Disclosures

We have no conflicts of interest or financial disclosures

Although some of this content overlaps with the UBC MDUP Yr 1 curriculum, this presentation is entirely supplementary to the curricular material and no exam questions will be generated from this presentation

We are not experts in this field. This presentation is intended to provide a brief overview of the physical activity recommendations and considerations for persons with SCI
Objectives

1. Briefly overview the epidemiology and etiology of spinal cord injury (SCI)

2. Overview of the nervous system and terms used to describe SCI

3. Discuss some of the health related consequences for persons with SCI

4. Discuss the use of physical activity in SCI

5. Discuss the current physical activity recommendations for persons with SCI

6. Discuss the special considerations and risks of physical activity for persons with SCI

7. Exercise referral and resources for more information
“It’s not our disabilities, it’s our abilities that count.”

CHRIS BURKE
There is no greater disability in society, than the inability to see a person as more." — Robert M. Hensel
Epidemiology and Etiology of Spinal Cord Injury (SCI)

**SCI Prevalence in Canada** (McMaster University, 2011)

~86,000 individuals with SCI  
~44,000 resulted from **traumatic** cause
Organization of the Nervous System

Central Nervous System
- Brain
- Spinal cord

Peripheral Nervous System
- Nerve

Spinal Levels
- Cervical (C1-4)
- Thoracic (T1-L2)
- Lumbar (L1-S1)
- Sacral (S1-5)
- Coccygeal (C5-G10)
- Foot motion (S1-5)
- Ankle and toe movement (S1-5)
- Knee extension (L5)
- Lower and gluteal area movement (S1-5)

(a) (b)
Functions of the Spinal Cord

**Motor**
- Muscle function, tone and bulk

**Sensory**
- Touch, pain, temperature, vibration, proprioception

**Autonomic**
- Parasympathetic & Sympathetic
SCI is COMPLEX and so is the Nervous System!

Myotomes

Spinal Levels

Hierarchical organization

Myotomes:
- Tracts
- Dermatomes
- Cross-sections, tracts, white matter, gray matter

Spinal Levels:
- Tracts
- Dermatomes

Hierarchical organization:
- Autonomic vs. Somatic
- Cross-sections, tracts, white matter, gray matter
Questions to consider in SCI

- What level is the lesion?
- How severe is the lesion?
What level is the lesion?

Tetraplegia (Quadriplegia):

“impairment or loss of motor and/or sensory function in the **cervical segments** of the spinal cord”

Paraplegia:

“impairment or loss of motor and/or sensory function in the **thoracic, lumbar or sacral (but not cervical)** segments of the spinal cord.”

= OVERSIMPLIFICATION
What is the level of the lesion?

Motor Level (Myotome)
Normal level of muscle function, tone and bulk

Sensory Level (Dermatome)
Normal level of touch, pain, temperature, vibration, proprioception
Autonomic Level

Parasympathetic

- CNs III, VII, IX, X
- S2-S4

VS.

Sympathetic

- T1-L2

Life Threatening: Neurogenic Shock
Clinical findings: Where is the lesion in the CNS?

- **UMN signs**: Hyperreflexia, hypertonia, mild weakness, grossly normal muscle bulk, rigidity, Babinski sign, pronator drift

- **LMN signs**: hyporeflexia/areflexia, hypotonia, severe weakness, muscle atrophy, absent Babinski’s sign
Where is the Lesion within the Spinal Cord?

Complete SCIs present as LMN lesions at the spinal level of the injury, and as UMN lesions below the level of the injury.
Major Considerations in SCI

Motor level

Sensory level

Autonomic function
- Parasympathetic (S2-S4)
- Sympathetic (T1-L2)
Health Considerations Beyond Paralysis

1. Physical deconditioning
2. Musculoskeletal changes
3. Autonomic dysregulation
4. Cardiovascular dysfunction
5. Impaired thermoregulation
6. Burden of chronic disease
7. Depression and anxiety
SCI can lead to a profoundly sedentary lifestyle:

- Physical factors (muscle paralysis, loss of function)
- Psychological factors (depression, anxiety, decreased interest in PA)

Consequences of chronic sedentary behavior:

- Decreased fitness, longevity, and quality of life
- Increased incidence and severity of chronic diseases.

