New Approaches to Gait Rehabilitation After Stroke

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USF Health

Objectives

- Identify gait impairments following stroke
- Describe current gait training methods for people with stroke.
- Differentiate an error augmentation approach from an error reduction approach.
- Discuss gait training approaches that destabilize the non-paretic leg.
- Implement the use of destabilizing the non-paretic leg in clinical practice.

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Outline

I. Gait impairments following stroke
II. Gait training approaches: error reduction vs. error augmentation
III. New overground gait training approach
IV. Discussion

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Gait Impairments Following Stroke

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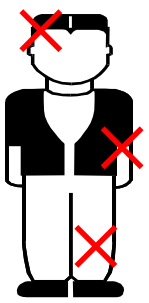
Stroke



- A brain lesion caused by an interruption of blood flow to part of the brain
- A leading cause of serious disability in the elderly
- 40% of survivors having moderate functional impairments and 15~30 % severely disabled (American Heart Association, 2015)

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Walking Ability After Stroke

- Decreased walking speed (Bohannon et al., 1987)
- Asymmetrical walking patterns (Kim et al., 2019)
- Increased the energy cost of walking (Gordon et al., 2004)
- Use of an assistive device

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Gait Asymmetry After Stroke

- Increased step length of the paretic side (Nascimento et al., 2015)
- Lengthened swing phase of the paretic side (Nascimento et al., 2015)
- Increased weight bearing on the non-paretic side (Kim et al., 2003)

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Gait Training Approaches

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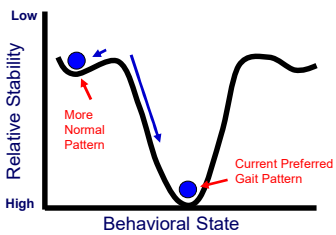
Gait Pattern after Stroke



- Facilitate motor learning by applying evidence regarding manipulation of practice and feedback.
- Perturb the current gait pattern to help the patient establish a new gait 'attractor'.

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Error Reduction Approach

- Traditional training approach
- Important for motor learning (Shadmehr et al., 2010)
- Assist-as-needed mechanism (Duschau-Wicke et at., 2010)
- Reducing subject's movement errors during training (Emken et al., 2007)

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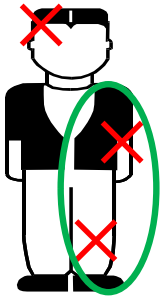
Current Gait Training

"Focusing on the paretic side"



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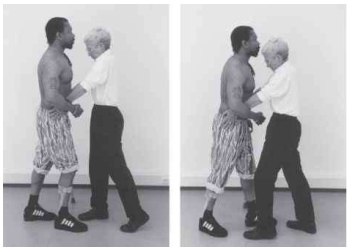
Conventional Gait Training

- Neurodevelopmental treatment (NDT), proprioceptive neuromuscular facilitation PNF), etc.
- Minimizing abnormal movements and facilitating normal patterns in the paretic side



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Body Weight Supported Treadmill Training

- Holding and moving the patient's leg along a gait-like trajectory
- Labor intensive
- Not superior to conventional physical therapy (Moseley et al. 2005)
- Limited carryover effects

Human Locomotion Research Center, UCLA

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Robot-Assisted Gait Training

- High repetition accuracy
- Prolonged training duration
- Computerized feedback
- However, the benefits of robotic training over conventional gait training are limited (Husemann et al., 2007, Hidler et al., 2009).

Neuro-Locomotion Lab, Chicago

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Robot-Assisted Gait Training

- Most existing applications of robotics to gait retraining move the patient's limb *passively* through a range of motion during training.
- This approach does not challenge the patient's error-correction mechanisms.

