WHAT'S THE DEAL WITH HIGH-INTENSITY GAIT TRAINING?

RESEARCH TO SUPPORT THE INTERVENTION

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THE UNIVERSITY OF KANSAS HEALTH SYSTEM

1

OBJECTIVES

1. Define the active ingredients of neuroplasticity
2. Understand the role of the active ingredients of neuroplasticity as they relate to improving locomotor function
3. Understand current recommendations to improve walking for individuals with neurologic injury, including stroke and traumatic brain injury

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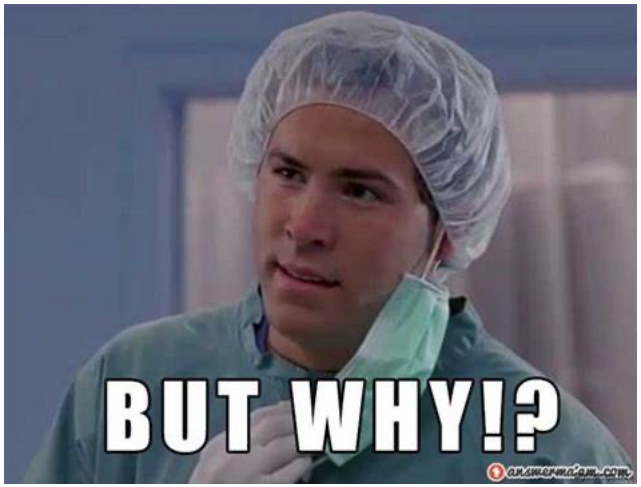

WHY SHOULD WE DO HIGH-INTENSITY GAIT TRAINING?

3

BACKGROUND

- Increasing need for rehabilitation due increasing rates of neurologic injuries
  - Annually in the United States:
    - 610,000 people have their first stroke
    - 2.5 million people sustain a traumatic brain injury (TBI)

(Centers for Disease Control)

4

BACKGROUND

- Reduction in payor sources and episodes of care
  - We need to provide individuals with neurologic injuries with the best therapeutic intervention to maximize their outcomes
- Increasing research
  - Stroke is most studied
  - TBI is least studied
    - Is this due to variability in mechanism of injury and presentation?

5

WHY GAIT?

- Walking is often a goal/priority for individuals with neurologic injury
- Gait velocity is considered the "6th vital sign" (Fritz and Lusardi, 2009)
  - Predictive of falls and mortality, along with other vital signs
  - Influences participation and independence in activities of daily living (ADLs) and mobility-related activities of daily living (MRADLs)
  - Slow gait velocity can cause social isolation at both household and community levels

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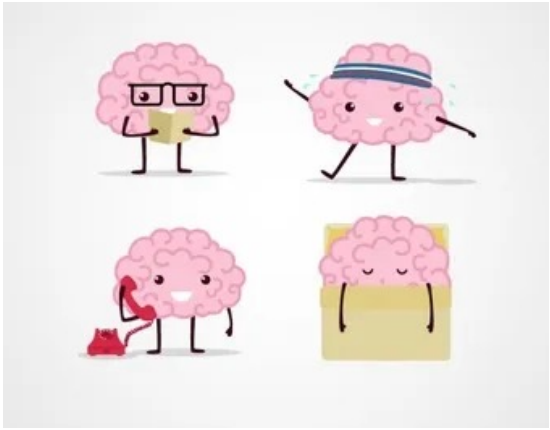

NEUROPLASTICITY

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NEUROPLASTICITY

- Complex process involving adaptive structural and functional changes to the brain
- It is defined as "the ability of the nervous system to change its activity in response to intrinsic or extrinsic stimuli by reorganizing its structure, functions, or connections after injuries, such as a stroke or TBI"

(Puderbaugh and Emmady, 2022)

