Spinal Cord Injury and Ambulation

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Ambulation

Ambulation vs. Wheelchair mobility
Which way to go?

Factors affecting ambulation potential

A. Level of injury and complete vs. incomplete
B. Patient functional ROM/strength/tone
C. Patient achievement of base skills (transfers, mat mobility, wheelchair mobility)
D. Motivation of patient
E. Benefits

Level of Injury vs. Ambulation

- C1-C8 not indicated
- T1-T9 typically not functional, walk for exercise
- T10-L1 functional, some assist to independent with KAFO’s (knee-ankle-foot orthoses) and walker/forearm crutches, most choose w/c for primary mobility
- L2-S5 Functional independent to some assist. KAFO’s or AFO’s (ankle-foot orthoses), walker to canes

*Note: only complete injuries are considered here!
### Statistics regarding ambulation

- Complete paraplegia: 5% achieve community level ambulation
- Incomplete paraplegia: 76% achieve community level ambulation
- Incomplete tetraplegia: 46% achieve community level ambulation

### Patient Achievement of Base Skills (Survival Skills)

- Limited rehab time
- Achieve primary functional skills
  - Transfers
  - Mat mobility
  - ROM and Strength
  - Wheelchair mobility
- Choose activities which will give them independence first

### Patient Motivation

- Verbal/subjective motivation
  - Everyone will want to walk, and is by far the number one initial goal of everyone after their initial injury
- Functional-physical objective
  - While everyone may verbalize the desire to walk, do they have the necessary prerequisites to walk?
    - Strength
    - ROM
    - Sensation
    - Spasticity

### Risks

- Unstable spine
  - Cervical: bracing (halo vs. cervical collar)
  - Thoracolumbar (hip precautions, TLSO)
- Skin: assess pressure areas
  - Fit and wear time of orthotic must be considered
- Injury from falls
  - Instruct in proper guarding technique/fall technique
Benefits

- Psychological
  - There is documented in the literature a tremendous psychological benefit to achieving an upright posture after injury.
- Cardiovascular and physical
  - Realistic functional mobility tends to be wheelchair mobility. Many will continue to use braces for exercise. A few will continue with braces for everyday ambulation and chores.
  - Sometimes they will surprise you!

Clinical Prediction for Walking after Traumatic SCI

- Report by Kay, et al.\(^1\) Reviewed medical records of 343 adult patients with traumatic SCI
- Data obtained
  - Age (equal to or greater than 50 years old vs under 50 years old)
  - Level of injury (tetraplegia vs paraplegia)
  - AIS grade
  - Syndrome type (central cord vs. other)
- Outcome measure used: FIM locomotion score at D/C

Clinical Prediction for Walking after Traumatic SCI

- The following factors were associated with better walking outcome (correlates with FIM ≥ 3)
- Age: lower age significantly better association with walking for patients with AIS D, but not C
- AIS:
  - Percentage walking at discharge (FIM ≥ 3)
    - A or B: < 1%
    - C: 28.3%
    - D: 67.2%

Clinical Prediction for Walking after Chronic SCI

- In a study by Scivoletto, et al.\(^2\), 65 ambulatory patients with chronic spinal cord injuries (both complete and incomplete) were investigated for the following factors:
  - Demographics
  - Pain
  - AIS score
  - Spasticity
- Outcome measures used:
  - Walking Index for Spinal Cord Injury (WISCI)
  - Timed Up and Go (TUG)
  - Ten-meter Walk Test (10MWT) – also known as gait speed
  - Six-Minute Walk Test (6MWT)
Clinical Prediction for Walking after Chronic SCI

- These following factors correlated with walking ability:
  - Muscle strength (ASIA key muscles)
    - Total motor score
    - Upper and lower extremity motor scores
    - Lower extremity proximal muscle scores
  - Balance
  - Spasticity
  - Age

Clinical Prediction Rule

- A European multi-center trial orchestrated by van Middendorp et al.3
- 492 adult patients with acute traumatic SCI were included
- Age: under 65 years old compared to equal to or greater than 65 years old
- ASIA exam findings (less than or equal to 15 days post injury)
  - Motor function in key musculature
  - Light touch in lower extremity key sensory points
  - Sensory and voluntary motor function @ anus
  - ASIA Impairment Scale

Clinical Prediction Rule

- Outcome assessment: ability to walk independently indoors 1 year post injury
- Spinal Cord Independence Measure (SCIM) used
  - Scores 0 to 3 (unable to walk or dependent on others) vs. Scores 4-8 (walks independently with or without aids)

