Rehabilitation after spinal cord injury

Based on:
- Expectations regarding functional outcomes predicted by the initial level of injury and severity of impairment
- Compensation for loss of function as a key strategy
- Development of a new repertoire of movement strategies and/or use assistive devices to accomplish daily tasks

If functional recovery is going to be possible in the future, we need to:
- Maintain target systems below the level of injury
- Maintain optimum health and fitness

The nervous system... has a body!

Image from Thibodeau & Patton (eds) Anatomy & Physiology, 3rd ed. 1996
Experience and the developing and mature nervous system

- **Experience-expectant processes:**
  - Shape developing sensory and motor systems
  - Involve a selection process in which aspects of sensorimotor experience determine the pattern of connections that remains

- **Experience-dependent processes:**
  - Incorporation of environmental information that is idiosyncratic, or unique to the individual
  - Involve active formation of new synaptic connections in response to experience

Greenough et al., Child Dev 1987; 58:539-59

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SCI: an extreme example of forced inactivity

- Immediate and severe loss of sensory and motor function
- Muscle atrophy
- Poor circulation
- Disruption of calcium and phosphate metabolism: loss of bone
- Immunosuppression: vulnerability to infections
- Exacerbation of neurological dysfunction due to inactivity
- Significant secondary complications: pressure ulcers and fractures
- Metabolic profile similar to that of premature aging

Lin et al., Brain 2007; 130:985-995

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Deterioration of nervous system function below the level of injury

- High threshold of motor axons
- Some axons inexcitable
- Stimulus-response curves shifted to the right
- Decreased amplitude of compound action potentials

Lin et al., Brain 2007; 130:985-995
Changes in spinal reflex responses after SCI

Hubli et al., Spinal Cord 2011; 49:582-587

Peripheral processes

Muscles and muscle receptors
Somatosensory inputs

Endo et al., Exp Neurol 2008; 209: 155–160

Age-related changes in neuromuscular junction

Valdez et al., PNAS 2010; 107: 14863–14868

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Cortical bone loss

- Accelerated bone loss due to increased resorption and reduced formation
- Intracortical remodeling produces porosity (thinning from ‘inside’)
- Cortical bone loss important for bone strength
- Optimal method of measuring bone strength not yet determined

Image courtesy of Ali Ghasem-Zadeh & Ego Seeman, Austin Health

Muscle atrophy and intramuscular fat accumulation post-SCI

Healthy

6 weeks post-SCI

Gogey & Dudley, Spinal Cord 2007; 45: 304-309

Disorders of hormonal and lipid metabolism

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>Leptin (ng/mL)</th>
<th>Plasma Insulin (μU/mL)</th>
<th>Plasma glucose (mg/dL)</th>
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<td>SCI Controls</td>
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Huang et al., Arch Phys Med Rehabil 2000; 81: 1582-6; Bauman & Spungen, Metabolism 1994; 43: 749-756

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Effects of exercise

The Neurobiology of Exercise

- Cognate Controls
- Executive Controls
- Motor Controls
- Sensory and Neurotransmission

CNS

- Learning & Memory
- Sleep

- Nutrition
- Stress

- Depression
- Schizophrenia

Muscle

- Myosin heavy chain (MHC) isoform changes in muscles with FES Exercise

Duration (months)

IL-6


Exercise and muscle

- Pre-training
- After 6 months FES cycling

Image courtesy of Prisca Eser


- Andersen et al., Pflügers Arch 1996; 431:513–518


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Muscle activation with locomotor training


Stimulation for peripheral nerve regeneration

- Al-Majed et al., J Neurosci 2000; 20:2602–2608
- Electrical stimulation dramatically reduces the time taken to full regeneration

Electrical stimulation for cauda equina injury

Time of commencing stimulation post-injury

- 5.4 yrs
- 3.2 yrs
- 1.7 yrs
- 1.2 yrs
- 0.8 yrs

Kern et al., Neurorehabil Neural Repair 2010; 24:709-721
Tenodesis grip

- A compensatory strategy for loss of grasp
- Effectiveness is determined by the passive properties of the hand
- Involves decrease in the resting length (i.e. adaptive shortening) of the long finger flexors
- Adaptive shortening of the flexor pollicis longus so thumb approximates the flexed fingers

Can hand function be restored?

Evaluation: brain motor control assessment

Kowalczewski et al., Neurorehabil Neural Repair 2011; 25:412-22; Harvey et al., Trials 2011; 12:14
Requirements for clinical trials of effectiveness

- Core set of measurement tools
  - ICF Core Sets provide list of areas of function that should be measured
- Classification of injury
  - International Standards for Neurological Classification of Spinal Cord Injury
- Neurophysiological measures
  - Brain Motor Control Assessment
  - Electrical perceptual sensory thresholds
- Classification of rehabilitation interventions
  - SCI-Intervention Classification System

Comparative effectiveness research in SCI

- Advantages:
  - Generalizability
  - Investigation of actual care provided
  - Longitudinal studies
  - Measure multiple outcomes concurrently

Re-assessing the goals of rehabilitation

- Restoration of function will not be possible without preservation of target systems below the level of injury
- Issues for further investigation:
  - Neurophysiological investigations to assess neural health
  - Measurement and classification of interventions
  - Optimal dosage of exercise programs
  - Provision of affordable exercise programs
  - Better measures of health risk in SCI (fracture risk, diabetes, cardiovascular disease)
  - How early should intervention be provided?
  - Research designs to assess the effectiveness of interventions