Does physical activity counteract the effects of sedentary behavior?

- Yes, but it takes work!

A 2016 meta-analysis (pooled n > 1 million) concluded that the detrimental effects of being sedentary for more than 8 hours per day (most of us!) was only negated by engaging in physical activity at a level of 35.5 MET-hours per week or more.

At least 1 hour of moderate to vigorous physical activity per day!

Exercise is medicine, for everyone.
SCI alters the musculoskeletal system

Skeletal muscle below the lesion → **atrophy**
- LMN vs. UMN lesion
- Early rehabilitation and physiotherapy is important!

**Spasticity and contractures**
- Hyperreflexic muscles can cause contractures → can impair function and mobility
- Stretching and range of motion very important!

Bone resorption and loss of bone density → **osteopenia and osteoporosis**.
- Risk of fracture
SCI can result in **sympathetic** ANS dysregulation

Recall: UMN lesions cause hyperreflexia, while LMN lesions cause areflexia. This applies to autonomic neurons as well!

**Tetraplegia** → loss of central command over all sympathetic nervous system functions.
- Blunted heart rate response to exercise
- Blunted or absent catecholamine response
- Lack of sweating response below the level of the lesion

**Paraplegia** → partial loss of sympathetic function
- Reduced catecholamine, vasomotor, and sweating responses to exercise.

**Autonomic hyperreflexia**
- Complete lesions above T6 = lack of control over sympathetic input to adrenal medulla.
- Noxious stimuli can result in sympathetic overactivation
- Can be life-threatening
SCI can result in **parasympathetic** ANS dysregulation

Recall: UMN lesions cause hyperreflexia, while LMN lesions cause areflexia. This applies to autonomic neurons as well!

**Neurogenic bladder dysfunction**
- Incontinence, urinary retention

**Neurogenic bowel dysfunction**
- Dysmotility, constipation, incontinence
SCI causes alterations in the arterial vasculature

Autonomic dysregulation: hypotension and orthostatic drop contribute to difficulty exercising, falls.

People with spinal cord injury have a high risk of atherosclerotic cardiovascular disease (CVD).

- CVD is now the most frequent cause of death in individuals with paraplegia, accounting for 46% of deaths in individuals over 30 years of age.
- Traditional risk factors, including diabetes
- Chronic sedentary behavior
- Physical activity prevents and treats CVD!
SCI causes alterations in the venous vasculature

Venous return to the heart is aided by movement, and by sympathetic vеноconstriction.

In SCI, both of these mechanisms can be impaired.

- especially when chronically sedentary
- This causes pooling and slow velocity of blood in the legs (circulatory hypokinesis)

Result: Increased risk of venous thrombosis

- Clots from deep veins can detach and travel to the lungs, resulting in pulmonary embolism → potentially life-threatening

- Positional (orthostatic) hypotension after vigorous exercise due to lack of ability to return pooled venous blood.
SCI can cause changes in cardiac function and structure

**Tetraplegia**: Poor venous return + lack of sympathetic vascular tone → chronic state of hypotension and bradycardia.
- Pressure unloading results in *left ventricular atrophy*
- Limited ability to increase cardiac output via ↑ HR
- **Poor exercise tolerance is a large barrier to PA**
- Extensive warm-up helps! (sympathetic spinal reflexes)
- PA helps preserve heart muscle!

**Paraplegia**: Poor venous return, but some level of sympathetic tone → chronic state of normotension and tachycardia.

**Autonomic innervation of the heart**
- *Parasympathetic*: vagus nerve (CN X)
- *Sympathetic*: T1-T4 spinal levels
SCI can cause impaired thermoregulation

Lack of sublesional vasomotor responses → lack of blood flow redistribution to skin for heat loss
  ○ Result: insufficient heat loss via radiation, convection, +/- conduction.

