Exoskeletons in the Rehabilitation Arena

Susan Golden, P.T.
Frank Hyland, M.S., P.T.

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The material in this presentation is for general clinical knowledge, and it is not considered treatment recommendations for specific patients.
Objectives

1. State the purpose of the use of the EKSO

2. Differentiate the inclusion and exclusion criteria for the EKSO
Clinical Application of Exoskeletons

Primary Users

- Spinal Cord Injury
- Stroke
SCI Statistics

- Currently, there are approximately 265,000 Americans with SCI with 12,000 new injuries annually

- Of these, about 100,000 individuals with paraplegia
Stroke Statistics

• Currently, there are approximately 7,000,000 Americans who have had a stroke.

• 795,000 Americans sustain strokes annually.

• 600,000 new strokes annually
  195,000 are recurrent attacks
  140,000 deaths
Consequences of Paralysis

- Loss of function / motor control
- Inability to walk
- Muscle atrophy
- Respiratory impact
- Loss of bowel / bladder control
- Skin breakdown
- Bone demineralization, fractures
- Deep vein thrombosis
- Weight gain
- Psychological and economic impact
Rehabilitation Principles

• Surveys show that the ability to walk and stand are the most desired goals for individuals with paralysis

• Heightened research to restore walking capabilities for those with paralysis

• Focus today is on maximizing individual’s functional recovery
Rehabilitation Principles

• For the past 75 years, compensation for loss of function was the primary focus of rehabilitation

• The brain and spinal cord were thought to be unresponsive to change and incapable of recovery

• However, research has shown that the brain and spinal cord are indeed plastic and can develop new neuronal interconnections so that new functions can be acquired and restored (Neuroplasticity)
Neuroplasticity: Shown by Functional MRI

Tissue damaged by stroke -
Results in loss of motor function

Alternative Pathway -
Other areas of the brain assume some function for the damaged area
Rehabilitation Principles

• Today rehabilitation protocols are being based on motor learning to induce neural plasticity

• Evidence shows that training should be:
  - Task specific
  - Meaningful and challenging
  - Repetitive and intensive
  - Performed in a relatively normal biomechanical position
Rehabilitation Strategies

• Constraint Induced Movement Therapy (CIMT)

• Body Weight Support Treadmill Training (BWSTT)

• Exoskeleton Training
Constraint Induced Movement Therapy (CIMT)

• Stroke strategy that forces paretic limb to be used to perform functional activities while the non paretic limb is restrained

• Skill acquisition with the paretic limb has been shown to be enhanced with CIMT and evidence of neural plasticity via neuroimaging studies

• Results just as encouraging for lower extremity and gait carry over as upper extremity function
Body Weight Support
Treadmill Training (BWSTT)

• Combines treadmill training with body weight support

• Allows patients to walk in a repetitive, symmetrical manner – enables patients to avoid compensatory walking habits
Body Weight Support Treadmill Training (BWSTT)

• Has a lasting effect specifically on short-step gait in Parkinson's Disease (Miyai, et. al.)

• Substantial improvements in walking and transfers patients s/p BI (Hoyer, et. al.)

• Individuals with chronic stroke improved gait outcomes with BWSTT (Sousa, et. al.)
Body Weight Support Treadmill Training (BWSTT)

- Can be labor intensive

- Recent study (post stroke) has shown that BWSTT may not be superior to home based physical therapy and incidence of falls were greater (Duncan, et. al.)

- Balance training needs to be incorporated
Exoskeleton Training

• Recent advances in robotic technology have led to emergence of lower limb exoskeletons

• Provide legged mobility to individuals with lower extremity paralysis

• Exoskeletons facilitate over ground walking in a reciprocating, relatively normal biomechanical position
Exoskeleton Training

• May provide locomotor training advantages, such as balance recovery, hip extension position and loading

• BWSTT has received significant research attention; exoskeleton studies are emerging

• Studies needed to determine:
  - Optimal dosage
  - Gait performance outcomes
  - Durability of outcomes
  - Impact of other therapeutic treatments
  - Motor changes / muscle mass
  - Bone density changes
Exoskeleton Training (Ekso™)

Ekso
- non tethered,
- reciprocating,
- Powered LE orthosis
Exoskeleton Training (Ekso™)

