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The Subcomponents of Gait: A Different Way to Look at Locomotor Function

Christina Voigtmann, PT, DPT, NCS

Speaker Bio

- Christina Voigtmann is a Board-Certified Specialist in Neurologic Physical Therapy. She currently works as a locomotor clinical specialist at Orlando Health ORMC Institute for Advanced Rehabilitation, where her specialties include direct patient care, research, and program development for patients with stroke, brain injury, and incomplete spinal cord injury. She received her Doctorate of Physical Therapy degree from the University of St. Augustine for Health Sciences in 2014. She is clinical faculty for the UCF-Orlando Health Neurologic Physical Therapy Residency Program, an adjunct professor at the University of Central Florida, and guest lectures annually with the University of Central Florida's Doctor of Physical Therapy program. She is a member of several special interest groups within the ANPT and received the Florida Physical Therapy Association's award for Clinical Excellence in 2020

Disclosures

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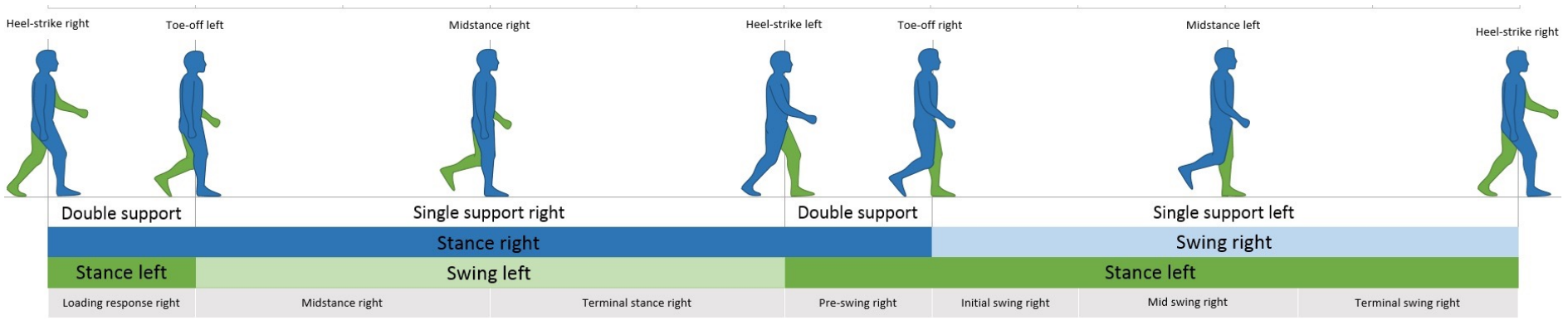
Learning Outcomes

After this course, participants will be able to:

- Name the Rancho Los Amigos phases of gait for stance and swing.
- List the four subcomponents of gait.
- Identify at least two treatment strategies for each subcomponent of gait (limb swing, stance, propulsion, and postural stability).
- Identify the metabolic cost of each subcomponent of gait from least to greatest.
- Define kinematics and discuss current evidence in locomotor training that impacts kinematics.

Gait Cycle Analysis



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Q4

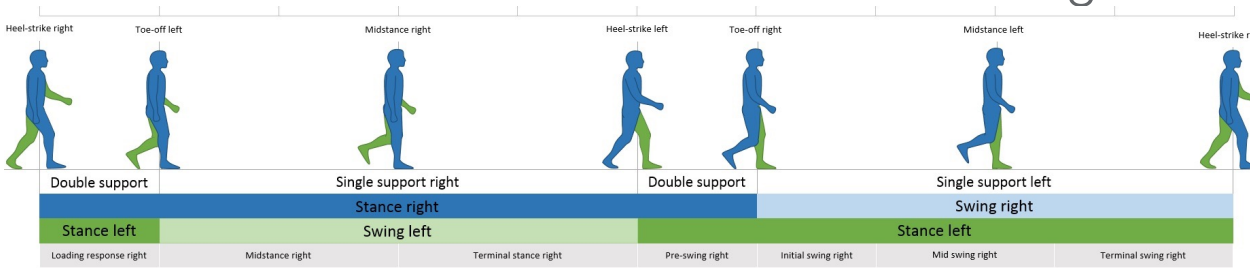
Stance Phase Comparison

Traditional Terms[1]