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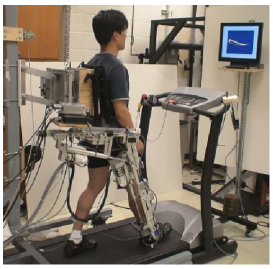
Active Leg Exoskeleton (ALEX)



- Active motors control knee and hip motion.
- Ankle is free to move in sagittal plane.
- Degrees of freedom at pelvis and trunk allow for side to side motion and rotation.
- Feedbacks

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Active Leg Exoskeleton (ALEX)

- *Constrains* the person's limb movement, i.e., preventing excessive deviation from desired foot path
- Requires *active control* of limb movement, using visual guidance, the patient must correct his pattern towards a more normal pattern.
- Leg is not forced to adopt a fixed trajectory.
- Desired foot path is gradually morphed towards a more normal pattern

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ALEX: Feasibility Study

- Participants: 39 healthy young adults (20-33 years old)
  - Group 1 (n=13): force-field constraints + visual guidance (FFC+VG)
  - Group 2 (n=13): force-field constraints alone (FFC)
  - Group 3 (n=13): visual guidance alone (VG)
- Training: Six blocks of 10-min gait training

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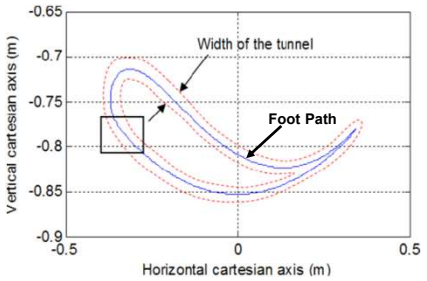
Force-Field Constraints



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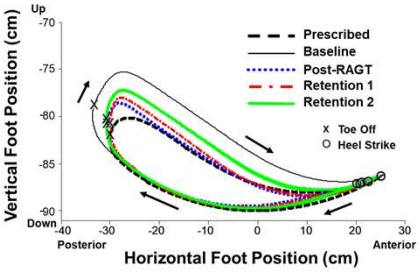
Adaptation of Foot Path



Kim et al, 2010

RAGT=robot-assisted gait training

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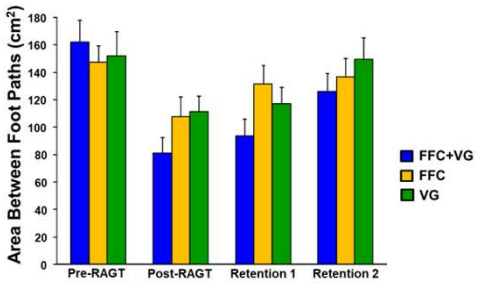
Adaptation of Foot Path



RAGT=robot-assisted gait training

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ALEX: Stroke Study

Subjects' Characteristics

Participants	Subject #1	Subject #2	Subject #3
Age at Training (year)	72	47	78
Years Post-stroke (year)	3.5	3.2	2.5
Gender	Male	Male	Male
Lesion	Left MCA	Left MCA	Left MCA
Height (cm)	187	180	173
Weight (kg)	97.1	79.4	72.6
Mini-Mental Status Exam	27/30	23/30	27/30
Berg's Balance Scale	49/56	54/56	46/56

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ALEX: Stroke Training

- All participants underwent 15 days of gait retraining spread over 5 weeks involving:
  - Total of 40 min/day of training, in 5-min blocks.
  - Intermittent visual guidance of foot path
  - Summary feedback after each 5-min block of training
  - Force-field constraints of foot trajectory

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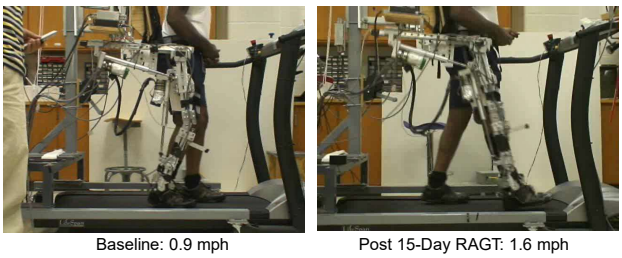
ALEX: Stroke Training



Baseline: 0.9 mph | Post 15-Day RAGT: 1.6 mph

Subject #1

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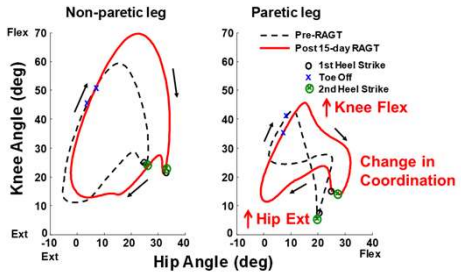
Adaptation of Foot Path



