Development of Segmental Postural Control in Children: Part 1
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Part 1: Learning Objectives
1. Describe how children with motor impairment use compensatory ‘closed chain’ biomechanics
2. Discuss the benefits of an ‘open chain’ approach during assessment and treatment of postural deficits
3. Identify the implications of open and closed kinetic chain patterns on treatment outcomes
4. Describe the implications of segmental trunk control on functional tasks

Presentation Outline
• Course purpose and outline
• Open and Closed Controlled Kinetic Chains
• Overview of the Segmental Assessment of Trunk Control (SATCo)
• Typical and atypical development of trunk control
• Implications of segmental trunk control for functional skills
• Summary discussion

What is observed in neuromotor disability?
A series of frequently seen postures in
Lying
Sitting
Standing
...all impacted by problems of trunk control
...and seen at all GMFCS Levels

Current methods of training trunk control are not effective

Gross Motor Development Curves

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Purpose of this educational session

New theories of postural assessment and training of trunk control
Benefits, challenges and evidence for this approach
Share: impact on pediatric therapy

Open and Closed Chains:
identifying & addressing control problems

Typical Development

Typical development of vertical control

What is movement control?

**Static**: Achieve / maintain neutral vertical position at all joints. Needs rapid response to changing moment signs to prevent joint collapse.

**CONTROLLING JOINT MOMENTS IN THE NEUTRAL VERTICAL POSTURE**

**Active and reactive**: Control of active movement and control during external perturbations (balance). Minimise joint moments during movement.

How do we control the upright posture?

Without appropriate control
A small movement at a joint (joint #2) results in a large joint moment – hard work to control
How do we control the upright posture?

With appropriate control, compensatory movements (joints 1 & 3) ensure that joint moments do not become too large – easy to control.

Objective of Physical Therapy:
to achieve functional goals

- The body is a complex structure
- High level of control needed to achieve functional goals in the ‘normal way’
- So, if control is reduced – neuromotor disability – can functional goals still be achieved?
  …..and in the way that the physical therapist wants?

What is a Chain?

A collection of rigid segments that are connected by joints

A Controlled Open Kinetic Chain?

Control essential at all joints to create/maintain geometry

Cerebral Palsy

• What muscle activity is present?
• What control strategies are used?

Cerebral Palsy

• What muscle activity is present?
• What control strategies are used?
Open Chain
End segment is free of constraint

- Such as single leg standing
- This forms an Open Chain
- Free movement is possible
- Neuromuscular control demands are maximal - at all joints if the position is to be held

Sports Scientists refer to this as closed chain – distal extremity is in contact with a support surface

Controlled Closed Kinetic Chain
Control requirements can vary

A Three-Segment Closed Chain
- a rigid structure

- No movement possible
- No control required
- Human structure –
  - bones (rigid segments)
  - joints
  - muscles (crossing the joints and producing movement)

The head is supported without any active neuromuscular control

Closed Chain

- Use of Closed Chains
- Helps give stability to focus on play / head control
- Simplifies and reduces control demands

THE FOUR-BAR CHAIN
A simple two-dimensional closed chain system

- Movement is possible
- The movement is predictable
- At least one joint requires control
- But which joint?
Closed Chain

- Use of Closed Chains
- Helps give stability to focus on fine motor tasks
- Simplifies control demands

THE FIVE BAR CHAIN

...let's get adventurous!

4 + 1 = ?

- Movement cannot be uniquely defined
- Ensuring a particular geometry requires control at an additional joint i.e. two joints
- Each added segment needs one further joint to be controlled

Closed Chain

- Use of Closed Chains
- Helps give stability to focus on fine motor tasks
- Simplifies control demands

Closed Chains: Summary

- Full neuromuscular control may not be present with control severely compromised
- Subtle use of closed chains means a posture can be held – and function achieved
- But... a Physical Therapist needs to know if Closed Chains are being used!

‘Closed Chain’ Exercises

- Orientation to gravity
- Control issues of open and closed chains – the important factor for neuro-physical therapists

Open chain exercise e.g. straight leg raise
Open Chain or Closed Chain?

Does equipment that we provide for children create opportunities for control learning? Should it do so?