- Heel strike
- Foot flat
- Midstance
- Heel off
- Toe off

Rancho Los Amigos Terms[2, 3]

- Initial Contact
- Loading response
- Midstance
- Terminal stance
- Preswing



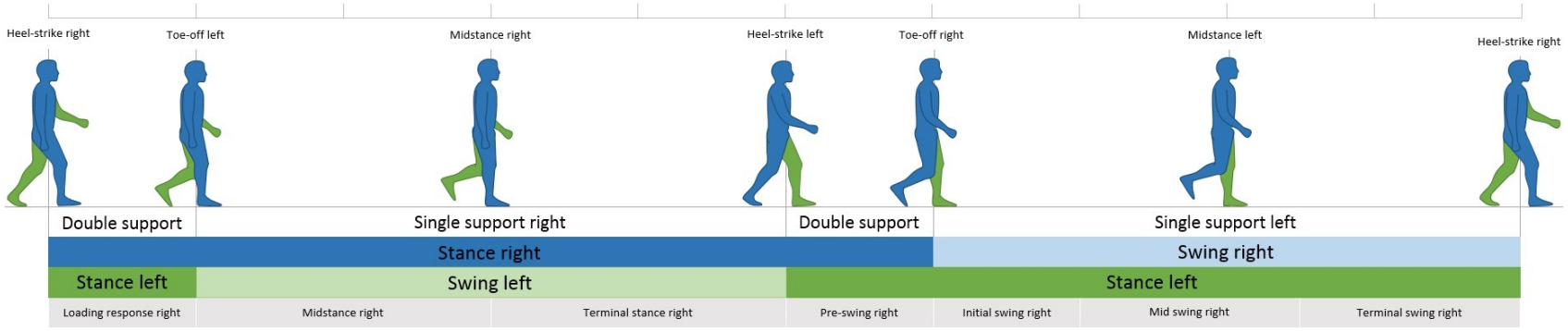
Swing Phase Comparison

Traditional Terms[1]

- Acceleration
- Midswing
- Deceleration

Rancho Los Amigos Terms[2, 3]

- Initial swing
- Midswing
- Terminal swing



What to address first?

- Multiple variables to discuss
  - Trunk
  - Pelvic rotation
  - Hip
  - Knee
  - Ankle
  - Toes

What are kinematics?

- Kinematics describe the angle, position, linear and angular acceleration of various joints in the gait cycle[4]
- Seen with gait analysis systems i.e., EMG and motion capture equipment
- Traditional PT paradigm attempts to normalize these kinematics and “recover” neuromuscular patterns to mitigate compensation[5, 6]

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Q5

What evidence is available to support interventions to improve kinematics?

- Bobath and Neurofacilitation techniques (PNF, NDT) have not shown carryover to significant gains in gait function or mechanics[7,8,9]
- Lotter and colleagues (2020) studied impairment based training versus high intensity variable stepping training at high intensities. Superior walking outcomes and balance confidence was seen in high intensity group versus impairment-based group[10]
- Body Weight Support Treadmill Training (BWSTT) or Robot Assisted Gait Training (RAGT) is not found to be superior to conventional overground gait training[11]

So what is effective?

The Locomotor Clinical Practice Guideline

- Hornby and colleagues released the CPG for locomotor function for stroke (CVA), incomplete spinal cord injury (iSCI), and Traumatic Brain Injury (TBI) in January 2020[12]
- A systematic review over 20 years (1995-2016) grading evidence and establishing guidelines that are demonstrated to improve walking speed and distance
- This guideline applies to ambulatory patients greater than 6 months post injury (chronic)

Categories of recommendations

- Green light- *Should* perform
- Yellow light- *May* perform
- Red light- *Should* not perform

