INS AND OUTS OF HIGH-INTENSITY GAIT TRAINING

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OBJECTIVES

1. Define the four biomechanical subcomponents of gait
2. Understand how to challenge the four biomechanical subcomponents of gait
3. Define the "FITT" Principle
4. Understand how to apply the "FITT" Principle to your practice
5. Identify potential barriers to implementation of high-intensity gait training

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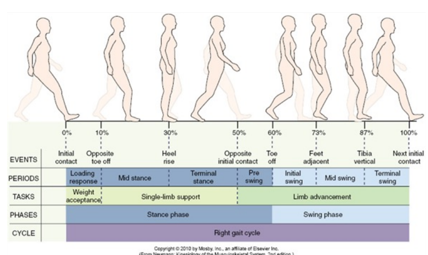
WHAT IS HIGH-INTENSITY GAIT TRAINING?

TRADITIONAL APPROACH



- Physical therapy traditionally focuses on perfecting movement and kinematic qualities
  - NDT theories
  - Impairment-based treatments
  - Kinematics can be challenging to scale when focusing on increasing gait velocity
  - Kinematic patterns tend to normalize when improving gait velocity

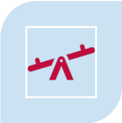
(Bowden et al., 2006; Nadeau et al., 1999; Hornby et al., 2008, 2015; Holleran et al., 2015; Mulroy et al., 2010)

BIOMECHANICAL SUBCOMPONENTS OF GAIT

STANCE
25-28% ENERGY COST

PROPULSION
42-48% ENERGY COST

SWING
10-20% ENERGY COST



POSTURAL/LATERAL STABILITY
6% ENERGY COST

(Grabowski, 2005; Gottschall 2003, 2005)

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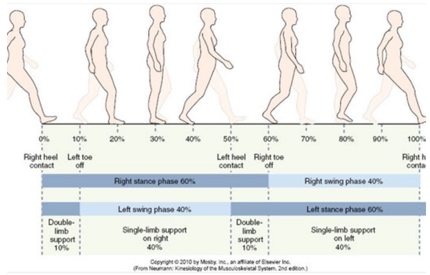
STANCE CONTROL



- To maintain postural stability, swinging limb must accept weight while supporting passenger unit
- Maintain upright posture—reliance on passive (skeletal) structures vs. active (muscular) structures to support weight
- Reduce center of mass movement outside of lateral base of support
- **Insufficient stance leads to buckling/collapse**

(Kuo & Donelan, 2010)

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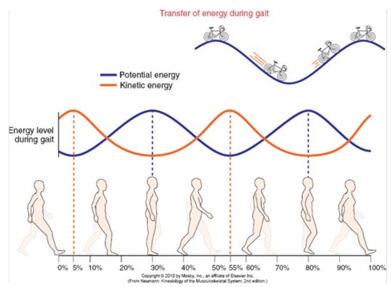
PROPULSION



- Propulsion: forward progression and the primary determinant of walking
- Redirecting center of mass gravitational energy to kinetic energy
- Inverted pendular motion
- Shock absorption redirected to propulsion
- Joint powers of hip and ankle tend to determine gait speed due to their propulsive forces
- **Insufficient propulsion leads to stepping in place/slow gait speed**

(Grabowski, 2005; Gottschall 2003, 2005; Donelan, 2004)

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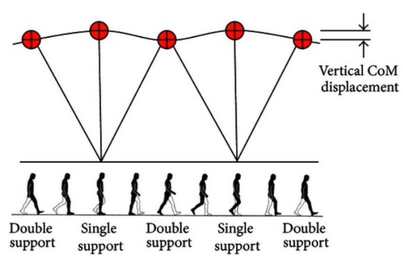
LIMB SWING



- Swing limb moves in pendular fashion opposite of center of mass
- Uses gravity and hip flexor activity to advance limb
- Progression of non-weight limb—pendular motion
- Preparation to accept weight
- **Insufficient swing leads to limited limb advancement**