Clinical Prediction Rule

Applying the Prediction Rule

STEP 1: assign score

- Age
  - < 65: 0
  - ≥ 65: 1
- ASIA exam results (if asymmetrical, use higher score)
  - L3 motor score (0-5)
  - S1 motor score (0-5)
  - L3 light touch score (0-2)
  - S1 light touch score
Applying the Prediction Rule

STEP 2: Multiply scores by weighted coefficient
- Age score: multiply by -10
- L3 motor score: multiply by 2
- S1 motor score: multiply by 2
- L3 light touch score: multiply by 5
- S1 light touch score: multiply by 5

STEP 3: Add all of the multiplied scores
STEP 4: Use the graph in the article to determine the probability of walking, based on the sum found in STEP 3.

Example application of clinical prediction rule:
- 68 y.o. with quad 3/5 & 2/5, plantar flexors 1/5 & 0/5, L3 light touch 1 on R & 0 on L, S1 light touch 1 on R & 0 on L

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<th>Range of test scores</th>
<th>Weighted coefficient</th>
<th>Test score</th>
<th>Test score X weighted coefficient</th>
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<td>0-1</td>
<td>-10</td>
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<tr>
<td>Motor score L3</td>
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<td>2</td>
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<td>Light touch score L3</td>
<td>0-2</td>
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Establish goals (patient vs. therapist)
1. Donn/Doff orthosis
2. Balanced standing
3. Sit to <> from Stand
4. Ambulation over even surfaces and obstacles
5. Falling and Floor Transfers
Distance/Efficient Ambulation

- What is a functional distance?
  - What will get them efficiently around their home versus the community?
    - FIMS: 150 feet
      - Magic number
- Efficiency is always the question
- Must also consider type of bracing and assistive devices to be used

General assistive device progression with ambulation

- Start with wheeled walker (or platform wheeled walker postural support is inadequate)
- Progress to loftstrand crutches after wheeled walker is "mastered"
- Progress to canes after loftstrands crutches are "mastered"

Guarding

- Keep patient safe without interfering with gait
- Ambulation: guard from behind
  - This will keep away from progress of step/crutch and allow better swing
  - Spotting should facilitate forward pelvis and backward shoulders (balanced standing posture)
  - One hand on hips, other on shoulder or around chest

Guarding cont.

- Note: therapist initial reaction may be to pull patient hips back into therapist, but this will cause an unstable "jackknifing" or "folding" at the hips
- Ambulation:
  - Give verbal cues along with tactile cues
  - Patient with decreased sensation may not be aware of how they are being assisted
  - Verbal cues help the patient to understand how they are being corrected and how to self adjust
  - Consider use of a mirror if proprioception is significantly affected.
The ups and downs

Need to be able to stand before you can walk, right?

Sit to stand

- Lock wheelchair brakes, move buttocks to front edge of seat, lock knees, position legs to extend straight forward from seat
- Place crutches in arms lateral to wheelchair or walker in front of wheelchair
- With hips flexed forward, forcefully push down through crutches or w/walker
- As legs move vertical, lift head, retract scapula, and push hips forward
- Quickly bring crutches/walker anterior to maintain balanced standing

Sit to Stand with walker

Stand to sit

- Stand in front of the wheelchair facing away
- Distance is very important
  - Too far and will miss seat
  - Too close will get stuck on chair or possibly tip chair
- Place crutches behind patient if using loftstrands
- Tuck head and jackknife at hips
- Lower self to wheelchair seat
- Improved balance in standing will make this more successful
- Descent is controlled to land without excessive force and align buttocks squarely
Orthotics

- Function:
  - Prevent motion
    - Ex: locked knee joints in KAFOs prevent knee flexion, or solid ankle joints to prevent motion at that joint.
  - Limit motion
    - Ex: double action ankle joints in KAFOs/AFOs can limit dorsiflexion and plantarflexion to a desired range.
  - Cause motion
    - Ex: dorsiflexion assist in an AFO via springs in ankle joint, or gas assist at knee joint to assist with extension in swing phase of gait.

- Begin with KAFOs locked
- KAFOs can be unlocked at the knee only when knee extensor strength is 3+/5 (fair plus) or greater (can hold knee in extension in stance)
- When the individual can consistently ambulate without knee buckling in stance with the KAFO unlocked, the KAFO can be cut down to an AFO
General orthotic progression with ambulation (con't)

- The use of a KAFO unlocked can control excessive genu recurvatum.
- Also, AFOs can control recurvatum to an extent when set into DF at the ankle
  - Be careful of excessive knee flexion at foot flat
- Can progress to eliminating the AFOs when adequate DF in swing is present, as well as adequate PF in terminal stance
  - Don’t forget about med-lat stability.