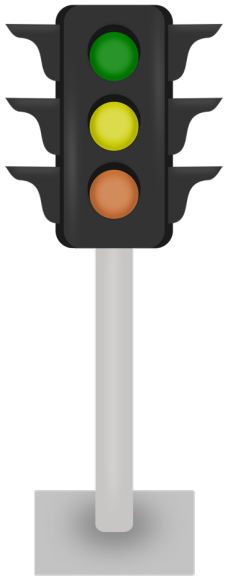

Image by Muhamad Rizky Kusumah from Pixabay

Key findings from the CPG

- Moderate to high intensity task specific training (walking) at 70-85% of the patient's age predicted HR max *should* be performed; strong support.[12]
- Walking practice with virtual reality *should* be performed; strong support.
- Weak evidence for strengthening, cycling/recumbent stepping, and circuit training. Clinicians *may* consider; weak support.

CPG key findings continued

- Clinicians *should not* perform sitting or standing and balance training for symmetry of weight bearing or postural stability with the goal of improving walking function. Clinicians *may* consider balance when coupled with virtual reality; strong support.[12]
- Body weight supported treadmill training *should not* be used greater than 6 months post injury compared to other interventions; strong support.
- Robotic-Assisted devices on a treadmill or elliptical *should not* be used compared to other interventions; strong support.

ANPT locomotor resources
https://www.neuropt.org/docs/default-source/cpgs/locomotor/locomotor-cpg-poster-5-6-21863d39a5390366a68a96ff00001fc240.pdf?sfvrsn=463e5f43_0

Discussion of the CPG states:

- "The collective findings suggest that large amounts of task-specific (ie, locomotor) practice may be critical for improvements in walking function, although only at higher cardiovascular intensities or with augmented feedback to increase patient's engagement. Lower-intensity walking intervention or impairment-based training strategies demonstrated equivocal or limited efficacy."[12]

Enter the kinematic debate

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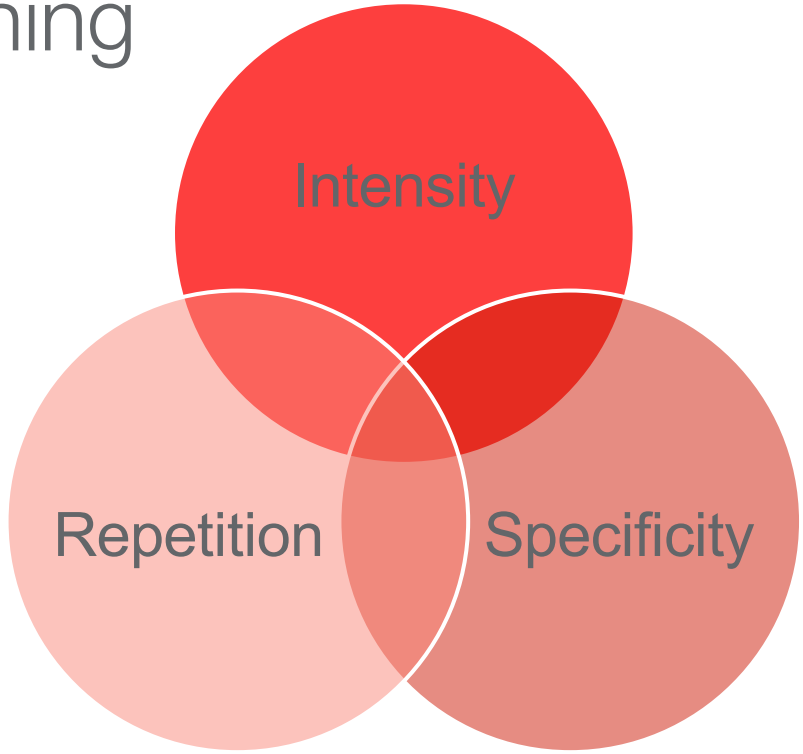
Q5

Kinematic Concerns

- Many clinicians have concerns regarding the kinematics
- Multiple studies show training for improved kinematics does not lead to better kinematics [10, 12-18]
- Rather, training at high intensities without emphasis on kinematics has shown improvement in the following: [10, 12-18]

✓ walking speed
✓ walking endurance
✓ kinematics
✓ interlimb coordination
✓ stance stability
✓ non-paretic limb propulsion and excursion

Motor learning



Error Augmentation

- Errors are essential to learning: error based learning[25]
- Purposefully inducing errors allows patients more opportunity for learning
- When you induce errors and perturbate the system, there is more ability to practice stepping reactions which are similar to community demands[19]
- Variable stepping practice elicits carryover into transfers, balance, and kinematics[20, 21, 22, 25]

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Does perfect practice really make perfect?

