Reappraisal of the Silfverskiöld Test: Ultrasonographic Assessment of Architectural Properties of the Triceps Surae Muscle Complex

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Silfverskiöld test

- Knee flexion - Ankle D/F above neutral
- Knee extension - Ankle D/F below neutral
- Test positive (Contracture of gastrocnemius only) – subjective...
- Perry (*JBJS Am, 1974*)
  - Electromyographic study in CP
  - Positive Silfverskiöld: Simultaneous activation of soleus & gastrocnemius
Ultrasonographic study for architectural properties of skeletal muscle

- **Kawakami (JAP, 1998)**
  - Study of NL triceps surae during relaxed position and isometric P/F contraction
  - Different fascicle length & pennation angle at different joint angle

- **Several studies in CP**
  - *Uncontrolled study for joint position*
  - *Uncontrolled study for skeletal deformity*
  - *Different disease entity*  
    - Diplegia, Hemiplegia
Purpose of the study

• Assessment of architecture of the triceps surae muscle complex
  – In normal children and children with SHCP
  – Fascicle length, pennation angle, and muscle thickness
  – At varying positions of the ankle and knee joints

• Assessment of the Silfverskiöld test *in vivo*
  – Suggest appropriate surgery for the correction of equinus foot deformity
Methods

• Hemiplegics
  – GMFCS I/II, Winter II
  – No ankle and knee deformity
  – 10 children (M : F = 6 : 4)
  – Average age: 7±1yrs (5±0yrs ~ 10±1yrs)
  – Group I (10 paretic legs)
  – Group II (10 non-paretic legs)

• Normal matched control
  – 10 children (M : F = 6 : 4)
  – Average age: 6±7yrs (5±2yrs ~ 8±0yrs)
  – Group III (20 normal legs)

Knee
  0°, 45°, 90° flexion

Ankle
  D/F 10°
  Neutral (G III only)
  , P/F 15°, P/F 30°
FASCICLE LENGTH
PENNATION ANGLE
MUSCLE WIDTH
Displacement of the fascicle-deep aponeurosis junction = $L_f \cos \alpha' - L_f \cos \alpha$
Statistical Analyses

• SAS (version 9.1, SAS Institute, Cary, North Carolina)
• Mixed model
  – Between the groups
  – Between different angles of the ankle & knee joints
  – Displacement of the fascicle-deep aponeurosis junction
    • Full range and Same range of ankle motion
• Two orthopaedic surgeons, measured twice
  – ICC : 0.5307 ~ 0.9915
Fascicle length

**Paretic (Group I)**

- Length [mm]: 30-35, 35-40, 40-45, 45-50

**Non-Paretic (Group II)**

- Length [mm]: 30-35, 35-40, 40-45, 45-50

**Normal (Group III)**

- Length [mm]: 30-35, 35-40, 40-45, 45-50

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**MG**

- Length [mm]: 50, 45, 40, 35, 30, 25, 20

**LG**

- Length [mm]: 50, 45, 40, 35, 30, 25, 20

**SOL**

- Length [mm]: 40, 35, 30, 25, 20

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Comparison:

- Paretic > Non-Paretic > Normal
Pennation angle

**Paretic (Group I)**

- MG
  - Angle $\alpha$
  - K90

- LG
  - Angle $\alpha$
  - K90

- SOL
  - Angle $\alpha$
  - K90

**Non-Paretic (Group II)**

- Angle $\alpha$
- K90

**Normal (Group III)**

- Angle $\alpha$
- K90
Muscle width

**MG**
- Paretic (Group I)
- Non-Paretic (Group II)
- Normal (Group III)

**LG**
- Paretic (Group I)
- Non-Paretic (Group II)
- Normal (Group III)

**SOL**
- Paretic (Group I)
- Non-Paretic (Group II)
- Normal (Group III)
Summary I

- **Fascicle length**
  - LG: Paretic > Normal ; SOL: Paretic < Normal

- **Pennation angle**
  - MG, LG: Paretic < Normal

- **Muscle width**
  - MG, LG, SOL: Paretic < Normal
Summary II

**Paretic (Group I)**
- Fascicle length
  - MG, LG: knee extension - ↑
  - SOL: ankle dorsiflexion - ↑
- Pennation angle
  - MG: knee flexion & ankle plantarflexion - ↑
  - LG: ankle plantarflexion - ↑
  - SOL: knee extension & ankle plantarflexion - ↑
- Muscle width
  - LG: knee extension - ↑

**Normal (Group III)**
- Fascicle length
  - MG, LG: knee extension & ankle dorsiflexion - ↑
  - SOL: knee flexion & ankle dorsiflexion - ↑
- Pennation angle
  - MG, LG: knee flexion & ankle plantarflexion - ↑
  - LG: ankle plantarflexion - ↑
  - SOL: ankle plantarflexion - ↑
- Muscle width
  - MG: ankle plantarflexion - ↑
Comparison with full ankle D/F – P/F