(Grabowski, 2005; Gottschall 2003, 2005; Donelan, 2004)

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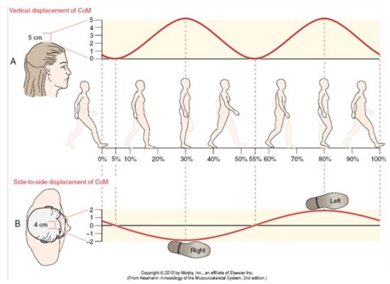
POSTURAL STABILITY



- Relatively stable in stance if sufficient knee/hip extensor control
- Relatively stable in anterior/posterior plane if propulsion and limb swing are sufficient
- Lateral movement of center of mass typically minimal
  - Sensorimotor feedback assists in stability control
    - Active stability control
    - Hip/trunk/ankle or foot placement

(Grabowski, 2005; Gottschall, 2003, 2005; Donelan et al., 2004)

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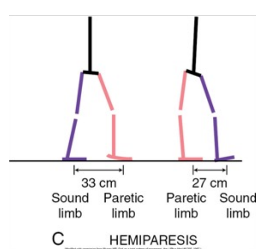
IMPACT OF NEUROLOGIC CONDITIONS



- Biomechanical subcomponents all contribute to walking
  - Stance Control
    - Quadriceps weakness may lead to collapse
  - Propulsion
    - Hip/plantarflexor weakness may reduce walking speed
  - Limb Swing
    - Stroke may limit ankle control
  - Postural Stability
    - Compromised by reduced ankle/pelvic/trunk control
    - Inability to process sensory information

(Hornby et al., 2020)

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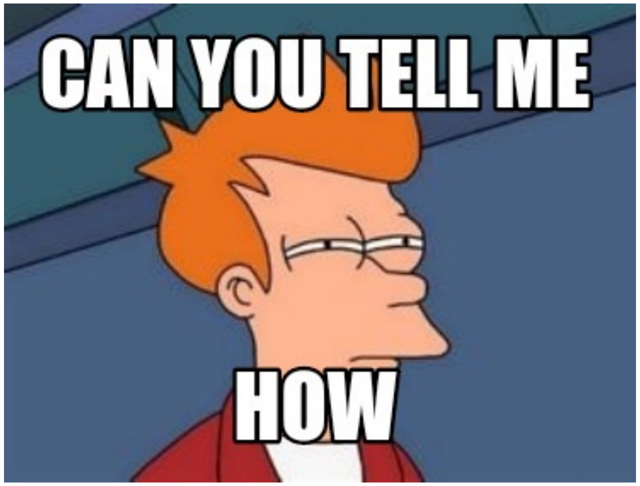

HOW DO WE DO HIGH-INTENSITY GAIT TRAINING?

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APPLICATION OF INTENSITY

- Specificity matters
  - Non-walking training at high intensities did not show the same positive changes as walking training at high intensities

(Moore. et al., 2010)

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PRECAUTIONS & CONTRAINDICATIONS

PRECAUTIONS

- Cardiac history/arrhythmias—discuss individual cases with physician
- Autonomic dysreflexia
- Diabetic patient (at risk for autonomic changes or hyper/hypoglycemia)
- Profuse sweating without corresponding heart rate or RPE

CONTRAINDICATIONS

- Complaint of chest pain/angina during intervention
  - Discontinue treatment and notify physician if this occurs
- Blood pressure of 200/100 mmHg is upper limit for blood pressure with exercise (ACSM 2021)
  - Discontinue treatment if patient reaches this level

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CONSIDERATIONS

Deconditioning

Understanding of "exertion" versus "difficulty" when using the RPE scale

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FITT PRINCIPLE

Frequency	Intensity	Time	Type
• 4-6 times/week	• 70-85% of age-predicted HR max • 15-17 RPE	• 40-60 minutes	• Variable stepping activities

(Hornby et al.,2020)

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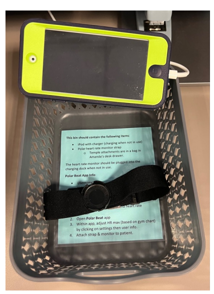
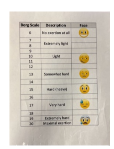
HOW TO DO IT?