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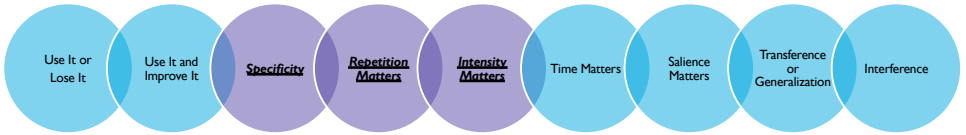
PRINCIPLES OF NEUROPLASTICITY



(Kleim and Jones, 2008)

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SPECIFICITY

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SPECIFICITY

- Specificity of practice is proven effective in rehabilitation
  - You must practice walking to get better at walking

(Hornby et al., 2011)

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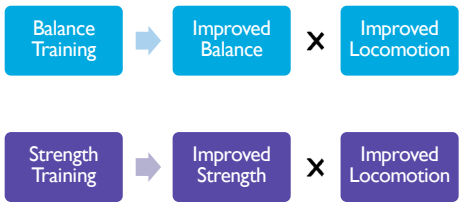
SPECIFICITY



(Patten et al., 2004; Jayaraman et al., 2013; Moore et al., 2010; Damiano et al., 1998, 2010; Hui-Chan et al., 2009; Au-Yeung et al., 2003)

12

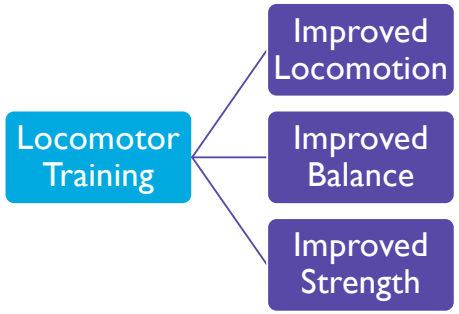
SPECIFICITY

Locomotor Training → Improved Locomotion

(Patten et al., 2004; Jayaraman et al., 2013; Moore et al., 2010; Damiano et al., 1998, 2010; Hui-Chan et al., 2009; Au-Yeung et al., 2003)

13

REVERSE TRANSFERENCE



(Hornby et al., 2011)

14

REPETITION

15

PRACTICE, PRACTICE, PRACTICE!

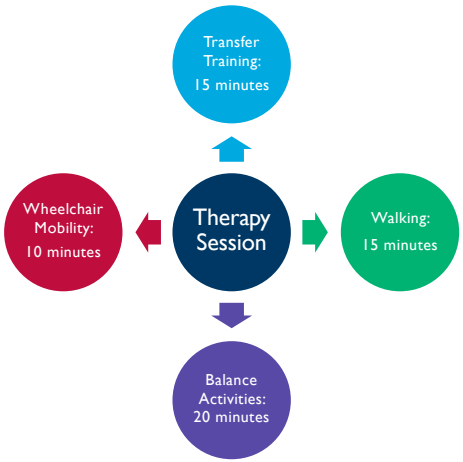
- Cortical reorganization occurs after ***hundreds*** of upper limb repetitions of a "challenging functional task" and ***thousands*** of steps
- Repetitions required to produce functional changes:
  - 31,500 repetitions over 35 days (Karni et al., 1995)
  - 9,600 repetitions over four weeks (Nudo et al., 1996)
  - 196 hours of practice over 14 days (Wolf et al., 2006)

16

PRACTICE, PRACTICE, PRACTICE?

- A 2010 study of individuals with stroke & TBI in acute hospitals & inpatient rehabilitation facilities (IRF) revealed that on average: (Jacobson, et al. 2010)
  - Individuals with stroke took 185 steps/session
  - Individuals with TBI took 317 steps/session
  - Clinicians who had 5-15 years of experience provided more opportunity for repetition of walking
- Average number of steps/session after stroke was 357 (Lang et al., 2009)
- Average number of steps/session after stroke was 886 (Moore et al., 2010)
- On average, stroke survivors in the US receive at least one hour of PT and OT on rehab units
- In Canada, a study of 123 patients revealed that they generally received about 37 minutes of combined PT & OT
- **What does this mean for meaningful practice & experience?**

17



18

INTENSITY

19

WHY DOES INTENSITY MATTER?