Loss of sublesional sweating reflexes → lack of evaporative cooling
  *most important heat loss mechanism in exercise*

Result: Predisposition to developing hyperthermia (high core temperature) during exercise.
  ○ Worse with higher lesion levels and more complete lesions.
  ○ Worse in hot / humid environment.
  ○ Intensity of the activity
Increased Prevalence of Secondary Disease

People with SCI are at increased risk of suffering from:

- Cardiovascular disease
- Depression and anxiety
- Diabetes
- Thromboembolic disease
- Pressure ulcers
- Osteoporosis and risk of fracture
- Urogenital and bowel complications

Regular physical activity has a role in prevention and treatment.
Coping with functional loss after SCI

- SCI is a devastating, life-altering event
- Impacts physical, psychological, emotional, social, and spiritual well being
- Changed social roles, self-image, self-esteem/confidence
- Sense of loss of control over body, future
- The majority of people with SCI adapt and cope with these changes amazingly well
- However, not everyone: still a high prevalence of depression and suicidal ideation
- Physical activity contributes to sense of independence, ability, community, physical health.

© 2009 Centre for Applied Research in Mental Health and Addiction (CARMHA) and BC Mental Health & Addiction Services (BCMHAS)
The resilience of the human spirit will astound you
- Dr. Jennifer Yao, Physiatrist

...and, exercise is medicine...

How others see you, is not important. How you see yourself means everything.
Physical Activity:
Benefits and Recommendations

MOVE
Even if haven’t lately
MOVE
Even if it’s slow
MOVE
Even if you have to roll
MOVE
Even if it’s just an inch
MOVE
Even if it’s moving others
MOVE
More and more everyday.
Enhancing Function and Restoring Independence

- Key consideration post-SCI

- Involves an interdisciplinary and collaborative approach
  - Doctors, PTs, OTs, kinesiologists, family, family doctor, etc...

- Level and degree of lesion must be considered
Rehabilitation: Activity-Based Restorative Therapies

- Based on theory of neuroplasticity
- Repeated activation of pathways using task specific training and assistive devices
- Shown to improve functional mobility and decrease risk for CV and other metabolic diseases
- Expensive, accessibility issues
Why Use Physical Activity in SCI?

Improved strength, endurance, and energy (Hicks et al., 2011, Hetz et al., 2009; Wolfe et al., 2010)

Improved regulation of blood glucose (Wolfe et al., 2010; Buchholz et al., 2009)

Less spasticity and pain (Wolfe et al., 2010)

Decreased movement during sleep (Wolfe et al., 2010)

Better overall health and quality of life (Wolfe et al., 2010)

Reduced cholesterol and fats in your blood (Wolfe et al., 2010; Buchholz et al., 2009)

Improved regulation of blood glucose (Wolfe et al., 2010; Buchholz et al., 2009)

Lowered risk of depression and stress (Wolfe et al., 2010)
Types of PA
Physical activity terms

**FITT Principle** for physical activity:

- **Frequency** (number of days per week)
- **Intensity** (mild to moderate to vigorous)
- **Time** (duration of physical activity)
- **Type** (type of exercise; eg. swimming, leg cycling, arm cycling)

Canadian Physical Activity Guidelines
PA Recommendations (CSEP)

Canadian Physical Activity Guidelines

FOR ADULTS - 18 – 64 YEARS

Guidelines

To achieve health benefits, adults aged 18-64 years should accumulate at least 150 minutes of moderate- to vigorous-intensity aerobic physical activity per week, in bouts of 10 minutes or more.

It is also beneficial to add muscle and bone strengthening activities using major muscle groups, at least 2 days per week.