Current evidence suggests not

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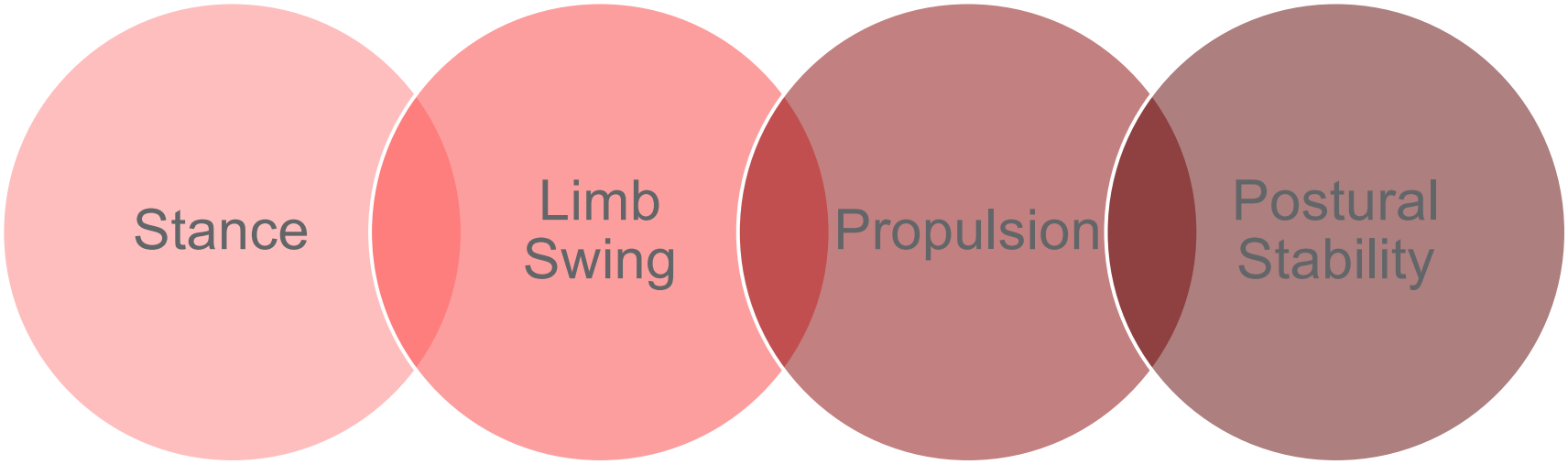
Therefore, should we continue to look at gait with 8 different phases and address each individual component to improve walking function?

Maybe there is another way

Biomechanical subcomponents of gait

4 Subcomponents



Stance

- The ability to bear weight and maintain upright trunk and limb support
- Described in literature as the ability to stand without limb or trunk collapse[19]

Photo by Liam Riby on Unsplash

Limb Swing

- Ability to clear the foot
- Produce a positive step length

(initial contact of the swing limb beyond the stance limb)[19]

Photo by Michael Drummond from Pixabay

Propulsion

- Bringing the COM over the stance limb
- Gait speed[19]

Photo by Dave Goudreau on Unsplash

Postural Stability

- Ability to maintain balance in dynamic situations
- Frontal/sagittal plane stability[19]

Photo by Mohamed_hassan on Pixabay

Photo by Niklas Ohlrogge on Unsplash

Case Videos


#FREEBRITNEY

What Subcomponents are Impaired?