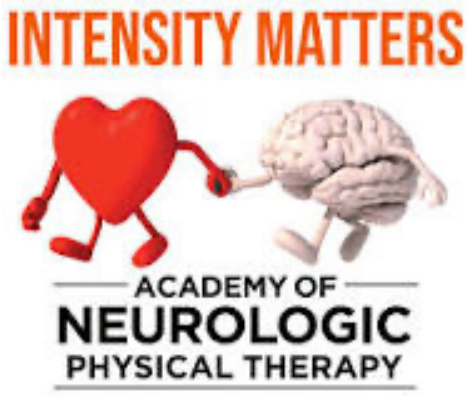
- Intensity of practice is essential for walking recovery
  - Given time restraints in current practice, repetition alone is not enough
- Oxygen delivery and aerobic capacity contribute to force production for walking
- Repetitive practice also helps improve conditioning

20

RESULTS OF NEUROLOGIC INJURY

- Decreased independence
- Increased reliance on assistive devices and/or braces
- Decreased speed/gait velocity

21



ROLE OF INTENSITY

22

WHAT IS INTENSITY?

The amount of time focused on each training procedure?

The number of therapy sessions?

The number of steps?

23

INTENSITY

Exercise physiology defines intensity as rate of work performed

- Work divided by time

Levels of intensity – ACSM 2017

- Low: <64% HR max
- Moderate: 64-77% HR max
- Vigorous: 77-94% HR max
- High: >94% HR max

24

INTENSITY

- Recommendations for able-bodied individuals and/or individuals following stroke (ACSM, AHA 2014):
  - >30 minutes at moderate intensity >5 days/week (60-75% predicted HR max)
  - >20 minutes at vigorous intensity >3 days/week (75-95% predicted HR max)
- Higher intensity exercise appears to improve selected locomotor outcomes (Pang et al., 2013; Billinger et al., 2014)
- Improved peak metabolic capacity or efficiency (Pang et al., 2013; Leddy et al., 2016)

25

INTENSITY VERSUS REPETITION

- It can be difficult to separate intensity from repetition
- In a 2015 study (Holleran et al.), individuals trained at high and low intensity for 4-week periods
  - Phases were matched for treatment time, walking speed, and number of steps
  - High-intensity phase performed gait activities with weighted vests, ankle weights, and manual resistance
  - High-intensity phase resulted in greater changes in walking function vs. low-intensity

26

INTENSITY VERSUS REPETITION

- Walking alone is insufficient
  - Robot vs. therapist assistance (Hornby et al., 2008; Hidler, 2009; Israel et al., 2006)
    - Treatment schedule, walking speed, and task repetition were the same for both groups
    - Data on metabolic cost and lower extremity muscle activity was collected
    - The therapist assistance group worked at a higher intensity
    - Robot assistance resulted in marked reduction in oxygen consumption, "Principle of Laziness"
  - LEAPS Trial (Duncan et al., 2011)
    - Did not focus on achieving higher heart rates
    - Heart rates often higher during 6-minute walk test vs. treadmill training
    - No difference between groups, demonstrating walking alone is insufficient

27

BENEFITS OF INTENSITY

Higher intensity activities may/should alter neuromuscular function and plasticity

Greater neural drive leads to greater neuroplastic changes

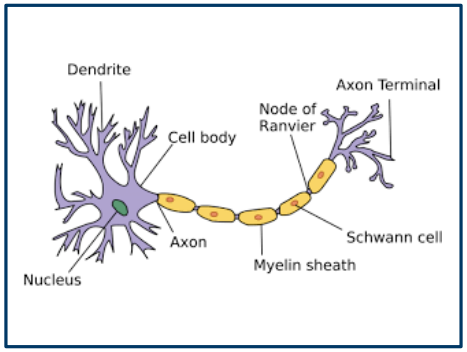
High intensity in exercise leads to increased levels of brain derived neurotrophic factor (BDNF) (Saucedo Marquez et al., 2015; Leech et al., 2017)

BDNF acts on certain neurons of the central and peripheral nervous systems, helping to support the survival of existing neurons and encourage the growth and differentiation of new neurons and synapses.