Reciprocal gait with w/w and KAFOs

- Begin with stable posture (i.e. pelvis forward and shoulders back)
- Move walker forward
- Extend elbows while depressing scapulae
- Weight shift to stance side
- Hip hike and flex hip (if musculature is available) on swing side to take step
- Place swing leg in front of stance leg
- Shift weight forward and laterally over stepped leg
- Achieve stable posture and move walker forward
- Repeat cycle with opposite side.

Amb with w/w and KAFOs

- Similar to gait with wheeled walker
- Begin in stable posture
- Move one crutch forward, and weight shift to same side.
- Once weight is shifted, hip hike and advance opposite leg
- Achieve stable posture by weight shifting forward on stepped leg (now in staggered stance) and then advance opposite crutch.
- Repeat sequence with opposite side.
- Also known as a four-point style gait.
Reciprocal gait with loftstrand crutches

Ascend:
- Approach face on
- Toes at edge of curb
- Place walker or crutch tips on higher surface of curb
- Lean forward on walker or crutches, tuck head, extend elbows and depress scapulae
- When toes lift past curb edge, they should swing forward
- When feet land on curb, throw head back, retract scapulae to regain balanced standing

Negotiation of Obstacles: Curbs

Descend:
- Approach face-on
- Loftstrand approach
  - Place crutch tips and feet close to edge of curb
  - Lean on crutches, extend elbows, depress scapulae
  - Extend upper trunk, swing legs forward like a pendulum
  - As feet hit, throw head back and retract scapulae to regain balance
- Walker approach
  - Get feet close to edge of curb, achieve standing balance position
  - Lower walker off of curb forward
  - After all four legs are down, lean forward, depress scapulae and extend elbows to swing feet off front of curb
  - As feet hit, throw head back and retract scapulae to regain balance
Gait Deviations

- Excessive Lordosis: hip flexion contracture
- Appearance of sitting on orthosis (excessive hip and knee flexion in stance): orthotic is not tall enough or circumference of the braces is too large to effectively approximate the girth of the braces.
- Continual jackknifing: hip flexion tightness or hip flexor spasticity

Gait Deviations cont.

- Pelvis rotates forward on one side and backwards on the other: ankle joints not set in equal amount of dorsiflexion or hip flexion contracture is present
- Standard walker forces hips into flexion and requires an increase in UE use, therefore use wheeled walker or loftstrands to attend to this issue. Also, LOB most often occurs with standard walker when it is picked up to move forward.

KAFOs vs. RGOs (Reciprocating Gait Orthoses)

- Consider use of RGOs when ambulation is appropriate, but perhaps the individual’s trunk is not stable enough for posture and/or cannot advance LE’s.
- The main difference between using KAFOs and RGOs:
  - With KAFOs, hip hiking with a component of swing through is necessary.
  - With RGOs, only lateral weight shifting is necessary due to the mechanism if the orthosis itself (no active hip flexion needed)

Other types of orthotics to consider when ambulation is a goal.
Mechanism behind the RGO

Ambulation with RGOs (including sit to stand)

Stand to sit using RGOs

Stance Control KAFO

- Use of this orthosis can be considered where there is focal paralysis/weakness to the quadriceps musculature.
- Promotes a much more normal gait pattern than with a KAFO locked into extension.
Stance Control KAFO

FES to Improve Gait

- Devices such as the Innovative Neurotronics Walk Aide and Bioness L300 units.
- Can effectively attend to “drop foot”, or a lack of effective dorsiflexion in the swing phase of gait due to weakness or spasticity.

PROs and CONs of FES (peroneal nerve stimulation)

**PROs:**
- Provides active muscle contraction and full joint ROM thus increasing sensory feedback and motor function
- Facilitates properly timed dorsiflexion during swing, thus improving clearance, timing and efficiency of gait
- Allows for strengthening of muscle and return of voluntary control
- Provides inhibition to spastic antagonists and improves the balance of tone across the ankle
- Facilitates neuroplastic changes and restoration of voluntary motor patterns

**CONS:**
- Requires patient to be independent and reliable with electrode placement
- Can result in skin irritation
- Medial lateral Stability of the ankle is not addressed

Contraindications

- Lower motor neuron (LMN) lesions
  - Poliomyelitis
  - Lumbar Sciatica
  - Guillian Barre Syndrome (GBS)
- Pregnancy
- Seizures (chronic)
- Malignancy in LE
- Deep vein thrombosis (DVT)
- Presence of a pacemaker
Precautions

- Surgeries with metallic implants
- History of falls
- Existing skin irritation beneath the electrode sites
- Fixed plantarflexion contracture
- Morbid obesity
- Excessive genu recurvatum

Gait without peroneal stim

Gait with peroneal stim

Now that you are up.....