- Limb Swing
- Propulsion
- Postural Stability


THE ROLLING STONES
'75 - US TOUR

What do I address first?

That depends…

Can they stand up?

- You must have stance to initiate locomotion
- Use of BWS to assist initially and progressing stance
- Assistive devices and assistance provided as needed
- Working towards reducing UE support

Can they advance their limb(s)?

- Clearance
- Positive step lengths
- Cannot participate in 10 MWT or 6MWT without independent limb swing[26, 27]

Are they moving their center of mass forwards? How fast?

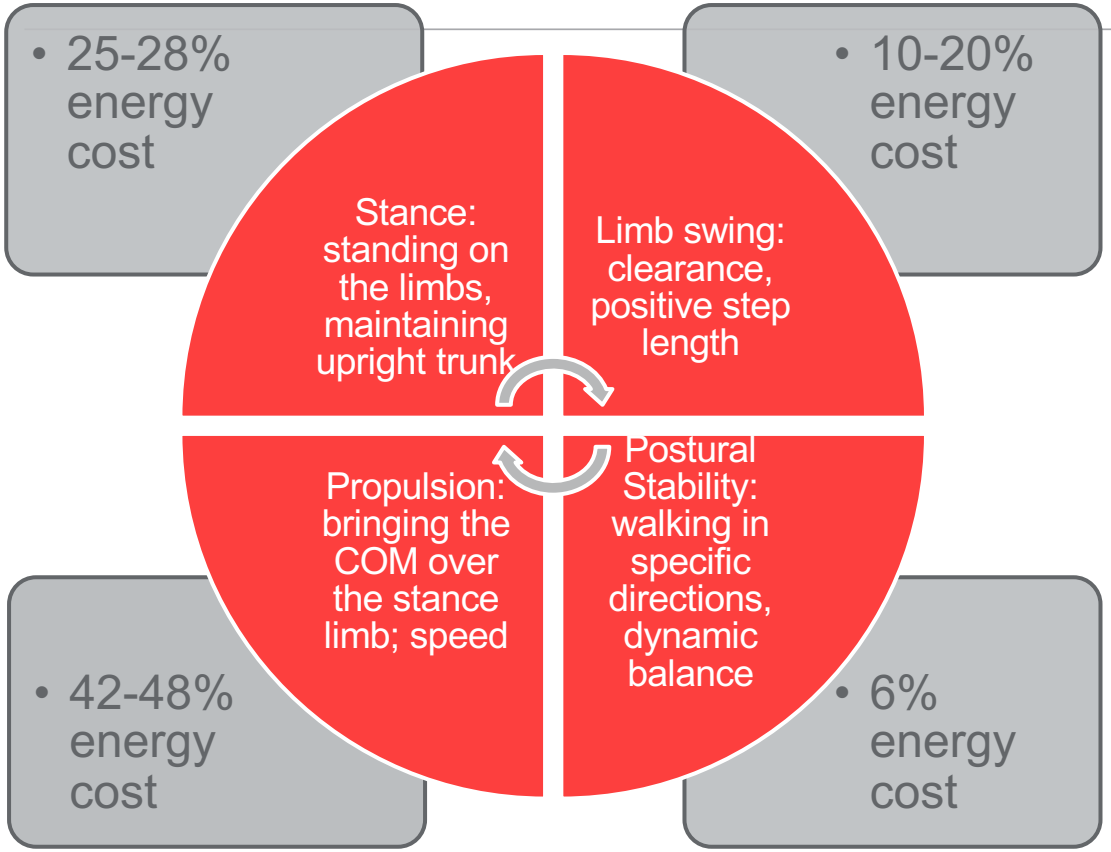
- What is their gait speed?
  - Household <0.4m/s, limited community 0.4m/s-0.8m/s, full community >0.8m/s[28]
- Slower gait speeds related to increased dependence, mortality, increased risk of falls, and hospitalization[24]
- Difficulty propelling up stairs

How is their balance and community access?