Intensive practice promotes secretion and uptake of neurotransmitters (serotonin and dopamine)

28

WHAT'S BDNF?



- Neurotrophin (protein) that is part of a family of nerve growth factors
  - It can be released pre- or post-synaptically
- Important in developing & maintaining CNS neurons, which maintain function, cognition, and emotions in the brain (Bjorkholm & Monteggia, 2015)
- Linked to brain plasticity and is considered helpful in reducing the size of a lesion post stroke (Schabitz et al., 2007)

29

BDNF POST-STROKE

- A systematic review of 21 articles (1 human study & 20 animal studies s/p experimental stroke) explored BDNF changes following exercise post-stroke
- Results:
  - Aerobic exercise induced BDNF changes in animals post stroke
    - Aerobic exercise (moderate or high intensity) induced changes in BDNF in the ipsilateral and/or contralateral hemispheres
    - Hippocampus and the motor cortex both showed an increase over the striatum.
    - Authors suggested timing of the measurement of BDNF could contribute to the different in BDNF source
  - Non-aerobic exercise training was inconclusive (reaching tasks, constraint-induced movement therapy) for BDNF release

(Alcantera et al., 2018)

30

WHAT ABOUT TRADITIONAL THERAPY?

31

THERAPEUTIC APPROACH: IMPAIRMENT-BASED TREATMENTS

Theory

Address underlying impairments leading to gait abnormalities

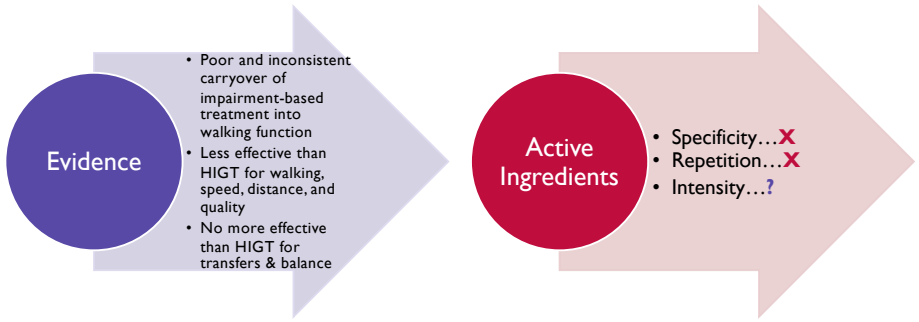
Method

Standing balance and weight shifting exercises, lower extremity strengthening, & transfer training

***adopted from the Academy of Neurologic Physical Therapy*
(Hornby, et al., JNPT 2020; Veerbeek, et al., PLoS One 2014; Lotter, et al., NNR 2020; Hornby, et al., NNR 2016; Moore, et al., Stroke 2020; Mahtani, et al., PTJ 2017)

32

THERAPEUTIC APPROACH: IMPAIRMENT-BASED TREATMENTS



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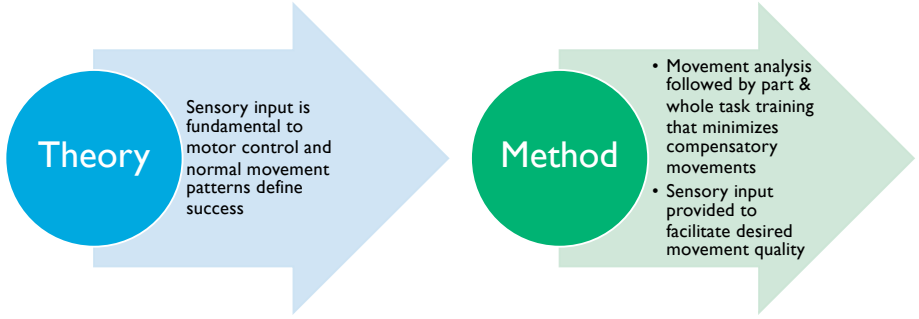
THERAPEUTIC APPROACH: BOBATH/NEURODEVELOPMENTAL TREATMENT (NDT)