<table>
<thead>
<tr>
<th></th>
<th>Paretic (Group I)</th>
<th>Non-paretic (Group II)</th>
<th>Normal (Group III)</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee 0°</td>
<td>0.8 ± 4.8</td>
<td>0.9 ± 3.2</td>
<td>1.5 ± 5.0</td>
<td></td>
</tr>
<tr>
<td>Knee 45°</td>
<td>5.2 ± 7.7</td>
<td>5.1 ± 4.5</td>
<td>6.0 ± 6.7</td>
<td></td>
</tr>
<tr>
<td>Knee 90°</td>
<td>6.4 ± 5.1</td>
<td>6.6 ± 4.6</td>
<td>6.1 ± 4.6</td>
<td></td>
</tr>
<tr>
<td>Knee 0°</td>
<td>5.1 ± 4.5</td>
<td>8.0 ± 6.7</td>
<td>2.3 ± 6.1</td>
<td></td>
</tr>
<tr>
<td>Knee 45°</td>
<td>5.1 ± 4.5</td>
<td>6.6 ± 4.6</td>
<td>3.9 ± 3.7</td>
<td>0.0075</td>
</tr>
<tr>
<td>Knee 90°</td>
<td>6.1 ± 4.6</td>
<td>3.9 ± 3.7</td>
<td>6.6 ± 5.5</td>
<td>0.6353</td>
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<tr>
<td>Group I vs Group II</td>
<td>0.0029</td>
<td>0.0008</td>
<td>0.7661</td>
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<tr>
<td>Group I vs Group III</td>
<td>0.0312</td>
<td>0.0948</td>
<td>0.3784</td>
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</table>

- MG, LG : smaller with knee flexion
- MG, LG : Paretic < Normal

**Table:**

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Knee 0°</th>
<th>Knee 45°</th>
<th>Knee 90°</th>
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<tr>
<td>LG</td>
<td>1.5 ± 3.1</td>
<td>3.2 ± 4.5</td>
<td>1.1 ± 4.8</td>
<td>7.9 ± 5.5</td>
<td>5.4 ± 3.0</td>
<td>11.4 ± 4.9</td>
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<td>8.6 ± 3.6</td>
<td>3.9 ± 3.7</td>
<td>0.0008</td>
</tr>
<tr>
<td>SOL</td>
<td>3.7 ± 2.0</td>
<td>7.1 ± 3.2</td>
<td>2.8 ± 2.7</td>
<td>8.0 ± 7.5</td>
<td>9.3 ± 3.4</td>
<td>5.6 ± 8.6</td>
<td>9.3 ± 3.4</td>
<td>6.6 ± 3.9</td>
<td>6.6 ± 5.5</td>
<td>0.0312</td>
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Comparison with constant range of ankle ROM

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<td>Knee 90°</td>
<td>Knee 0°</td>
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<td>1.5 ± 5.0</td>
<td>3.3 ± 3.0</td>
</tr>
<tr>
<td>LG</td>
<td>1.5 ± 3.1</td>
<td>3.2 ± 4.5</td>
<td>1.1 ± 4.8</td>
<td>3.0 ± 2.7</td>
</tr>
<tr>
<td>SOL</td>
<td>3.7 ± 2.0</td>
<td>7.1 ± 3.2</td>
<td>2.8 ± 2.7</td>
<td>1.6 ± 5.4</td>
</tr>
</tbody>
</table>

- MG, LG only in Group III: smaller with knee flexion
- No difference between group
**Fascicle length**

- **This study**
  - MG: no difference
  - LG: Paretic > Normal
  - SOL: Paretic < Normal

- **Mohagheghi et al (Clin Biomech 2007)**
  - Fascicle length & Muscle thickness ↓
  - Only resting length
  - Ankle P/F → Fascicle length ↓

- **Kawakami et al (J Appl Physiol 1998)**
  - Fascicle length of LG: longest among the triceps surae in normal
  - Number of sarcomere is the largest

- **The effect of palsy in fascicle length was only noted in the LG**
Pennation angle & Muscle width

- This study
  - MG, LG pennation angle: Paretic $<$ Normal
- Kawakami et al *(J Appl Physiol 1993)*
  - Pennation angles: greater in hypertrophied muscle
- Shortland et al *(Dev Med Child Neurol 2004)*
  - Pennation angle $\uparrow$: after lengthening

- This study
  - MG, LG, SOL muscle width: Paretic $<$ Normal
- Malaiya et al *(J Electromyogr Kinesiol 2007)*
  - Lack of cross-sectional growth in SHCP
- Muscle width $\equiv$ Muscle atrophy
Appropriate lengthening site

Lateral gastrocnemius:
most affected muscle at same knee-ankle joint angle
Complex movement between Gastrocnemius and Soleus

- Normal
  - Fascicle length change
    - MG, LG: increase with knee extension
    - SOL: increase with knee flexion
  - Pennation angle change
    - MG, LG: increase with knee flexion
    - SOL: no change with knee motion

- Different movement between Gastrocnemius & Soleus
Disruption of normal differential movement between Gastrocnemius and Soleus

Fascicle length

Paretic (Group I)  Normal (Group III)

MG

LG

SOL

Pennation angle

Paretic (Group I)  Normal (Group III)

MG

LG

SOL
Conclusion

• In paretic legs in SHCP with Silfverskiöld negative SHCP
  – Altered muscle architectures of both the Gastrocnemii and SOL
  – Altered differential actions of the muscles according to the joint positions
  – TAL for Silfverskiöld negative Spastic hemiplegic CP