A Combination of Open and Closed Chains

- Such as standing or double stance period of walking
- Selected movement is possible
- But not all joints need full active control even in TD children and adults

Complete information about presence or absence of control cannot be made without specific testing

Sitting Balance

- A combination of Closed and Open Chains
- The spine/trunk will be under full active control as long as joints are not at end of range

SITTING BALANCE?

- Combination of Closed and Open Chains
- A further Closed Chain has been introduced
- Only the cervical spine is unquestionably under active control

Open Chains are essential for learning control
How many children do you know who….
• …sit with one or both hands on knees or on a support?
• …cannot maintain an upright trunk posture without supportive seating or a harness/breastplate?
• …can sit ‘hands free’ but show thoracic and/or lumbar collapse?
A posture may be from choice but are you sure it is not compensation due to poor control?

Collapse of the Lumbar Spine into Full Flexion
• Semi-Closed Chain (Posterior ligaments fully extended in tension)
• Control force introduced without active control

Collapse of the spine into full flexion or full extension
Control force present but without active control

What are we training?
Cerebral palsy

Does this child have full control of the neutral vertical trunk posture?
In sitting?
In standing?

Another subtle closed chain
• Resting on posterior knee ligaments
• Helps give stability in standing
• Simplifies control demands

Cerebral Palsy
Development of Segmental Postural Control in Children: Part 1

Full knee extension / hyperextension forms a Pseudo-Closed Chain. No need for active control.

The therapy mix of Open and Closed Chains

Application of theory

How effective is our therapy?
Closed Chains can occur during therapy sessions

Confident controlled ‘bridging’
Weakness or poor control

But do Closed Chains matter?
- Lax ligaments, hypotonia, muscle imbalance
- Potential compensatory tightness e.g. hip flexors
- Possible longer term joint strain
- Closed Chain functional skills may not lead to true skills with active control
- Limiting future development

Simple strategies can help

Instruction given “Soft knees”
Can the Closed Chain be a positive aspect of therapy?

What can we do as Physical Therapists?
- Be aware of the Closed Chain, especially during therapy sessions
- Develop therapy techniques to improve Open Chain control

Careful use of the Closed Chain
- Give support (close the chain) – if needed but be sure that…
  - You know you are doing so
  - It is essential
  - It is the minimal possible

Introduction to the Segmental Assessment of Trunk Control SATCo
- Manual Support
  - Shoulders
  - Axillae
  - Superior Scapula
  - Lower Ribs
  - Below Ribs
  - Pelvis
  - No Support

SATCo elements
- Trunk Segment
  - Head
  - Upper Thoracic
  - Mid Thoracic
  - Lower Thoracic
  - Upper Lumbar
  - Lower Lumbar
  - Full Trunk

Sufficient distal segments are supported to ensure effective stability of the top-most supported segment
How is the SATCo done?

Child is seated on a bench

Feet on floor or a stool

Manual support is provided for upright posture

Strap system for thigh and pelvic alignment

Head is upright

Hands and arms free

At each segmental level, 3 aspects of control are assessed

Static

Static (steady state)
Align and maintain 5 seconds

H

MT

UT

LFT

Reactive

Hold alignment while turning head or reaching

React

Maintain or quickly return to upright when perturbed

Active

Hold alignment while turning head or reaching

LFT = Learning Full Trunk Control

FTC = Has Full Trunk Control

Questions about Open and Closed Chains and SATCo?

Longitudinal development of trunk control in typically developing and preterm born infants

Psychometric study of SATCo in preterm infants

• Aim to examine the reliability, validity and responsiveness of the SATCo in preterm infants (4 to 12 m CA)
• N= 20 preterm + 20 full-term
• SATCo monthly, Alberta Infant Motor Scale (AIMS) at 4, 8 and 12m CA
• Preliminary results on full-term control infants (correlation btw SATCo and AIMS)

Alberta Infant Motor Scale (AIMS) (Piper & Darrah 1994)

• Norm-referenced Ax from birth to 18 m
• 3 scoring criteria- posture, weight-bearing area, anti-gravity movement
• 4 positions- prone, supine, sit, stand (4 sub-scores to a total score)
• Validated in preterm infants (Pin et al, 2010)
Development of Segmental Postural Control in Children: Part 1

Preliminary findings

- 4 m - no significant correlation (Spearman correlation)
- 8 m -

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<th>Prone</th>
<th>Supine</th>
<th>Sit</th>
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<td>0.586</td>
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Longitudinal changes in trunk control in TD infants