- Enables individuals with lower extremity paralysis to stand and walk over ground with a weight bearing, four point reciprocal gait

- Walking is achieved by the user’s forward lateral weight shift to initiate a step

- Battery-powered hip and knee motors drive the legs and replace neuromuscular function

- Applied over user’s clothing. Weighs about 50 pounds (23kg)
Ekso™ Inclusion Criteria

• Lower extremity paralysis/weakness

• 220 pound weight limit

• 5’ 2” – 6’ 2” height restriction

• Sufficient upper extremity strength to manage crutches or walker
Ekso™ Exclusion Criteria

- Significant contractures
- Heterotopic ossification that limits joint ROM
- Unhealed spine/extremity fractures
- Open lower extremity wounds
Good Shepherd Rehabilitation Preliminary Experience

• 54 users received training with Ekso

• All users have been able to transfer to stand and return to sit independently

• All users have been able to walk independently with either lofstrand crutches or a walker

• Ambulation distances have ranged from 300 to 3000 feet

• No falls; no adverse skin reaction

• Do not view it as an end product
Good Shepherd Rehabilitation
Preliminary Experience

Very High User Satisfaction Level
Physiological Benefits

- Studies have shown an increase in VO2
- Increased proprioception/body awareness in space and balance
- Bowel / bladder function improvement
- Fewer urinary tract infections
- Fewer illnesses
- Less tone noted in their legs
- Unanswered question - Will the use of exoskeletons improve bone density?
Psychological Benefits

• “Hope for the Future”
• Being given another chance
• Lead a healthier lifestyle
• Follow through with skin care and stretching
• Camaraderie in the clinic and outside of the organization
• Courage to try new activities, to become involved in their community again
• Case reports
Case Study

- 46-year-old male

- 2001 – patient sustained a T12 ASIA A injury
  - Multiple vertebral fractures T11-L5
  - Left scapular fracture
  - Underwent internal fixation T9-T10 extending to L1-2
  - Spent 18 days in inpatient rehabilitation

- Discharge status:
  - Independent in ADLs
  - CS for sit pivot transfers
  - Independent wheelchair propulsion
  - Sensation - absent along T12 Dermatome
  - U/E strength - 5/5
  - L/E strength - 0/5 except for trace hip flexors bilaterally
Case Study

• **For 10 Years Following Injury:**
  - Continued periodically in OP therapy concentrating on ROM to L/E’s and trunk and attempted walking with long leg braces

• **August 2011:**
  - Returned to OP therapy
  - Evaluation revealed: tightness of both legs at hips, knees and ankles
  - L/E strength remained at trace iliopsoas bilaterally
  - L/E strength remained at 0/5
  - Initiated intensive program of L/E stretching of trunk, pelvis in order to be fitted for Stance Control KAFOs
  - Began working out regularly at the gym, participated in aquatic therapy 2-3x/week
Case Study

• September, 2012

  – Began gait training with Stance Control KAFOs requiring moderate cueing for weight shifting and midline orientation

  – In 6 months, reached a cg level with his braces, but still requiring cues for midline and weight shifting.
    • Hip flex and extension increased to ¼ gravity eliminated position
Case Study

- **March 2012:**
  - Began using EKSO 3x/week

- **June 2013:**
  - Gains with increased proprioception/ body awareness, L/E ROM WNL, strength changes:

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<tr>
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<tr>
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- **Sensory changes:** patient reports that he now feels deep pressure in buttocks area for first time
Case Study

• Current functional status:

- Currently walking 3000 feet with loftstrand crutches with EKSO on level surfaces and ramps, where he controls all his stepping motion on his own with close supervision.