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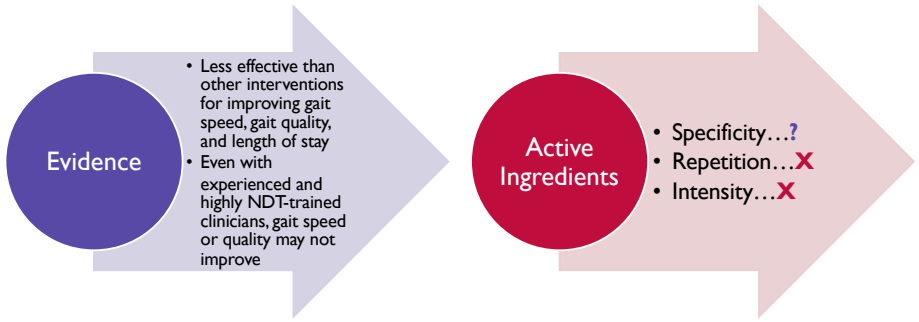

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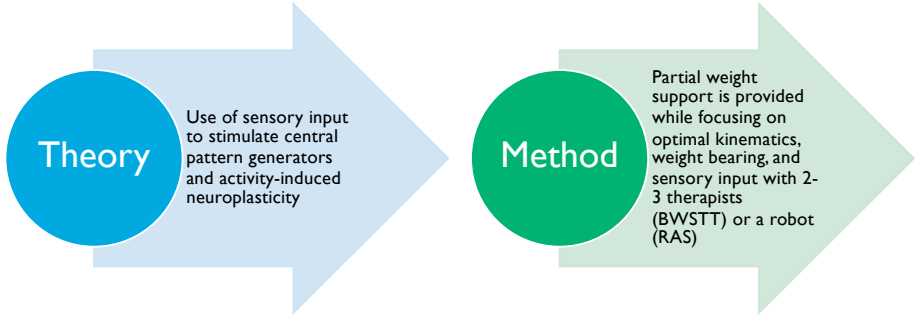
THERAPEUTIC APPROACH: BODY-WEIGHT SUPPORTED TREADMILL TRAINING (BWSTT) AND ROBOTIC ASSISTED STEPPING (RAS)



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36

THERAPEUTIC APPROACH: BODY-WEIGHT SUPPORTED TREADMILL TRAINING (BWSTT) AND ROBOTIC ASSISTED STEPPING (RAS)

Evidence

- Neither BWSTT nor RAS is superior to traditional low intensity overground gait training or treadmill training with a single therapist
- Both require additional personnel and equipment resources
- Excessive therapist or robotic assistance limits intensity
- Practicing normal movement patterns does not result in more normalized spatiotemporal patterns

Active Ingredients

- Specificity…✅
- Repetition…✅
- Intensity…❌

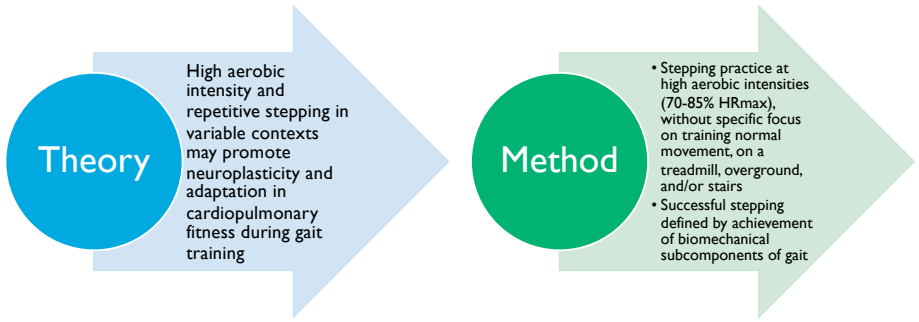
***adapted from the Academy of Neurologic Physical Therapy*
(Hornby, et al., JNPT 2020; Dobkin, et al., NNR 2012; Hornby, et al., Stroke 2008)