Subject #1

RAGT=robot-assisted gait training

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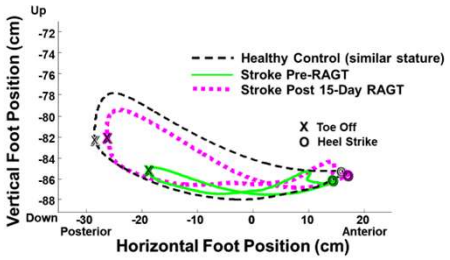
Adaptation of Foot Path



Subject #1

RAGT=robot-assisted gait training

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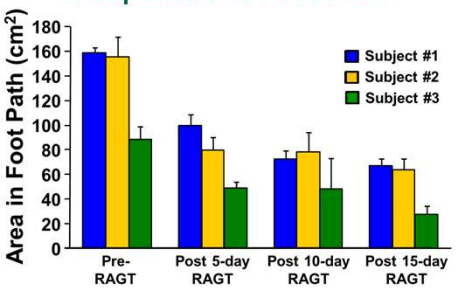
Adaptation of Foot Path



RAGT=robot-assisted gait training

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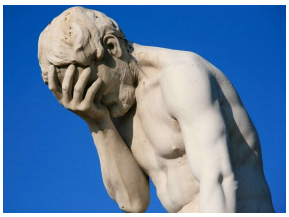
Are Errors Bad?

"A person who makes few mistakes makes little progress." - Bryant McGill



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Error Augmentation Approach

- Opposite to traditional training approach
- Augmenting patient's movement errors during training (Domingo et al., 2010)
- Enhancing functional recovery in people with neurological disorders (Patton et al., 2006)

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Error Augmentation Approach

- Encouraging active participation and physical effort
- Preserving movement variability
- Allowing individuals to discover optimal movement patterns

(Kao et al., 2015)

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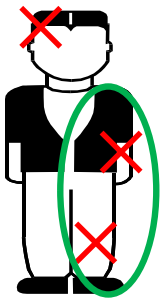
New Training Approaches

"Utilizing the non-paretic side"



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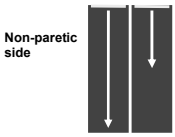
Split-belt Treadmill Training



- Destabilizing the non-paretic side
- Augmenting patient's movement errors
- Producing after-effects with correct gait

Bertec split-belt treadmill

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Split-belt Treadmill Training

UD split-belt treadmill training

- Improved symmetrical walking, especially spatial variables
- Limited carryover effects to overground walking

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Why Limited Carryover Effects?

- Conflicting sensory experiences between the treadmill training environment and the overground environment.
- The perceptual change → the new environment is not the same as that in which the patient was trained.

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What If?

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New Overground Gait Training Approach

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iStride™

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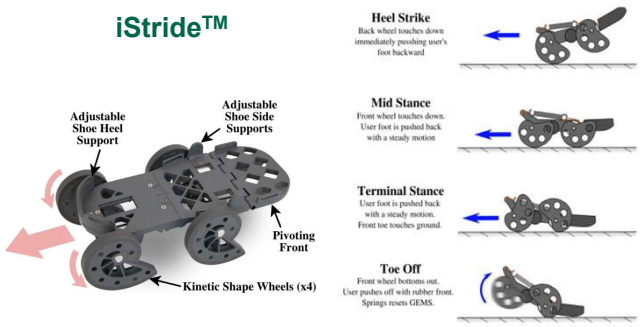
iStride™



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iStride™

- Mimicking the effects of the split-belt treadmill while walking overground
- Alleviating the dynamic and psychological differences of walking on a treadmill
- Increasing the transfer of the new walking pattern from treadmill to overground walking.

Dr. Kyle Reed at USF

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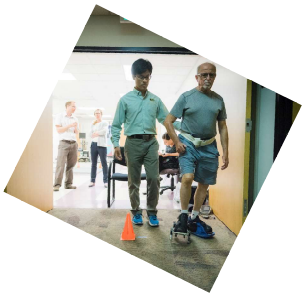
iStride™: Feasibility Study



- Purpose: To assess if the iStride™ can improve walking patterns in individuals with stroke
- Subjects: 6 patients with chronic stroke

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Assessments and Training

- Assessments: Overground walking using ProtoKinetics Zeno Walkway, 6 Minute Walk Test (6MWT), Timed Up & Go Test (TUG)
- Training: 4 weeks training, 3 sessions per week, 30 minutes each

