Standing in children with bilateral spastic cerebral palsy: Aspects of muscle strength, vision and motor function

Cecilia Lidbeck, PT, PhD
Department of Women’s and Children’s Health
Karolinska Institutet
Motoriklab
Karolinska University Hospital, Solna
Supervisors

Main supervisor
Åsa Bartonek, PT, Assoc. Prof. KI

Co-supervisors
Lanie Gutierrez-Farewik, Engineer, Assoc. Prof. KTH
Kristina Tedroff, MD, Assoc. Prof. KI
Per Åstrand, MD, PhD

Co-authors
Kerstin Hellgren, MD, PhD, KI
Priti Yadav, PhD student, KTH
Cerebral palsy (CP)

- Describes a group of disorders of movement and posture
- Lesion in the developing brain before two years of age

Activity limitations are presumed to be a consequence of the motor disorder

*(Rosenbaum et al. 2007)*

**Gross Motor Function Classification System - GMFCS**

*(Palisano et al. 1997)*
- Prevalence for CP in Sweden: 2-3/1000
- Bilateral spastic CP (BSCP): 35%

Subtypes
- Spastic
- Dyskinetic
- Ataxic

Distribution
- Unilateral
- Bilateral

Classification
- Ambulation
- Manual ability

Accompanying disturbances in CP

“...The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour, by epilepsy, and by secondary musculoskeletal problems.”

- Sensations: vision and other sensory modalities
- Perception: capacity to incorporate and interpret sensory and/or cognitive information
  
  (Rosenbaum et al. 2007)

- Visual dysfunction influence motor functions (Jacobsson et al. 2000)
- Proprioceptive deficits have been related to instability in standing (Damiano et al. 2013)
- Perceptual impairments with disturbed interactions between the sensory systems may complicate posture modulation (Ferrari et al. 2010)
Postural control
Interaction of the individual with the task and the environment controlling the body’s position in space for orientation and stability

- **Postural Orientation**
  - Alignment of body segments
  - Maintenance of body position

- **Postural stability**
  - Controlling center of mass in relation to base of support

Prerequisite for standing –
Spatial perception of the body in space

A combination of sensory systems:
- Vision
- Somatosensory (tactile, proprioception)
- Vestibular

➤ Detect gravity as a reference frame enabling perception of the vertical

(Shumway-Cook et al. 2012, Berthoz 2000)
What causes difficulties with standing?

- Activation of muscles?
- Muscle weakness?
- Sensory disturbances?
- Vision?
- Difficulties with spatial perception?
To investigate factors influencing standing in children with bilateral spastic CP, GMFCS levels I-IV, with respect to their various standing abilities
Overview

Study I. Investigating postural orientation i.e. body position & body movements during quiet standing

Study II. Exploring lower limb muscle strength with respect to standing ability with or without support

Study III. Exploring the influence of visual stimuli on standing posture

Study IV. Exploring motor function in other positions than standing, such as lying, sitting and kneeling
Participants in total

55 children with CP
- 25 standing with support (CP-Sws)
- 30 standing without support (CP-SwoS)

Reference group:
46 typically developing (TD) children

Inclusion criteria
- Bilateral spastic CP, GMFCS levels I-IV
- Standing ability 30 sec
- Age 5 – 17 years
Aim

To investigate postural orientation with body position and body movements during quiet standing

Postural Orientation During Standing in Children With Bilateral Cerebral Palsy

Cecilia M. Lidbeck, PT, MSc; Elena M. Gutierrez-Farewik, PhD; Eva Broström, PT, PhD; Åsa Bartonek, PT, PhD

Department of Women's and Children's Health (Ms Lidbeck and Drs Gutierrez-Farewik, Broström, and Bartonek) Karolinska Institutet, Stockholm, Sweden; KTH Mechanics (Dr Gutierrez-Farewik), Royal Institute of Technology, Stockholm, Sweden.
Study 1

Methods

Participants
26 children with BSCP
- CP-SwoS: 15
- CP-SwS: 11
19 TD children

3-D motion analysis: Standing posture
- Standing 30 s with habitual shoes and orthoses
- The more weight-bearing limb was analysed
Study I

3-D Motion Analysis *(Vicon® Oxford, UK) (Force plates, Kistler® Switzerland)*

- Standing posture: **Body position** and **Body movements**
Study I

Graphical illustration of 3-D Motion Analysis
(three trials in one child)

- = neutral position
- = right limb
- = left limb
Study I

Results - Body position angles° (median)