37

COMBINING OUR ACTIVE INGREDIENTS

38

THERAPEUTIC APPROACH: HIGH INTENSITY GAIT TRAINING



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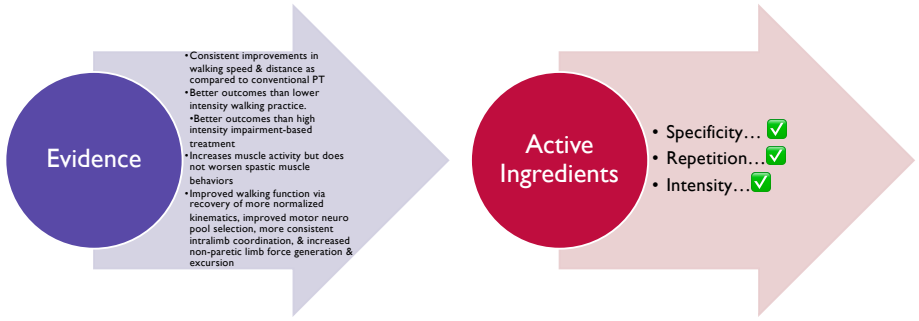
39

THERAPEUTIC APPROACH: HIGH INTENSITY GAIT TRAINING



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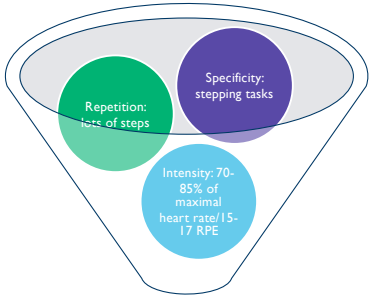
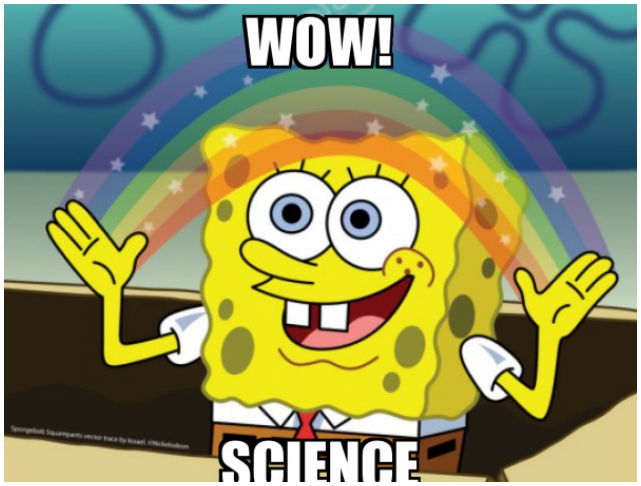
40

HIGH INTENSITY GAIT TRAINING



Improved Locomotion

41



IMPLEMENTATION SCIENCE

42

CLINICAL PRACTICE GUIDELINE

- Academy of Neurologic Physical Therapy's (ANPT) purpose of clinical practice guideline (CPG) was to "synthesize research evidence to improve clinical practice"
- CPG published in Journal of Neurologic Physical Therapy in January 2020
- Focus of CPG was to improve walking speed and distance for individuals with chronic neurologic injury (>6 months post stroke, incomplete spinal cord injury, and traumatic brain injury) who were already ambulatory at some level
  - >6 months chosen to reduce the interference of spontaneous recovery that occurs following acute neurologic injury

43

CPG METHODS

- Systematic review of randomized control trials published between 1995-2016
- Development of "should," "may," and "should not" recommendations of interventions for individuals with goals of improving locomotor function