More physical activity provides greater health benefits.
Current physical activity recommendations for persons with SCI (2011)

- Similar to Canadian PA guidelines
  - Strength and aerobic PA considerations
  - FITT principle used

- More specific guidelines
  - Sets and reps indicated for strength training activities
Current physical activity recommendations for persons with SCI (SCI Action Canada, 2011)

- **Aerobic PA**
  - **Frequency:** 2x/week
  - **Intensity:** moderate to vigorous
  - **Time/amount:** gradually increase to 20 minutes of continuous PA
  - **Type:** upper body, lower body, whole body

- **Strength PA**
  - **Frequency:** 2x/week
  - **Intensity:** 8-10 reps max (safely finish this amount); rest 1-2 minutes between sets
  - **Time/amount:** 8-10 reps of each exercise; work up to 3 sets
  - **Type:** free weights, resistance bands, machines, functional electrical stimulation
Types of PA
Special Considerations: Wheelchair Sports
Special Considerations: Extreme Wheelchair Sport
"I think a hero is an ordinary individual who finds strength to persevere and endure in spite of overwhelming obstacles..."

- Christopher Reeve (1952-2004)
Special Considerations and Risks of Exercise after SCI (Nash, 2005)

1. Thermal Dysregulation

2. Musculoskeletal Injury
   a. Overuse
   b. Fracture

3. Adrenergic Dysregulation
   a. Pressor Decompensation (during and after exercise)
   b. Autonomic dysreflexia
Thermal Dysregulation (Nash, 2005)

● Causes:
  ○ Altered blood flow redistribution during exercise
  ○ Loss of sublesional vasomotor responses
  ○ Absence of sublesional sweating reflexes
    ■ Worse with higher lesions of injury

● Prevention strategies:
  ○ Exercise in temperate environment
  ○ Appropriate clothing, cooling vests, fans, mist spray bottles
  ○ Frequent monitoring for hydration and signs and symptoms of heat stress

Cooling Vest
Musculoskeletal Injury  (Nash, 2005)

Overuse injury

- **Cause:** use of upper body for locomotion
  - Most common site → shoulder/rotator cuff
    - Can lead to major impact on Activities of Daily Living
  - Decreased sublesional sensation

- **Prevention:**
  - Upper extremities: monitor for ROM, strength, balance and skill of locomotion
  - Especially in wheelchair sports
  - Lower extremities: monitor for spasticity, swelling, pain, warmth or erythema
Musculoskeletal injury  (Nash, 2005)

- **Fracture**: pathological fracture risk (i.e. normal forces on abnormal bone):
- **Cause: Osteoporosis/Osteopenia**
  - ~35% decrease in total trabecular bone two years post-SCI (de Bruin et al., 2000)
  - 50% decrease in BMD in paralysed limbs of SCI patients 3 years post-SCI (Beiring-Sorensen et al., 1991)
- **Prevention**: Cannot maintain/increase sublesional bone mineral density with any intervention (including exercise).
  - Careful transfers and avoidance of trauma.
Adrenergic Dysregulation (Nash, 2005)

- **Pressor decompensation** during and after exercise
  
  - **Cause:** loss of sympathetic reflex responses to exercise and post-exercise pooling of blood in lower extremities
  
  - **Prevention:** careful avoidance of orthostatic decompensation through conservative exercise progression and active cool downs post exercise to support venous return. Can recline subjects post exercise to prevent syncope.
Adrenergic Dysregulation (Nash, 2005)

**Autonomic Dysreflexia (AD) with exercise**

- **Cause:** loss of central autonomic control → reflex adrenergic responses to noxious stimuli
- **Prevention:** bowel and bladder routine emptying; avoid noxious stimuli

  - Of 99 participants, >50% had previously heard of AD
  - 16.7% (all males) had used AD to enhance performance.
Who Prescribes the Exercise?

- All health professionals should prescribe or refer
  - Family physicians
  - Medical Specialists (Physiatry, Neurology, Orthopaedic surgeons etc.)
  - Therapists (physical, occupational, recreational)
  - Allied (Exercise Physiologists, Kinesiologists, dietician etc.)