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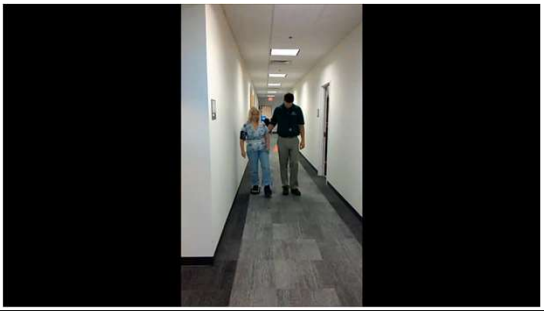
iStride™ Training



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iStride™

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Baseline

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Posttest

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Follow-up

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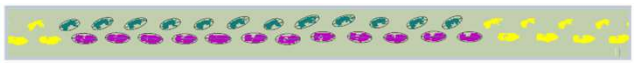
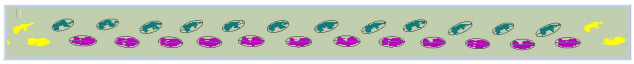
iStride™ Results

Baseline (24 steps)



Posttest (24 steps)



Follow-up test (24 steps)

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iStride™ Results

- Noticeable increase in gait velocity
- Improvements in step length and double limb support symmetry after training
- Improvements in 6-Minute Walk Test, and Timed Up & Go Test

Kim et al., 2019

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iStride™: Home-Based Training

- Purpose: To assess if the iStride™ device can be safely utilized in the home environment.
- Subjects: 21 patients with chronic stroke

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Assessments and Training

- Assessments: 10 Minute Walk Test, Functional Gait Assessment, Timed Up & Go Test, Berg Balance Scale
- Training: 4 weeks training, 3 sessions per week, 30 minutes each

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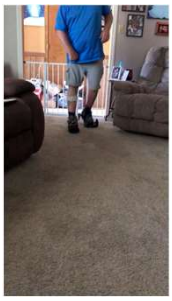
Home-Based Training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Before and After Training


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Home-Based Training: Results

Table 3. Statistical Analysis of Five Outcome Measures.

Outcome Measure		Mean	SD	SE	T	p-value
10MWT (m/s)	Baseline	0.551	0.245	0.053	T (20)	
Small Meaningful Change = 0.06[35]	1 Wk Post	0.820	0.313	0.068		
MCID = 0.16[38]	Difference	0.269			7.450	0.0001
TUG (seconds)	Baseline	19.20	8.06	1.76	T (20)	
MDC = −3.5[37]	1 Wk Post	14.39	5.74	1.25		
	Difference	−4.81			−6.428	0.0001
BBS (points)	Baseline	43.52	6.41	1.40	T (20)	
MDC = 2.5[37,38]	1 Wk Post	47.43	4.82	1.05		
	Difference	3.91			3.790	0.001
FGA (points)	Baseline	15.00	4.89	1.07	T (20)	
MDC = 4.2, 14.1%[39]	1 Wk Post	19.43	4.56	0.99		
	Difference	4.43			5.727	0.0001
	Difference (%)	37.8			4.487	0.0002
SS-QOL (points)	Baseline	165.05	23.84	5.47	T (18)	
N/A	1 Wk Post	181.58	25.29	5.80		
	Difference	16.53			3.027	0.007
	Difference (%)	11.1			3.150	0.006

Abbreviations: 10MWT, Ten-Meter Walk Test; m/s, meters per second; TUG, Timed Up and Go Test; BBS, Berg Balance Scale; FGA, Functional Gait Assessment; SS-QOL, Stroke Specific Quality of Life Scale; MCID, minimal clinically important difference; MDC, minimal detectable change; 1 Wk Post, one-week post-treatment; N/A, not applicable

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Discussion

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Effectiveness of iStride™

- A new overground gait training approach is effective in improving walking ability in people with stroke.
- A wearable device that destabilizes the non-paretic leg improves gait symmetry and functional walking following stroke.
- The iStride™ device can be safely used in the home environment.

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Clinical Relevance

- Then, how can we mimic this approach (e.g., destabilizing the non-paretic leg) during training?
- Be creative!!!

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Future Research

- Compare iStride™ training with conventional gait training or split-belt treadmill training
- Combine with sensory cues (e.g., auditory rhythms)
- Develop an individualized iStride™ device

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Research Team

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Questions?

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Thank you!

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