- TD children: erect position (hip 5°, knee -5°)
- CP-SwoS: flexed position (hip 20°, knee 15°)
- CP-SwS: flexed position (hip 30°, knee 45°)
Study I

Results – Standing vs passive joint angles° (median)

- CP-SwoS: hip 0° vs 20°, knee 0° vs 15°
- CP-SwS: hip 0° vs 30°, knee -10° vs 45°

![Images of CP-SwoS and CP-SwS with统计数据](image)
Study I

Results – Body movement range° (median)

- TD children: almost still in all joints < 5°
- CP-SwoS: movements hip and knee 5°
- CP-SwS: movements hip and knee 10°

(p<0.05)
Children with CP had varying abilities to stand and maintain standing posture with or without support

- Both groups stood in a crouched body position with more flexion than their potential passive joint extension

- The crouched body position and the body movements were more obvious in the children standing with support

How **muscle strength** and **spatial perception** influence posture remains to be explored!
Aim

Explore muscle strength in the lower limb muscle groups in children with BSCP with respect to their standing ability with or without support.
Study II

Methods

Participants
25 children with BSCP
- 11 CP-SwoS
- 14 CP-SwS

Hand-held dynamometer (HHD) (Chatillon®)
Isometric muscle strength
- Hip flexors (HF)
- Knee extensors (KE)
- Dorsiflexors (DF)
- Plantarflexors (PF)
Study II

Methods

Testing positions:

- Hip flexors
- Knee extensors
- Dorsiflexors
- Plantarflexors

Two seated positions: on a chair and on a stool
Study II

Results – Muscle strength Nm/kg (median)

- CP-SwoS and CP-SwS: No difference in hip and ankle muscles
- CP-SwS vs CP-SwoS: Stronger knee extensors (p=0.038)

- No difference between seated conditions

(p<0.05)
Study II

Conclusions

Children standing with support were not weaker compared to those standing without support

Muscle strength does not explain:
- the requirement for support for standing
- the more crouched knee flexion in the children standing with support

How vision, somatosensory deficits and/or difficulties with perception of gravity influence standing need to be further investigated!
Aim

Explore the influence of visual stimuli on standing posture while blindfolded and during an attention demanding task in children with various standing abilities with or without support
Study III

Method

Participants
36 children with BSCP
- 19 CP-SwoS
- 17 CP-SwS
27 TD children

3D-motion analysis: Standing posture

Surface Electromyography (Noraxon®, USA): Muscle activity
Four lower limb muscle groups:
- knee extensors (KE)
- dorsiflexors (DF)
- plantarflexors: gastrocnemius (GM), soleus (S)
Study III

Method
Quiet standing: 30 s./condition

No-task  Blindfolded  Watching a video

- Body position
- Body movements
- Muscle activity

Visual function - examined by an ophthalmologist
- neuro-ophthalmological impairments in 28/32
- no difference in ophthalmological status between the groups
- visual acuity sufficient to see the film
Results: No-task condition (mean)

TD children: erect and still position
Children with CP vs TD children: flexed position with more body movements, more obvious in CP-SwS

**Head movements**

TD: almost still
CP-SwoS: 25°
CP-SwS: ~50°
Study III

Results: Standing conditions TD children (mean)

<table>
<thead>
<tr>
<th></th>
<th>Blindfolded (BT)</th>
<th>Watching the movie (AT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body position:</td>
<td>increased head extension 3°</td>
<td>no change</td>
</tr>
<tr>
<td>Body movements:</td>
<td>no change</td>
<td>no change</td>
</tr>
<tr>
<td>Muscle activity:</td>
<td>increased in calf 35 %</td>
<td>no change</td>
</tr>
</tbody>
</table>

Muscle activity

<table>
<thead>
<tr>
<th>KE</th>
<th>DF</th>
<th>GM</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BT
Study III

Results: Standing conditions CP-SwoS (mean)

Body position:  
- Blindfolded (BT): no change
- Watching the movie (AT): no change

Body movement:  
- Blindfolded (BT): more still head 10°
- Watching the movie (AT): more still head 10° and knee 2°

Muscle activity:  
- Blindfolded (BT): increased in calf 35%
- Watching the movie (AT): decreased in knee and calf 10%

![Graphs showing body movements and muscle activity](image-url)
Study III

Results: Standing conditions CP- SwS (mean)

Blindfolded (BT)
- Body position: increased flexion hip, knee 5°
- Body movements: no change
- Muscle activity: increased in knee 10%