- Medical director buy-in (if in an inpatient setting)
  - HIGT is within our scope of practice
  - Physician guidelines always supersede published guidelines
- **Equipment to monitor vital signs**
  - Heart rate monitor & an app to track/easily view data
    - We use the Polar OH1 and Polar Beat app connected to an iPod
  - Dynamap or sphygmomanometer to monitor blood pressure
  - RPE scales
    - Especially if patient on beta blocker or has pacemaker
- Monitor outcomes
  - 6-Minute Walk Test, 10-Meter Walk Test, Berg Balance Scale, 5 Time Sit to Stand Test, Functional Gait Assessment, Activities-Specific Balance Confidence Scale

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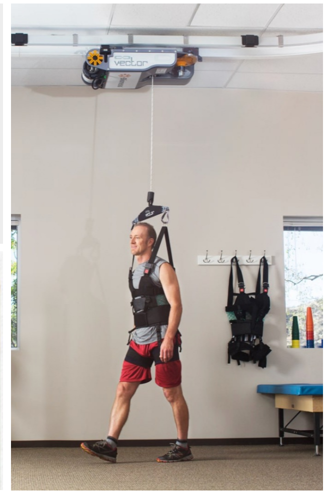
HOW TO DO IT?

- PT Equipment
  - Assistive devices
  - Supportive braces
  - Treadmill
  - Stairs
  - Overhead harness
  - Therabands
  - Weighted vest



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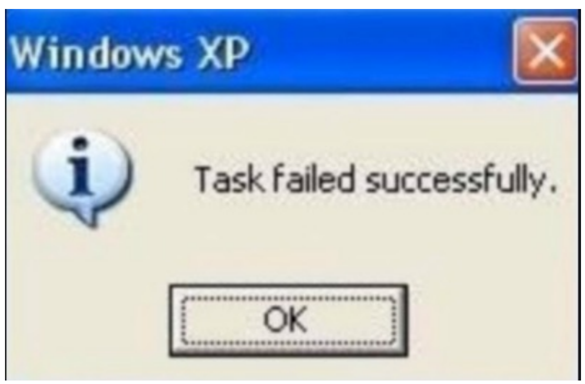

IMPORTANCE OF ERROR

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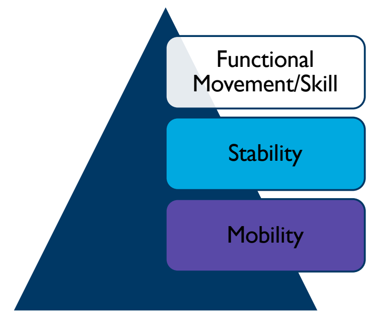
LEARNING THROUGH ERROR

- PT traditionally emphasizes "normal" movements
  - One task at a time
  - Focus on kinematics
  - Avoid challenging tasks/conditions/activities until consistent performance with simpler task
  - Intervene to correct errors
    - Avoiding error may slow recovery



(Cai et al., 2006; Hornby et al., 2008; Lewek et al., 2009; Shah et al., 2012; van den Brand et al., 2012)

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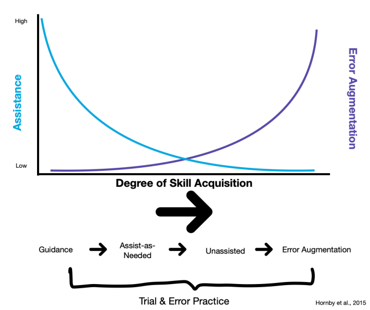
ERROR AUGMENTATION



- Motor tasks have variability, even with familiar tasks
- Learning occurs through error
- "Principle of Laziness"
  - If an individual is given too much assistance during walking tasks, they may conform to natural tendency to conserve energy
  - Therapist-assisted (high variability) gait group improved walking speed and symmetry more than robotic-assisted (low variability) gait group
- Augmenting errors is accomplished by:
  - Increasing the difficulty of the task
  - Modifying the environment
  - Applying external forces

