Selective Motor Control
Assessment of the Lower Extremity in Patients with Spastic Cerebral Palsy
Marcia Greenberg MS, PT*
Loretta Staudt MS, PT*
Eileen Fowler PT, PhD

Overview
- Selective Motor Control
  - Definition
  - Clinical relevance
- SCALE (Selective Control Assessment of the Lower Extremity)
  - Reliability and validity
  - Administration, instruction and scoring
  - Patient examples
- Clinical and research applications
- Questions/discussion

Selective Motor Control
... ability to isolate the activation of muscles in a selected pattern in response to demands of a voluntary posture or movement
TD Sanger et al. Pediatrics 2006

Selective Voluntary Motor Control (SVMC)
The ability to perform isolated joint movements upon request, without using mass flexor/extensor patterns and without undesired movement at other joints, such as mirroring

Spastic Cerebral Palsy
Multiple Impairments
- Spasticity
- Balance
- Strength
- Selective motor control

Selective Motor Control
- Develops during infancy
  - All newborns - coupled kicking
  - Isolated hip/knee ankle patterns - in typical development
  - Coupled kicking persists in infants with white matter damage
  - Best time for intervention?
- Children and adults with CP
  - Relatively stable
Periventricular white matter damage
Damage to corticospinal tracts

Spastic Form of Cerebral Palsy
- Damage – pathways for voluntary movement
- Patients with good selective voluntary motor control of their lower limbs do well despite severe spasticity
- SVMC – used as screening for selective posterior rhizotomy

Review of SVMC Clinical Assessment Tools
- Post stroke, adults
  - Brunstrom 1966
  - Fugl-Myer 1975
- Cerebral palsy
  - Staudt and Peacock 1989; Fowler et. al. 2007
  - Boyd and Graham 1999 (ankle)
  - Voorman 2007 (knee and ankle)
  - Fowler et. al. 2009 (SCALE)

SCALE
- Numerical scores
- 5 joints
  - Hip
  - Knee
  - Ankle
  - Subtalar
  - Toes
- For each joint SVMC is graded as:
  - Normal = 2 points
  - Unable = 0 points
  - Impaired = anything else = 1 point
- Maximum of 10 points per limb

SCALE: Content Validity
- 14 expert clinicians rated 32 statements about SCALE components
- 448 Total Responses
  - Blank 18 (4%)
  - Undecided 23 (5%)
  - Disagree 12 (3%)
  - Agree 395 (92%)

SCALE: Construct Validity
- Fowler et. al. Dev Med Child Neuro 2009
Interrater Reliability

- Participants (n=20)
- Mean age 12y,3m (Range 7-23y)
- 7 males, 13 females
- 16 diplegia, 3 hemiplegia, 1 quadriplegia

<table>
<thead>
<tr>
<th>GMFCS Level</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3</td>
</tr>
<tr>
<td>II</td>
<td>6</td>
</tr>
<tr>
<td>III</td>
<td>8</td>
</tr>
<tr>
<td>IV</td>
<td>3</td>
</tr>
</tbody>
</table>

Interrater Reliability

- 6 trained raters
  - 3 physical therapists, 1 pediatric orthopedist, 1 pediatric neurologist and 1 pediatrician
  - Experience range 1 – 29 years
- 2 teams of 3 raters
  - Team A assessed 10 participants
  - Team B assessed 12 participants
    (2 scored by both teams)

Interrater Reliability

- Random order of raters
- Scored right and left
- Analysis
  - Intraclass Correlation Coefficients (ICC) and 95% Confidence intervals (CI)
    - for each team
    - for each lower extremity

SCALE Interrater Reliability

<table>
<thead>
<tr>
<th>Group</th>
<th>Limb</th>
<th>ICC</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Left</td>
<td>0.88</td>
<td>0.69, 0.97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>A</td>
<td>Right</td>
<td>0.89</td>
<td>0.72, 0.97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>B</td>
<td>Left</td>
<td>0.90</td>
<td>0.77, 0.97</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>B</td>
<td>Right</td>
<td>0.91</td>
<td>0.79, 0.97</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Fowler et al. Dev Med Child Neuro 2009

Is Impairment Greater Distally?
SCALE score hip > knee > ankle > STJ > toes

<table>
<thead>
<tr>
<th>Joint</th>
<th>Mean SCALE Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip</td>
<td></td>
</tr>
<tr>
<td>Knee</td>
<td></td>
</tr>
<tr>
<td>Ankle</td>
<td></td>
</tr>
<tr>
<td>STJ</td>
<td></td>
</tr>
<tr>
<td>Toes</td>
<td></td>
</tr>
</tbody>
</table>

Significant downward trend p < .0001

* significant between all joint pairs (p<.05)
* left ankle significantly different from left hip, knee, STJ scores (p<.05)
* right ankle joint score was significantly different from right hip and knee (p<.05)
* right ankle vs STJ score (p<.05)

Fowler et al. Dev Med Child Neuro 2010
Overview of the Assessment

- Minimum of 4 years old
- Hip, knee, ankle, subtalar and toe motion
- Non-synergistic movement task
- Note passive ROM
- Move within 3 second verbal count
- Move ONLY the joint being tested
- Grade best performance

Scoring System

<table>
<thead>
<tr>
<th>Grade</th>
<th>Hip</th>
<th>Knee</th>
<th>Ankle</th>
<th>STJ</th>
<th>Toe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Impaired</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Example of scores for a child with spastic diplegic CP

Maximum score per each lower limb = 10

Grading

- Normal
  - Completes isolated movement within 3 seconds
- Unable
  - Cannot perform movement out of synergy
- Impaired
  - Less than 50% available motion
  - Slower than 3 second verbal count
  - Mirror movements of contralateral limb
  - Motion at other joints
  - Movement occurs only in one direction