Watching the movie (AT)
- Body position: head extended 5°
- Body movements: more still head 20°
- Muscle activity: no change
**Study III**

**Conclusions**

- Without vision the children CP-SwS had difficulties to maintain posture:
  - crouched position increased

- Visual stimulus changed posture in both groups of children with CP:
  - CP-SwoS stood more still and with less lower limb muscle activity
  - CP-SwS stood with more upright and still head position

- How impairments in the sensory systems and difficulties with perception of gravity influence standing need to be further investigated!
Aim
To explore motor function in other positions than standing, such as lying, sitting, and kneeling in relation to standing ability

Gross motor function and standing ability in children with bilateral spastic cerebral palsy
Cecilia Lidbeck & Åsa Bartonek
Study IV

Methods

Participants
36 children with BSCP
- CP-SwoS: 19 (GMFCS I:5, II:12, III:2)
- CP-SwS: 17 (GMFCS II:1, III:13, IV: 3)

Gross Motor Function Measure (GMFM-66 & GMFM-88)
Motor activities in lying/rolling, sitting, crawling/kneeling, standing and walking/running/jumping

Timed Up and Go (TUG) test:
Functional mobility in walking
### Study IV

#### Results: GMFM (median)

<table>
<thead>
<tr>
<th></th>
<th>CP-SwoS</th>
<th>CP-SwS</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMFM - 66 score:</td>
<td>70</td>
<td>54</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total GMFM-88 score (%)</td>
<td>88</td>
<td>70</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

(p< 0.05)
### Study IV

**Results: GMFM % (median)**

<table>
<thead>
<tr>
<th>Activity</th>
<th>CP-SwoS</th>
<th>CP-SwS</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Lying &amp; Rolling:</td>
<td>100</td>
<td>96</td>
<td>0.271</td>
</tr>
<tr>
<td>B) Sitting:</td>
<td>100</td>
<td>96</td>
<td>0.285</td>
</tr>
<tr>
<td>C) Crawling &amp; Kneeling:</td>
<td>98</td>
<td>93</td>
<td>0.035</td>
</tr>
<tr>
<td>D) Standing:</td>
<td>80</td>
<td>31</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>E) Walking &amp; Running:</td>
<td>72</td>
<td>22</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

(p < 0.05)

![Graph showing GMFM % for different activities](image)
Study IV

Results: GMFM-88 Crawling & Kneeling

<table>
<thead>
<tr>
<th>C) Crawling &amp; Kneeling %:</th>
<th>CP-SwoS</th>
<th>CP-SwS</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>98</td>
<td>93</td>
<td>0.035</td>
</tr>
</tbody>
</table>

Total: 14 items

Item 48: High kneeling 10 sec
19/19 (100%)          14/17 (82%)

Item 51: Walks forward on knees 10 steps
16/19 (84%)            10/17 (59%)

(p < 0.05)
Study IV

Results

No correlation between knee extensor muscle strength (Nm/kg) and GMFM dimension D (%): $r = 0.093$, $p = 0.612$
Study IV

Results - Timed Up and Go (TUG) test (median, range)

TUG: in 32/36 children with CP

<table>
<thead>
<tr>
<th></th>
<th>TD (22/27)</th>
<th>CP-SwoS 19/19</th>
<th>CP-SwS 13/17</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUG test (sec)</td>
<td>8.2 (6.5, 10.6)</td>
<td>11.1 (7.4, 28.6)</td>
<td>25.6 (11.0-70.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mobility device (nr):</td>
<td>2</td>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Study IV

Conclusions

- Children CP-SwoS and CP-SwS performed motor tasks:
  - equally in Lying and Sitting
  - differently in Standing and Walking
  confirming that capacity to perform motor tasks depends on position

- Motor tasks in Crawling & Kneeling were performed similarly despite challenging tasks such as standing and walking on the knees

The question arises whether these findings refer to somatosensory disturbances and difficulties with spatial orientation?
Summary of the thesis

- Investigation of standing posture verified a crouched body position with increased body movements – most obviously in the children who required support to stand.

- Muscle strength measurements indicated equally strong lower limb muscles despite various standing abilities.

- Without vision and during the attention demanding task various solutions were seen ranging from difficulties to maintain posture, to more still body positions, and change of lower limb muscle activity.

- Motor function measurements indicated that the children who stood with support were capable to perform motor activities in Crawling & Kneeling despite difficulties in standing.
Challenge remains to develop methods to measure factors contributing to the multifactorial process of postural orientation during standing

Thank you for your attention!