(Selinger et al., 2015; Hornby et al., 2008; Lewek et al., 2009)

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SUCCESSFUL VS. UNSUCCESSFUL WALKING

Successful Walking

- If successfully stepping (advancing limb), do NOT intervene
- Abnormal movement not a concern if patient meets criteria for success (without experiencing pain)
- Continued success should result in adjusting training parameters to make task more challenging

Unsuccessful Walking

- Inability to step (advance the limb)
- Failure = 3-5 consecutive errors
- Assist or adjust parameters to make task easier

(Hornby et al., 2015)

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LIMITATIONS OF ERROR AUGMENTATION

Must determine whether patient can adapt to errors

- Patient needs to be able to self-evaluate then recalibrate movement
- In some cases, introducing error may be detrimental

Must self-evaluate then recalibrate movement

- Not feasible if ability to learn has been compromised
  - Sensory or memory deficits
  - Cerebellar lesions

(Ghez et al., 1995; Liu & Wrisberg, 1997)

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CHALLENGING THE BIOMECHANICAL SUBCOMPONENTS OF GAIT

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GENERAL GUIDELINES

Stance
- Maintain appropriate weight-bearing with limited knee/hip collapse

Limb Swing
- Ensure positive step length

Propulsion
- Walk in specific directions, increase speed

Postural Stability
- Maintain postural control and sufficient mediolateral base of support

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GENERAL GUIDELINES

- Do NOT intervene immediately to correct kinematics
- Allow patients to experience errors
- Vary task/increase difficulty to introduce more error
- Activity should be intensive and challenging, NOT impossible
- Pay attention to psychological responses
- Educate patients on benefits of errors for motor learning

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INCREASING THE CHALLENGE: STANCE CONTROL

Stair climbing with upper extremity support

Elliptical stair climbing

Stepping up onto obstacles with upper extremity support

Walking up stairs without upper extremity support

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INCREASING THE CHALLENGE: LIMB SWING

- Stair climbing with upper extremity support
- Elliptical stair climbing
- Stepping up onto obstacles with upper extremity support
- Stepping over obstacles without upper extremity support
- Walking up stairs without upper extremity support
- Adding an ankle weight to affected limb

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INCREASING THE CHALLENGE: PROPULSION

- Fast treadmill walking with upper extremity support
- Resisted forward walking without upper extremity support

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INCREASING THE CHALLENGE: LATERAL STABILITY

- Walking on uneven surfaces
- Lateral stepping on a treadmill with upper extremity support
- Stepping over obstacles without upper extremity support
- Resisted forward walking without upper extremity support
- Walking while dribbling basketball without upper extremity support
- Walking up stairs without upper extremity support

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WHO NEEDS HIGT?

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RECOMMENDED FOR…

- Chronic stroke (Hornby et al., 2020)
- Chronic traumatic brain injury (Hornby et al., 2020)
- Chronic incomplete spinal cord injury (Hornby et al., 2020)
- Found to be safe in subacute stroke (Hornby et al., 2015; Moore et al., 2020; Moore et al., 2021)
- Emerging research on its efficacy in acute neurologic injury population (Fahey et al., 2022)

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BARRIERS TO IMPLEMENTATION

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BARRIERS TO IMPLEMENTATION

- "The time has come to let go of the neurophysiologic approaches as a basis for neurologic physical therapy education and practice. Instead, we should discuss the therapeutic principles that drive the nervous system to respond and adapt."
  - K. Sullivan, JNPT 2009 editorial
- "Currently, the best available evidence in our field does not support the use of traditional rehabilitation strategies, including NDT, PNF, or Neuro-IFRAH, for which high-quality research to demonstrate their comparative efficacy is weak or absent. Rather, the available evidence supports the application of training parameters that offer the greatest probability of harnessing the effects of neuroplasticity and functional gains, including specificity, amount, intensity, and saliency of task practice."
  - P. Scheets et al., JNPT 2021 editorial