- Remember how important physical activity can be for persons with SCI, and also how dangerous it can be if prescribed ineffectively
Exercise Prescription and Referral

WHAT DO WE KNOW ABOUT EXERCISE?
- Exercise will make you feel good and can be fun!
- Exercise is effective. If exercise was a drug, it would be one of the most effective and safe ways to prevent and treat many chronic diseases such as heart disease, hypertension, diabetes, osteoporosis, anxiety disorders and depression.
- Exercise is safe for your joints. Regular low impact exercise and gradual muscle strengthening can stabilize and protect your joints from osteoarthritis and reduce the risk of falls and injuries that is associated with poor physical fitness.
- Improving fitness is more important than losing weight. Low cardiovascular fitness is associated with a much higher risk of disease and death than being overweight.
- Walking is free anywhere and any day of the year!

WHAT ABOUT AEROBIC INTENSITY AND MUSCLE STRENGTHENING?
- How can I assess intensity?
  - Light exercise will usually not cause adults to sweat and breathe harder. It is easy to have a conversation at this intensity. Walking is the typical example of light exercise.
  - Moderate-intensity exercise will cause adults to sweat a little and breathe harder. It is possible to have a conversation in short sentences. Examples are brisk walking (as if you are late for the bus) and bike riding.
  - Vigorous-intensity exercise will cause adults to sweat and be "out of breath". It is difficult to have a conversation. Examples are jogging, swimming laps, cross-country skiing and hiking on hills.

- What is strength and resistance exercises?
  - Strength and resistance exercises make your muscles work harder by adding weight or resistance to the movement.

For more information
You can consult your health professional, an exercise professional or visit the Resources page on exerciseismedicine.ca.
Summary

- SCI incidence is projected to increase (up to 5800 per year) by 2030
- SCI is very complex
  - Not as simple as the terms Tetraplegia and Paraplegia
- Special Considerations must be taken when consulting patients with SCI about physical activity
- Physical Activity is beneficial when prescribed appropriately for chronic disease and ADLs
  - When in doubt, refer to an exercise is medicine specialist
- Guidelines exist for SCI and other special populations (on the CSEP and ACSM websites)
The goal you set must be challenging. At the same time, it should be realistic and attainable, not impossible to reach. It should be challenging enough to make you stretch, but not so far that you break.

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Rick Hansen
References


How Severe is the Lesion?

American Spinal Injury Association (ASIA) scale uses sacral sparing (motor and sensory) as the criterion for determining neurological completeness

**Complete**: a term describing absence of sensory and motor function in the lowest sacral segment

**Incomplete**: partial preservation of sensory and/or motor functions below the neurological level and including the lowest sacral segment

Sacral sensation includes sensation at the anal mucocutaneous junction as well as deep anal sensation
Exercise Opportunities for Persons with SCI

1. Atypical physiological responses to acute exercise
   a. Damage to SC dissociates homeostatic mechanisms which regulate physiological responses needed to sustain exercise. Further disrupts signal integration among motor, sensory and autonomic targets and thus influences acute adjustments to activity and peak exercise capacity.
   b. Progressively higher levels of injury:
      i. Greater muscle mass loss in those muscles that serve as prime movers and stabilizers of the trunk. Arms must simultaneously generate propulsive forces and steady the trunk during exercise.
      ii. Greater degrees of adrenergic dysfunction, and at key spinal levels totally dissociate adrenal, cardiac, and sympathetic nervous system regulation from central command. Decreased adrenergic/noradrenergic function leads to altered cardiovascular and metabolic efficiencies achieved by individuals who exercise in the presence of an intact neuraxis.
   c. Evidence strongly supports a direct relationship among level of injury, peak workload, and peak oxygen uptake from arm crank testing.
      i. Individuals with injuries below the level of sympathetic outflow at T6 have significantly lower resting stroke volumes and higher resting heart rates than those without disability. Increased heart rate is thought to compensate for lower SV imposed by pooling of blood in lower extremity and venous circuits, diminished venous return and cardiac end-diastolic volumes or frank circulatory insufficiency. Upregulation of intact adrenergic system after SCI may also compensate to increase HR responses during exercise→ observed in paraplegia with persons have mid thoracic injuries.
      ii. Hypersensitivity of the supralesional spinal cord is believed to regulate the atypical adrenergic state and dynamic changes in cardiovascular status. Hyperadrenergic state can lead to elevated oxygen in persons with paraplegia having injuries below T5 may be due to adrenergic overactivity accompanying upper extremity strength gains of 13% to 40% depending on site tested.