- Balance is major deficit in acute CNS injury
- Impaired balance requires assistance of a caregiver, devices and affects fall risk
- Multidirectional and variable stepping addresses these concerns
- This may be one of the more important aspects for community integration and safety
- Variable stepping practice produces gains in transfers and balance without addressing these tasks specifically[19-23]

How are they responding to interventions?

- What is the HR response?
- How can you drive HR?
- Higher aerobic intensities is the key ingredient with repetition and task specificity to make neuroplastic change[12, 13]



Grabowski JAP 2005, Gottschall JAP 2003, 2005, Selinger 2015

Q3

Ideas for Interventions

Treating each subcomponent of gait

Interventions to Address Stance

- Stance:
  - Limit BWS
  - Limit UE use
  - Stairs
  - Arguably the most critical element to begin gait training
  - Remember: 25-28% energy cost

continuED

Interventions to Address Swing

- Swing:
  - Stepping over obstacles
  - Weighting the limb
  - Adding incline
  - Stairs
  - Remember: only 10-20% energy cost

CONTINUED

Q3

Interventions to Address Propulsion

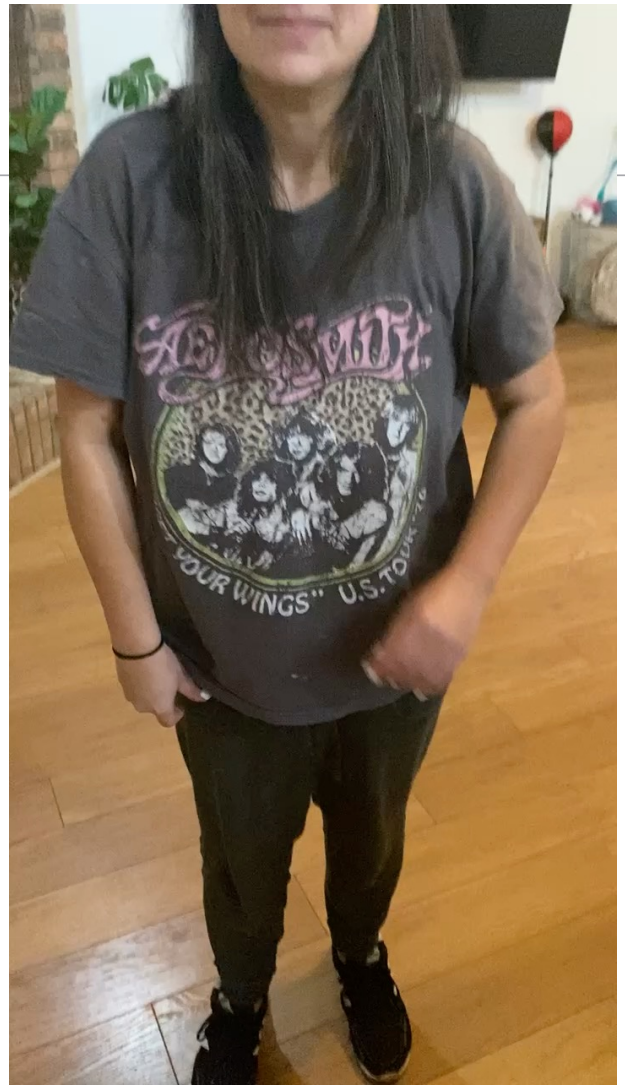
- Propulsion
  - Weighted vests/limbs
  - Resisted walking
  - Walking fast/running
  - sled pushing
  - Stairs weighted or increased speeds
  - Remember: 42-48% LARGEST energy cost