44

CPG RECOMMENDATIONS

Clinicians **should** perform:	Clinicians **may** consider:	Clinicians **should not** perform:
-Walking training at moderate to high aerobic intensities -Walking with virtual reality	-Strength training at ≧70% 1 rep max -Circuit training, cycling, or recumbent stepping at 75-85% HRmax -Balance training with virtual reality	-Static or dynamic balance activities, including pre-gait -Body-weight support treadmill training with emphasis on kinematics -Robot-assisted gait training

45

EMERGING RESEARCH

- High-intensity interval training (HIIT) resulted in improved six-minute walk test distances as compared to moderate-intensity continuous training
  - HIIT protocol:
    - Repeated 30-second bursts of walking at maximum safe speed, alternated with 30- to 60-second rest periods, targeting a mean aerobic intensity above 60% of the heart rate reserve (HRR)
  - Moderate-intensity protocol:
    - Continuous walking with speed adjusted to maintain an initial target of 40% of the HRR, progressing up to 60% of the HRR as tolerated

(Boyne et al., 2023)

46

ADDITIONAL BENEFITS

47

CARDIOVASCULAR HEALTH

- Billinger et al., 2012
  - Individuals with subacute stroke participated in aerobic exercise on recumbent stepper at 40-69% of heart rate reserve for 3 times/week for 8 weeks
  - Improved cardiovascular health, reducing cardiac risk, and improving physical performance
- Luo et al., 2019
  - Systematic review of 17 studies
  - High-intensity exercise beneficial for cardiorespiratory fitness after stroke

48

REDUCTION OF SECONDARY EVENTS

- Individuals with stroke should participate in aerobic exercise
- Reduced sedentarism and improved cardiovascular health can be a component of risk management for prevention of additional strokes

(Billinger et al., 2014)

49

MOOD

- Individuals with chronic TBI (>6 months post injury) participated in 12 weeks of aerobic exercise, 3 times/week, 30 minutes each session
  - Exercised at 70-80% of heart rate reserve
- Improved scores on Profile of Mood States–Short Form, indicating improved overall mood

(Weinstein et al., 2017)

50

FUNCTIONAL OUTCOMES

- Systematic review of a total of 6 randomized controlled trials, 1 quasi-randomized trial, and 4 controlled trials
- Revealed consistent evidence for a beneficial effect of early onset neurorehabilitation in the trauma center and intensive neurorehabilitation in the rehabilitation facility on functional outcomes compared with usual care
- Remaining questions of optimal timing and intensity due to variable definitions of intensity in studies

(Königs et al., 2018)

51

FUNCTIONAL OUTCOMES

- HIGT for individual with anoxic brain injury
  - Treadmill training and overground training were performed for a maximum of 30 minutes per session throughout ten days of inpatient rehabilitation
  - Heart rate was monitored via continuous pulse oximetry with a goal of reaching 70-80% of the individual's age-predicted maximal heart rate
  - HIGT was achieved by varying speed, increasing incline, and incorporating forward, backward, and lateral stepping
- Results:
  - Progression from non-ambulatory to household ambulation with assistance achieved at discharge
  - Improvement in 10-meter walk test

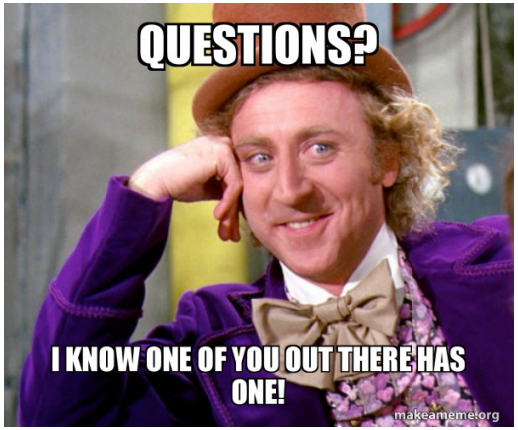
(Gadelha and Voigtmann, 2021)

52

OPPORTUNITIES

- As more research comes out on intense gait training for recovery of walking after neurologic injury, we need to figure out optimal dosing/timing
- More research needed for traumatic brain injury population

53



54