2. Resistance training after SCI
   Reversal of adaptive left ventricular atrophy reported in tetraplegia. Shoulder pain was reduced or eliminated (40%). Can initiate pedaling via electrically stimulated contractions of bilateral quadriceps, hamstrings and gluteus
   Greater muscle mass loss in those muscles that serve as prime movers and stabilizers of the trunk. Arms must
   Ambulation training enhances upper extremity fitness. Other beneficial adaptations include: increased lower extremity bone mineralization, although most subjects begin
   Also lowered their total and LDL cholesterol while increasing HDL by almost 10%.
   Thus CRT is supported for persons with paraplegia over either endurance or resistance exercises alone.
   In most cases of SCI→ lower limbs either entirely paralyzed or with insufficient strength, endurance or motor control to
   Despite homeostatic and physical limitations→ can still benefit from exercise reconditioning. Upper extremity function
   Evidence strongly supports a direct relationship among level of injury, peak workload, and peak oxygen uptake from arm
   Electrically-stimulated muscle contractions
   Ambulation training has failed to increase lower extremity bone mineralization, although most subjects begin
   Both endurance and RT benefit those without SCI→ same effects of circuit resistance training in those with paraplegia.
   Hypersensitivity of the supralesional spinal cord is believed to regulate the atypical adrenergic state and dynamic
   Usually used with SCI target muscle strengthening of limb segments whose motor function is partially spared by
   Damage to SC dissociates homeostatic mechanisms which regulate physiological responses needed to sustain exercise. Further disrupts signal integration among motor, sensory and autonomic targets and thus influences acute adjustments to activity and peak exercise capacity.
   Progressive higher levels of injury:
      i. Greater muscle mass loss in those muscles that serve as prime movers and stabilizers of the trunk. Arms must simultaneously generate propulsive forces and steady the trunk during exercise.
      ii. Greater degrees of adrenergic dysfunction, and at key spinal levels totally dissociate adrenal, cardiac, and sympathetic nervous system regulation from central command. Decreased adrenergic/noradrenergic function leads to altered cardiovascular and metabolic efficiencies achieved by individuals who exercise in the presence of an intact neuraxis.
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3. Arm endurance training

4. Fabrication and application of orthoses

5. Electrically-Stimulated Exercise after SCI

Sequenced electrical stimulation has been used as an ambulation neuroprosthesis for those with complete motor damage to SC dissociates homeostatic mechanisms which regulate physiological responses needed to sustain exercise. Further disrupts signal integration among motor, sensory and autonomic targets and thus influences acute adjustments to activity and peak exercise capacity.

Progressively higher levels of injury:

i. Greater muscle mass loss in those muscles that serve as prime movers and stabilizers of the trunk. Arms must simultaneously generate propulsive forces and steady the trunk during exercise.

ii. Greater degrees of adrenergic dysfunction, and at key spinal levels totally dissociate adrenal, cardiac, and sympathetic nervous system regulation from central command. Decreased adrenergic/noradrenergic function leads to altered cardiovascular and metabolic efficiencies achieved by individuals who exercise in the presence of an intact neuraxis.

iii. Evidence strongly supports a direct relationship among level of injury, peak workload, and peak oxygen uptake from arm crank testing.

a. Individuals with injuries below the level of sympathetic outflow at T6 have significantly lower resting stroke volumes and higher resting heart rates than those without disability. Increased heart rate is thought to compensate for lower SV imposed by pooling of blood in lower extremity and venous circuits, diminished venous return and cardiac end-diastolic volumes or frank circulatory insufficiency. Upregulation of intact adrenergic system after SCI may also compensate to increase HR responses during exercise→ observed in paraplegia with persons have mid thoracic injuries.

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iv. Ambulation

v. Ambulation

vi. Ambulation

vii. Ambulation
6 Month Myth: “Rehabilitation only works for 6 months post injury” (FIND PAPERS ABOUT THIS)

From previous slide clearly this isn’t true

Extra slides