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CLINICIAN BUY-IN

- **"You're ignoring their impairments."**
  - Strength, balance, transfers improve with high intensity variable stepping training (Straube et al., 2014; Hornby et al., 2016; Hornby et al., 2005; Hornby et al., 2015)

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CLINICIAN BUY-IN

- **"They aren't ready for walking."**
  - Impairment based interventions often don't improve walking function (CPG Locomotor Function 2020)
  - "Pre-gait" activities are neither "pre" nor "gait"
    - They have limited translation to gait

(Moore et al, 2010)

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CLINICIAN BUY-IN

- **"What about facilitation of normal kinematics?"**
  - Practicing "normal" may result in limited gains in function or kinematics (Dobkin et al., 2006; Hornby et al., 2008; Hidler et al., 2009; Lewek et al., 2009; Duncan et al., 2011)
  - Practicing "normal" is insufficient
  - It also is unnecessary because gait quality improves with high-intensity gait training (Hornby et al., 2016; Mahtani et al., 2017; Ardestani et al., 2019)

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CONCERN FOR PATIENT

- **"I don't want to hurt my patient."**
  - No increased risk of cardiovascular/orthopedic injury with high intensity training (Pang et al., 2013; Hornby et al., 2015; Moore et al., 2020)
  - Strategies to reduce risk:
    - ACSM Guidelines
    - MD approval with concerns
    - AFO, taping, knee cage, gait belts to prevent orthopedic injury

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IMPLEMENTATION OF HIGH-INTENSITY GAIT TRAINING AT UNIVERSITY OF KANSAS HOSPITAL IPR

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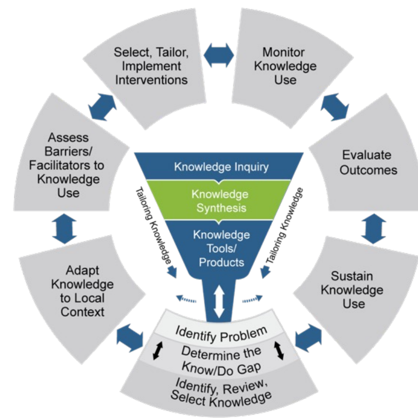
KNOWLEDGE TRANSLATION

- Determine where you are on the knowledge translation cycle



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FIRST STEPS

September 2018

- 3 PTs from KU inpatient rehab unit attended HIGT course
- Presented information to management & PT team upon return; team wanted more info

November 2018 & January 2019

- Presented inservices on HIGT implementation

Summer 2019-January 2020

- Management agreed to purchase of one heart rate monitor (besides use of Dynamaps)
- Continued mentoring of PT team on implementation and identifying barriers (primary barriers were lack of necessary heart rate monitoring equipment & documentation in EMR)

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NEXT STEPS

January-August 2020

- New therapy manager on rehab unit very supportive of HIGT implementation
- Approved purchase of 2 additional heart rate monitors
- Facilitated changes to documentation flowsheets to build in HIGT
- Made promotion of HIGT a priority at team meetings and set expectation that it should be the standard of care for individuals post-stroke
- Created reference materials for therapy team that could be easily accessed

September-December 2020

- Presented six-hour CEU reviewing high intensity training (collaborated with OT & SLP)
- Medical director of unit interested in retrospective study related to outcomes of patients post-stroke who received HIGT
- Submitted study design with IRB department at KUMC
  - As it was a quality improvement study, it did not require full IRB submission

January-March 2021

- Built Excel spreadsheets for data collection
- Collected data from EMR for patients in designated time periods admitted to rehab unit with a diagnosis of stroke
- Management approved purchase of 3 iPods to use with heart rate monitors so staff no longer had to use personal phones

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“FINAL” STEPS

Summer 2021

- Presented parts of initial data collection to rehab manager as there were opportunities for increased use of outcome measures
- Presented data to PT team
- As a team decided we were attempting to focus on collection of too many outcome measures (core set) and chose 2 measures to collect on every patient at admission & discharge