- He can stand and walk with loftstrand crutches using stance control KAFOs with cg on level surfaces 200 ft and manage ramps with contact guarding.
Ekso With Variable Assist

• **Who?**
  - Patients who have had a stroke or other neurological condition
  - Same criteria as earlier versions of Ekso

• **What?**
  - Software upgrade

• **How?**
  - Therapists control power contribution and parameters
  - Patient feedback
Benefits for Inpatients

- On their feet sooner
- Prevent compensatory strategies
- See progress faster
Future of Exoskeletons for Rehabilitation (if used as an orthotic)

- Lighter, portable, sleeker
- Will be able to get in and out of car with device on
- Be able to navigate ramps, curbs, stairs, uneven terrain
- Home custom model
- Lower cost
Future of Exoskeletons for Rehabilitation
(if used as an orthotic)

- Be able to don and doff and wear all day long
- Stand and sit to any surface
- Be able to step backwards, sideways
- Flexible ankle
- Be able to travel by airplane - access airplane and sit in seat with device on
- Will change how rehab is performed with people with neuromuscular disorders or limb amputations
Future of Exoskeletons for Rehabilitation  
(As a powerful rehabilitation tool))

- Flexible ankle
- Be able to navigate ramps, curbs, stairs, uneven terrain and easily change directions
- Easily adjustable for larger persons and children
Conclusion

• This will open doors for many people to lead fuller lives, have environmental access to so much more.

• Patients will be able to be “mainstreamed” back into the community.

• Many more people with different diagnoses will be able to benefit from exoskeletons.

• (MS, ALS, etc) to lead fuller lives for a longer period of time.
“Long-term effect of body weight-supported treadmill training in Parkinson's disease: a randomized controlled trial”
Miyai I, Fujimoto Y, Yamamoto H, Ueda Y, Saito T, Nozaki S, Kang J.

“Body weight supported treadmill training versus traditional training in patients dependent on walking assistance after stroke: a randomized controlled trial”
Høyer E, Jahnsen R, Stanghelle JK, Strand LI.

“Gait training with partial body weight support during overground walking for individuals with chronic stroke: a pilot study”
Journal of Neuro Engineering and Rehabilitation. 2011 Aug 24; 8:48
Catarina O Sousa, José A Barela, Christiane L Prado-Medeiros, Tania F Salvini and Ana MF Barela

“Body-Weight–Supported Treadmill Rehabilitation after Stroke”
Pamela W. Duncan, P.T., Ph.D., Katherine J. Sullivan, P.T., Ph.D., Andrea L. Behrman, P.T., Ph.D., Stanley P. Azen, Ph.D., Samuel S. Wu, Ph.D., Stephen E. Nadeau, M.D., Bruce H. Dobkin, M.D., Dorian K. Rose, P.T., Ph.D., Julie K. Tilson, D.P.T., Steven Cen, Ph.D., and Sarah K. Hayden, B.S.
Reference List

“Neuroplasticity after Spinal Cord Injury and Training: An Emerging Paradigm Shift in Rehabilitation and Walking Recovery”
Andrea L Behrman, Mark G Bowden, and Preeti Nair.

“Towards more effective robotic gait training for stroke rehabilitation: a review”
Journal of Neuro Engineering and Rehabilitation. 2012 Sept 1; 1 – 13
Andrew Pennycott, Dario Wyss, Heike Vallery, Verena Klamroth-Marganska and Robert Riener

“Rehabilitation with Post Stroke Motor Recovery: A Review with a Focus on Neural Plasticity”
Stroke Research and Treatment Volume 2013, Article ID 128641
Naoyuki Takeuchi and Shin-Ichi Izumi
Exoskeleton Resources


- **Ekso Rehab** at Good Shepherd  
  [http://goodshepherdrehab.org/ekso](http://goodshepherdrehab.org/ekso)

- **Good Shepherd** Ekso with Variable Assist:  
  [http://goodshepherdrehab.org/ekso](http://goodshepherdrehab.org/ekso)

- **Time** – The 50 Best Inventions of 2010-  
  [http://content.time.com/time/specials/packages/article/0,28804,2029497_2030618_2029794,00.html](http://content.time.com/time/specials/packages/article/0,28804,2029497_2030618_2029794,00.html)
Post Test

• Which of the following conditions would not be appropriate for using an exoskeleton in physical therapy?
  1. Paraplegics
  2. Unilateral patients post-stroke
  3. Quadriplegics with no upper-body strength
  4. Multiple sclerosis (with minimal spasticity)

• What is a limiting factor for ability to use the exoskeleton in physical therapy?
  1. -50° of hip extension
  2. Able to transfer with ☐
  3. Good upper body strength
  4. Height <74" and weight <220 lbs