Grading Guidelines

- Only grade what you observe – no assumptions
- If contracture is present
  - Grade movement that you see, not palpate
  - Note contracture in descriptor section
  - Area for comments

Suggested General Instructions

- “I am going to ask you to move in a certain way. Only do the movement I ask you to do. Try not to move any other part of your body. If you have any questions or do not understand what I am asking you to do, please tell me and I will explain.”
- “I will take you through the motion first and then I would like you to do it yourself.”
**Administration and Grading Guidelines**

- **Hip**
  - Tight hamstrings
- **Knee**
  - Allowed to lean back on hands
  - Watch for trunk movement
- **Ankle**
  - Can flex knee to 20°
  - Must observe at least 15° of motion
- **Subtalar**
  - Need active eversion
- **Toes**
  - Motion at all five toes
Extensor Synergy

Resisted Flexor Synergy ("Confusion Test")

Descriptors

• Contractures/spasticity (hip, knee, ankle)
• Ankle: inverts/everts, not pure dorsiflexion
• Ankle: primarily moves toes
• Mirrors motion on opposite limb
• Motion slower than 3 sec verbal count
• Moves one direction only
• Movement of other joints
• Motion less than 50% of range

Clinical Examples

• Each joint
• Each grade
• Patient example
Videos

Clinical Decisions and Goal Setting
Spasticity Reduction

- Poor SVMC: Uses flexor pattern to dorsiflex
- Good SVMC: Isolated ankle dorsiflexion

What is the goal?

- Must also consider strength, balance, range of motion, age, current function, rehab

- Increased potential to benefit from interventions
- Most important for irreversible procedures
- Must also consider strength, balance, range of motion, age, current function, rehab

- Poor SVMC
- Maintain same patterns of movement
- May lose “positive support” for transfers, gait

Solid Ankle AFOs/DAFOs

- What is the goal?
- Good SVMC: Isolated ankle dorsiflexion
  - Blocks loading response, tibial advancement & MTP extension
  - Interrupts movements/crawling
  - Medial/lateral control?
- Poor SVMC: Uses flexor pattern to dorsiflex
  - AFO maintains functional position for standing, transfers and walking

Therapeutic Exercise

- Good SVMC
  - Able to learn new pattern?
  - Incorporate into function?
  - Factor of age?
  - Program limited by imagination
- Poor SVMC
  - Constrained to move in pattern
  - Focus on strength within pattern
  - Cycling
  - Both strengthening and cardio-respiratory

SVMC: Clinical Decision Making

- Spasticity reduction
  - Botulinum toxin injections
  - Intrathecal baclofen pump
  - Selective posterior rhizotomy
- Therapeutic exercise
- Bracing
- Gait/Orthopaedic Surgery

Spasticity Reduction
Botox, ITB & SPR

- What is the goal?

- Factor of age?
The Relationship Between SCALE and Gait

- SVMC compared to SMC
  - Requested versus natural movement
- SCALE
  - Gait lab measurement
  - MRP
- Orthopaedic surgery
  - Hamstring lengthening

Relative Phase Analysis – Methods

SCALE - MRP Correlation

$$r = -0.81, p = 0.0001$$

Relationship Between MRP and Other CP Impairments

All had significant correlations
SCALE: strongest predictor in subsequent step down analysis

<table>
<thead>
<tr>
<th></th>
<th>Pearson r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCALE Score</td>
<td>-0.81</td>
<td>0.0001</td>
</tr>
<tr>
<td>Spasticity Index</td>
<td>0.67</td>
<td>0.0045</td>
</tr>
<tr>
<td>Strength Index</td>
<td>-0.57</td>
<td>0.0203</td>
</tr>
</tbody>
</table>

Hamstring Lengthening Literature

- Baumann et al. (1980) suggested that tight hamstrings lead to shorter stride lengths
- Limited terminal-swing knee extension is often accompanied by decreased stride length (Cooney et al., 2006)
- Thometz et al. (1989) did not find a significant difference in stride length before and after surgery
  - Some patients improved while others deteriorated
  - Found no correlations between preoperative variables and stride length improvements

Hamstring Lengthening

- Goals
  - Stance: Improve knee extension (crouch)
  - Swing: Improve knee extension (stride length)
- Good SVMC
  - Realistic goals
- Poor SVMC
  - Stance: realistic goal
    - simultaneous hip & knee extension normal mid-stance
  - Swing: not realistic goal
    - knee cannot fully extend with hip flexion despite length
Case Examples

- 2 patients with spastic diplegic CP
- Contrasting SCALE scores, same hamstring spasticity
- Hamstring lengthening surgery
- Gait analysis before and after surgery

Participant Characteristics

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Preoperative age (yrs)</th>
<th>Time between analyses (yrs)</th>
<th>GMFCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>10.5</td>
<td>1.8</td>
<td>III</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>9.6</td>
<td>2.3</td>
<td>III</td>
</tr>
</tbody>
</table>

Videos

Gait Parameters

<table>
<thead>
<tr>
<th>Participant</th>
<th>SCALE Score</th>
<th>Speed (m/sec)</th>
<th>Normalized Stride Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td>Pre</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0.41</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>5</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Left Hip and Knee Angles

Results: Stride Length

- Poor SVMC
  - Pre: TO, Post: IC
  - Pre: SL, Post: SL

- Good SVMC
  - Pre: TO, Post: IC
  - Pre: SL, Post: SL

TO = toe off, IC = initial contact
Conclusions

• Individuals with good SVMC are able to increase stride length following surgery due to the ability to
  – Isolate hip and knee motion on the swing limb
  – Utilize increased hamstring length

• Individuals with poor SVMC may not improve stride length due to
  – Constraints to move in synergy
  – Inability to utilize increased length in hamstrings