Fall 2021

- Decided to collect data from another summer following addition of iPods
- Grant approval for 5 more iPods & heart rate monitors (1 for each PT)

Spring 2022

- Cleaned up data spreadsheet in preparation for analysis (collaborating with a PhD student)
- Submitted for a poster/platform presentation for CSM 2023 (poster presentation accepted on 9/28)

Spring 2023

- Presented findings of retrospective study at CSM and APTA Kansas Spring Conference

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PERCENTAGE USAGE FOR PATIENTS WITH STROKE

2019 *18.5%*

2020 *34.6%*

2021 *55.9%*

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RESULTS OF RETROSPECTIVE ANALYSIS

Table 1	HIGT (n=33)	Standard Care (n=83)	P-Value
Age	66 ± 12	69 ± 11	0.24
Sex, n (% female)	13 (39%)	33 (40%)	1.00
Length of Stay (days)	16 ± 8	11 ± 7	0.002*
Discharge Location, n (%); Home	30 (91%)	57 (69%)	0.002*
Discharge Location, n (%); Acute	0	18 (21%)	
Discharge Location, n (%); SNF	2 (6%)	8 (10%)	
Discharge Location, n (%); LTACH	1 (3%)	0	
HIGT Sessions	4 ± 3	N/A	

(Britton-Carpenter et al., 2023)

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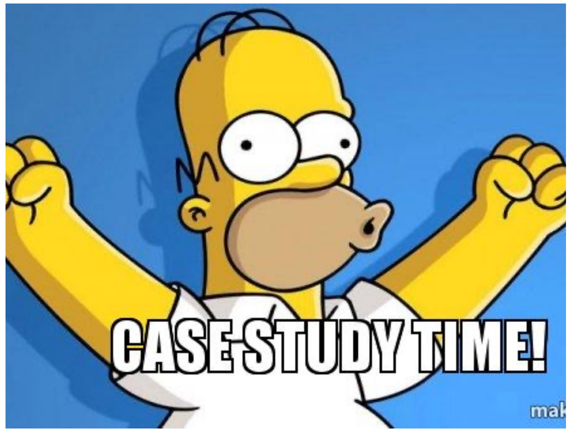

CASE STUDIES

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CASE STUDY #1

- 57-year-old female with a history of multiple myeloma and current acute myeloid leukemia, independent prior to admission
- Presented to acute inpatient rehabilitation (IPR) after three right craniotomies for evacuation of subdural empyema
- Patient demonstrated the following at initial evaluation:
  - Non-ambulatory, requiring two-person assistance for transfers
  - Left lower extremity (LLE) strength of 1/5
  - Left-sided neglect
  - Pusher Syndrome

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CASE STUDY #1: INITIAL OUTCOMES ASSESSMENT

Outcome	Score
Berg Balance Scale	3/56
6-Minute Walk Test	0 feet
10-Meter Walk Test	0.0 m/s
5 Time Sit to Stand Test	0 seconds
Functional Gait Assessment	0/30
Activities-Specific Balance Confidence Scale	10.6%

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CASE STUDY #1: INTERVENTION

- Participated in 16 HIGT sessions
  - Achieved 70 to 85% of her age-predicted maximal heart rate as well as 15 to 17 on the RPE.
    - Patient initially achieved 11 minutes in the target zone, progressing to 48 minutes in a HIGT session.
- Interventions included:
  - Treadmill gait to address propulsion/gait velocity
    - Initially required 15% body-weight support and two-person assistance, progressing to a harness for safety only
  - Stair training to challenge LLE stance control
  - Overground gait with obstacles to increase variability and challenge
  - Gait with a weight on her left lower extremity to challenge limb swing

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CASE STUDY #1: INTERMEDIATE OUTCOMES ASSESSMENTS

Reassessment #	Admission Day / # of HIGT Sessions	Berg Balance Scale	6-Minute Walk Test	10-Meter Walk Test	5 Time Sit to Stand Test	Functional Gait Assessment	Activities-Specific Balance Confidence Scale
1	7 / 5	13/56	Not Tested	Not Tested	Not Tested	0/30	Not Tested
2	14 / 10	32/56	692 feet	0.49 m/s	0 seconds	7/30	Not Tested