Interventions to Address Postural Stability

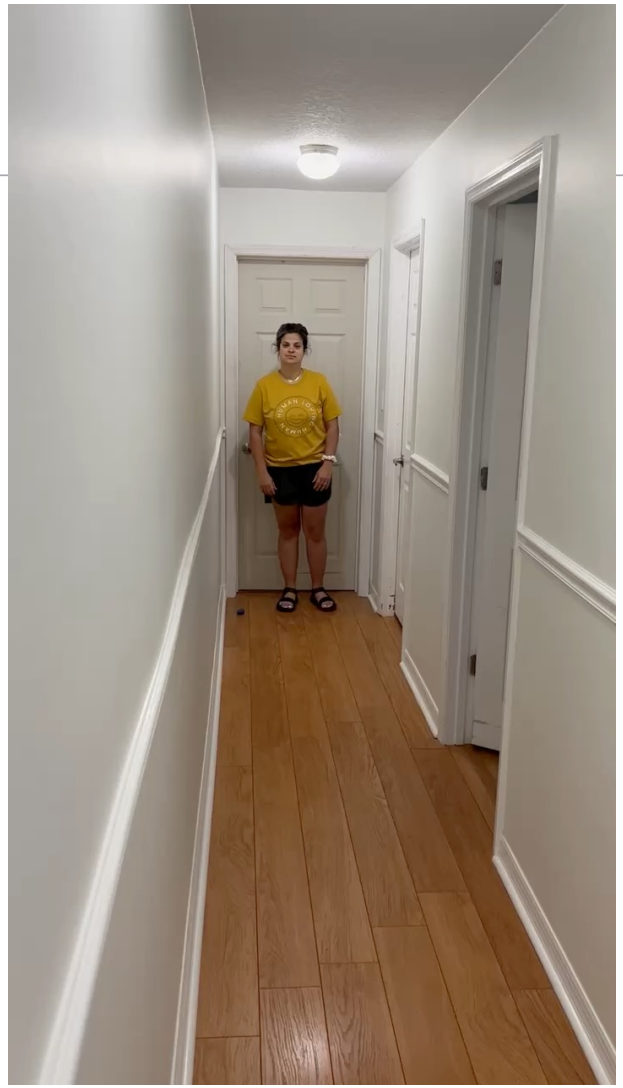
- Postural Stability
  - No UE support
  - Variable stepping in all directions
  - Compliant surface negotiation
  - Changing the AD
  - Stairs without UE support
  - Remember: 6% energy cost

No Assistive Device

- Stance and postural stability



Changing the Assistive Device

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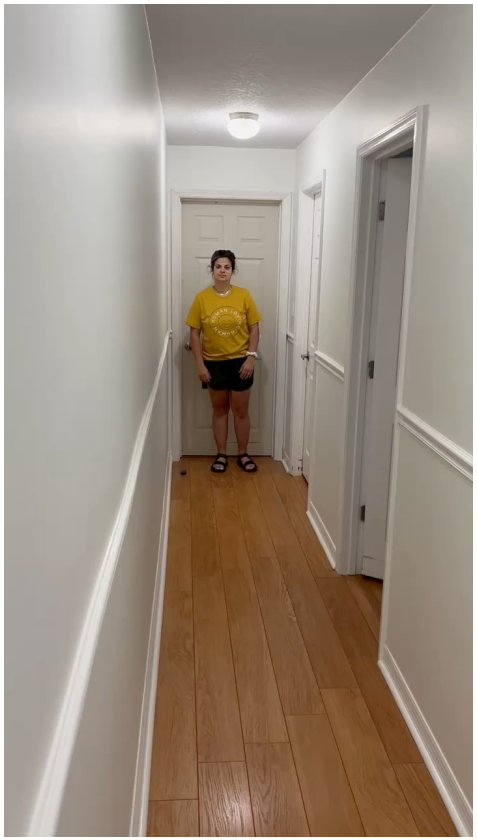

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Summary

- Looking at the 4 biomechanical subcomponents may be another way to address gait impairments for the neurologic client[19]
  - Stance, Limb swing, Propulsion and Postural Stability
- Less emphasis on kinematics and more on error-based learning or augmentation
- Variable stepping produces better walking outcomes when performed at high aerobic intensities[10-22]

Treating the Subcomponents

- Make sure they can stand on their limbs
- Work on positive step lengths/limb swing
- Then, make it harder
  - Challenge their propulsion (most metabolic demand and HR response)
  - Challenge their postural stability
  - Add weights
  - Change the environment
  - Make it specific to your patient's impairments

Intensity Matters!

Questions and Discussion

Thank you!

References

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