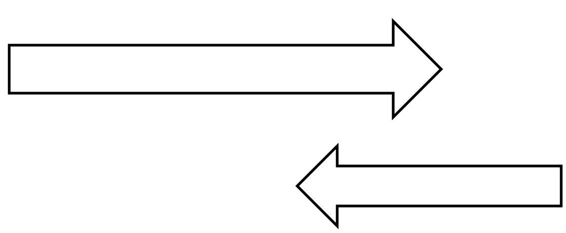
Some thoughts….

- Normalize biomechanics
- Control/limit degrees of freedom
- Anticipate problems
- Understand patterns of recovery and treat appropriately
- Facilitate the capacity to walk without abnormal patterns
- Work to make walking automatic
- Match demand to capacity
- Task specific practice and task specific training
- Find a way to increase speed
- Create opportunities for motor learning

continued



WALKING is way more than just WALKING forward!



Case Example

- 60 y/o with Right hemiplegia following a hemorrhagic stroke
- Review video and determine gait deviations
- Impairments: R: limited DF(neutral only), 2/5 DF, 1/5 PF, 4/5 quads, 3/5 hamstrings, 3/5 hip flexors, abductors and extensors
- Intact sensation, no pain
- Evidence of extensor synergy, MAS of 2 in PFs and quads

Case Example

- Gait deviations
- Suggested interventions
  - Specific impairments to target and how
- Assistive device and orthotic prescription
  - Appropriate or change?