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CASE STUDY #1: DISCHARGE OUTCOMES ASSESSMENT

Admission Day / # of HIGT sessions	Berg Balance Scale (minimal detectable change (MDC) = 6.9)	6-Minute Walk Test (minimally clinical important difference (MCID) = 112.9 feet)	10-Meter Walk Test (MCID = 0.16 m/s)	5 Time Sit to Stand Test	Functional Gait Assessment (MDC = 4.2)	Activities-Specific Balance Confidence Scale
	Cut-Off = 45/56	Patient predicted distance based on age, height, weight, & gender = 1,723 feet	Community ambulator = 0.8-1.35 m/s	≤15 seconds = increased risk for recurrent falls	Cut-Off ≤22/30	Cut-Off = 81.1%
21 / 16	45/56	1,062 feet	0.91 m/s	18.2 seconds	15/30	63.1%

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CASE STUDY #1: SUMMARY

- This patient discharged home independently using a forearm crutch

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CASE STUDY #2

- 58-year-old male with right ACA acute strokes, ACA-MCA watershed area strokes.
  - PMH: Hypertension; Hypothyroidism
- Initial evaluation demonstrated:
  - Left lower extremity strength grossly 1/5
  - Transfers maximal assist x2
  - Unable to ambulate
  - Highly distractable

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CASE STUDY #2: INITIAL OUTCOMES

Outcome	Score
6 Minute Walk Test	0 feet; patient unable to attempt
10 Meter Walk Test (self-selected)	0; unable to attempt
Berg Balance Scale	3/56
Functional Gait Assessment	0/30

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CASE STUDY #2: INTERVENTIONS

- Primary biomechanical subcomponent to target was limb swing
  - Also had deficits in propulsion, stance control, and lateral stability
- Initiated HIGT on admission day 2; performed 17 sessions of HIGT
- Utilized RPE scale as primary measurement of intensity as patient was on beta blockers
- Started in Rifton Tram; we had a few rough days due to increased hypertonicity in left lower extremity and patient required maximal assist to advance left lower extremity
- Ordered a left carbon fiber AFO
- Initiated treadmill activities on day 8; very slow, 0.2 mph for 3-minute bouts
  - Progressed to 10-15 minute bouts at up to 1.2 mph
- Also incorporated stair training, sidestepping, backwards ambulation, obstacle navigation

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CASE STUDY #2: INTERMEDIATE OUTCOMES

Outcome	Score
6 Minute Walk Test	656 feet, minimal assist, no device
10 Meter Walk Test (self-selected)	0.36 m/s, minimal assist, no device
Berg Balance Scale	8/56

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CASE STUDY #2: BIOMECHANICAL SUBCOMPONENT TARGETS/INTERVENTIONS

- Limb swing
  - Added ankle weight to left lower extremity
  - Obstacle navigation
- Stance control:
  - Stair training
- Lateral stability
  - Stepping over obstacles without upper extremity support
  - Walking up stairs without upper extremity support
- Propulsion
  - Increasing speed on treadmill

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CASE STUDY #2: DISCHARGE OUTCOMES

Outcome	Score
6 Minute Walk Test	750 feet, standby assist, no device
10 Meter Walk Test (self-selected)	0.68 m/s, standby assist, no device
10 Meter Walk Test (maximal)	0.93 m/s, standby assist, no device
Berg Balance Scale	44/56
Functional Gait Assessment	18/30

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CASE STUDY #2: VIDEOS

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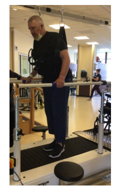
CASE STUDY #2:VIDEOS