- What happens when you go down???
Falling Safely

- This is important because **everybody** falls.
- Should teach falling that will minimize risk of injury
- Move crutches/wheeled walker out of way to prevent injury by landing on crutches/wheeled walker or catching arm.
- Throw crutches laterally and/or posteriorly, walker forward and/or laterally if possible
- Break fall with flexed arms to allow elbows and shoulders to give.

Assume Standing Position From Floor

- Get into prone position: hips adducted and externally rotated
- Maneuver assistive device(s) close to body so as to keep near as the person begins his/her transfer
- Perform press-up with hands while tucking head to raise to plantigrade position

Assume Standing Position From Floor cont.

- Walk hands toward feet while keeping head tucked
- Once patient has achieved legs in vertical position, shift weight and balance on one hand
- Grasp crutch or walker with un-weighted hand
- If using crutches, balance on one crutch to grab other crutch
  - Try different options or positions with crutches
- Position 2\textsuperscript{nd} crutch on forearm, if 1\textsuperscript{st} crutch is not on forearm, position now
- Push to standing position by pushing downward on crutches or walker
- Push pelvis forward by lifting head
- Walk crutches or walker back until upright

Floor $\leftrightarrow$ Stand Transfer with walker
Floor <> Stand transfer using loftstrand crutches

Other means of gait training

- Body weight supported training
  - Performed over a treadmill or over ground
  - Can be in conjunction with FES or with robotic assisted movement
  - Pioneers are individuals such as Andrea Behrman, Susan Harkema and Edelle Field-Fote
  - Body is traditionally de-weighted 30% to 80%

Pros/Cons

- **PROs:**
  - Provides a more normal gait pattern
  - Can be less labor intensive for the therapy team (especially with the robotic driven devices)
  - Can provide a means of support to allow patients to ambulate further with less assistance

- **CONS:**
  - Specialized equipment is required
  - Can be more labor intensive for the therapy team
  - Set-up time can be longer than with traditional gait training
  - Expense?
Body Weight Supported Gait training

Robotic Assisted Locomotor Training

- http://vimeo.com/26054511

Influence of a Locomotor Training Approach on Walking Speed and Distance in People With Chronic Spinal Cord Injury: A Randomized Controlled Trial

*Edelle C. Field-Fote, Kathryn E. Roach*

Physical Therapy, Vol. 91, 2011, Number 1, 48-60
Take home message:

- Compared the following body weight support approaches:
  - Treadmill training with manual assistance
  - Treadmill training with electrical stimulation
  - Overground with electrical stimulation
  - Treadmill training with robotic assistance
- All groups improved with the outcomes measured, but greatest improvements noted with overground training with stim.

Should Body Weight-Supported Treadmill Training and Robotic-Assistive Steppers for Locomotor Training Trot Back to the Starting Gate?

Bruce H. Dobkin, MD and Pamela W. Duncan, PT, PhD
Neurorehabilitation and Neural Repair. Published online March 12, 2012.

Take home message:

- In the absence of evidence for physical therapists to employ the strategies of Body Weight Supported Treadmill Training and Robotic-Assisted Step Training, these interventions should not be provided routinely to disabled, vulnerable persons in place of Over Ground Training outside of a scientifically conducted efficacy trial.

Comparison of training methods to improve walking in persons with chronic spinal cord injury: a randomized clinical trial.

Alexeeva, N., Sames, C., Jacobs, P.L., et al
Considering those individuals with either ASIA C or D injuries, split between comprehensive PT, a body-weight supported program on a fixed track and a body-weight supported program on a treadmill, no group showed a significant improvement over another in regards to ambulation. They all did show significant improvement in their quality of life outcomes.

**Take home message**


**References**

**Take home message**

Body weight-supported gait training for restoration of walking in people with an incomplete spinal cord injury: a systematic review.


After reviewing 18 different studies, BWS treadmill training was not as effective to over-ground training in regards to Functional Independence Measure-Locomotion (FIM-L), but equally as effective considering walking speed. It does postulate that those that may benefit most from body-weight supported training are those with the largest deficits that may not be able to complete traditional over-ground training.