- Aim to systematically investigate and document the development of trunk control in typically developing full-term infants from 4 to 12 m using the SATCo
- N = 20 TD infants
- SATCo and AIMS biweekly
- Preliminary results based on 10 infants

Developmental trend of trunk control in TD infants

A New Paradigm for Exploring Sensorimotor Contributions to Trunk Control

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Cerebral palsy (CP) is the most common disability in children (2.4–3/1000 live births)

- 48% are unable to walk independently
- 34% lack stable sitting balance

Lack of postural control is severely limiting

8 year old with severe CP (GMFCS V)
Trunk control develops spontaneously in typical infants by 6-8 months of age

Segmental progression is present in typical and atypical development

Segmental support and SATCo allow more specific analysis of the development of reaching

3 month infant reach

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Reach and trunk control are tightly correlated until full control is achieved.

What level of trunk control is necessary for stepping?

Three sensory systems contribute to postural control

Three sensory systems contribute to postural control

Three sensory systems contribute to postural control

Segmental contributions to supported stepping

Segmental Approach Collaborations at University of Hartford

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Development of Segmental Postural Control in Children: Part 1

Experimental-based System Identification

Postural Control System

Tilt stimulus

Body sway (θ)

Transfer Functions via Fourier Transforms

Similar results between CP and TD based on segmental level of control

What are the Processes of Change?

Targeted Training for Head & Trunk Control

Home Based

20-30 min/day; 5-6 days/wk; for 9 months

Recheck every 8 wks for device adjustment

Challenges for Data Interpretation

Level of Support Changes

Children Grow Quickly

Functional implications of segmental trunk control

Neural Control Changes
Aim:
Investigate the relationship between the segmental control of the trunk and gross motor function.

Subjects:
- 92 children
- Cerebral Palsy
- GMFCS I-V

Method
Linear regression analysis

Dependent Variables
- PEDI
- GMFM

Independent Variables
- Age
- Neuromotor Disability
- SATCo

Results
Positive relationship between the segmental level of trunk control and age with GMFM and PEDI Mobility.

Segmental trunk control could explain:
- 38%-40% of the GMFM variation
- 32%-37% of the PEDI variation

Predicted increase in GMFM by SATCo level
Conclusion
Segmental level of trunk control is important for gross motor function and mobility skills in children with CP.

Trunk control is a fundamental determinant of gross motor function.

Introduction to a segmental treatment approach:
Targeted Training

Our synthesis

Targeted Training
To gain sequential control of the upright posture

- Optimal vertical position
- Define the start point of intervention using the SATCo (the targeted joint)
- Give firm support directly beneath the targeted joint
- Use of open chains to ensure control learning
- Challenge to active and reactive control
- Means of progression
- Adequate input over time to allow movement learning

Targeted Training
Case Study

- Edith, 3 years 10 months
- Quadriplegic Cerebral Palsy
- Tight SCM
- Jenx Monkey prone standing frame
- Comprehensive physio programme
**Targeting Equipment**

30 minutes 5 days / week

- Head support
- High tray to help stabilise shoulder girdle
- Firm support for trunk stability

Closed Chain therapy to achieve neutral vertical head posture

**Targeting Equipment**

- Head support to keep head centred
- Gradual increase of range as control was gained

**Summary**

- Closed Chain Targeted Training to ensure control learning of neutral vertical posture
- Gaining head control in neutral vertical carries over into functional skills
  
  Targeted Training shows excellent potential for head control problems

**Targeted Training:**

Case examples from University of Oregon

**Example of child with severe disability  GMFCS Level 5**

8 year old quadriplegic cerebral palsy

**Training Program**

- ORLAU 1000 swivel walker
- Head Control
- Upper Thoracic Control
- Home program
  
  20-30 min
  
  5-6 days per week
  
  6 months

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Example of child with moderate disability
GMFCS Level 3

8 year old diplegic cerebral palsy

Training Program
- School program
  - 20-30 min
  - 5 days per week
  - 6 months
- Targeted training Equipment
  - Upper lumbar
  - Progressed to lower lumbar hips

Performance on standing skills

Before

After

Discussion
Examples for practical application

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Bibliography: Development of Segmental Postural Control Part 1 and 2.