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CASE STUDY #2:VIDEOS

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CASE STUDY #2:VIDEOS

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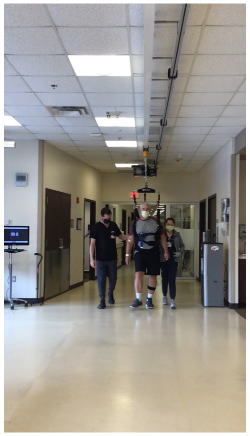
CASE STUDY #2:VIDEOS



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CASE STUDY #2: SUMMARY

- This patient discharged at an ambulatory level without an assistive device
- He did continue to use the AFO

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CASE STUDY #3

- 58-year-old male with traumatic cervical spinal cord injury s/p C3-6 laminectomy and posterior fusion resulting in central cord syndrome.
  - PMH: Ulcerative colitis-controlled; Bilateral posterior uveitis-controlled; Chronic A. Fib; Hypertension; Hyperlipidemia; Pulmonary edema; **patient on beta-blockers**
- Patient demonstrated the following at initial evaluation:
  - Bilateral lower extremity strength of grossly 4/5
  - Maximal assist x2 for transfers
  - Unable to ambulate

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CASE STUDY #3: INITIAL OUTCOMES

Outcome	Score
6 Minute Walk Test	0
10 Meter Walk Test (self-selected)	0.0 m/s
Berg Balance Scale	4/56
Functional Gait Assessment	0/30
5 Time Sit to Stand Test	0

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CASE STUDY #3: INTERVENTIONS

- Primary biomechanical subcomponent to target was propulsion
  - Also had deficits in stance control and lateral stability
- Initiated HIGT on admission day 5; performed 16 sessions of HIGT
- Utilized RPE scale as primary measurement of intensity as patient was on beta blockers
- Initiated gait training in Rifton Tram to provide patient with necessary upper body support
- Transitioned to treadmill to address propulsion
  - Initially tolerated 5-minute bouts at 1.0 mph; progressed to 20 minutes at 1.6 mph
- Also incorporated stair training, sidestepping, backwards ambulation, obstacle navigation

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CASE STUDY #3: BIOMECHANICAL SUBCOMPONENT TARGETS/INTERVENTIONS

- Limb swing
  - Ankle weights
- Lateral stability
  - Stepping over obstacles without upper extremity support
- Propulsion
  - Treadmill gait with focus on increased speed

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CASE STUDY #3: DISCHARGE OUTCOMES

Outcome	Score
10 Meter Walk Test (self-selected)	0.58 m/s, standby assist with single forearm crutch
Berg Balance Scale	27/56

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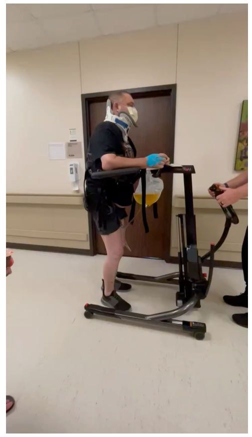

CASE STUDY #3:VIDEOS

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CASE STUDY #3: SUMMARY

- This patient discharged at an ambulatory level with an assistive device

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WRAP-UP

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RESOURCES

Academy of Neurologic Physical Therapy

- https://www.neuropt.org/practice-resources/best-practice-initiatives-and-resources/intensity_matters

Moving Forward Paper

- https://journals.lww.com/jnpt/Fulltext/2021/01000/Moving_Forward.10.aspx

Institute for Knowledge Translation

- https://www.knowledgetranslation.org

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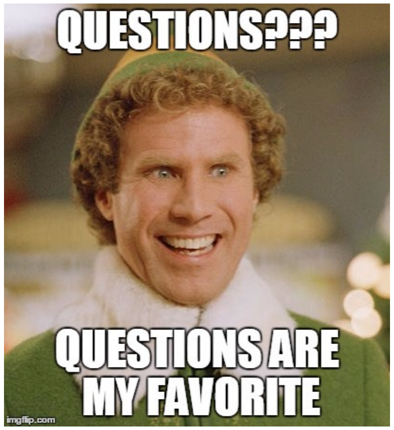

QUESTIONS

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