Reduction of Kyphosis Progression from Backpack Loading in the Cervical and Thoracic Spinal Segments

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Loads on the Spine

- The spine is under constant load
- Movement capabilities similar to those of a ball and socket joint
- Mechanically:
  - *Annulus fibrosus* acts like a coiled spring
  - *Nucleus pulposus* acts like a ball bearing
- Postural changes have varying effects on lumbar disc stress
Spine Physiologic Range of Motion

- Spinal motion is measured in degrees of range of motion, or ROM.
  - Flexion
  - Extension
  - Lateral Flexion
  - Rotation
Exercise | Lateral Shear (N) | A-P Shear (N) | Compression (N)
--- | --- | --- | ---
Relaxed | 0 | 2 | 122
Left Twist | 33 | 70 | 778
Extension | 0 | 135 | 1164
Flexion | 0 | 31 | 558
Left Bending | 125 | 93 | 758

Kyphosis

- Vertebrae become wedge shaped
- “Hunchback” & anterior head carriage
- Kyphotic curve exceeds 20-45° range
- Mild to severe back pain
- Issues with breathing, digestion, limited physical function, body image
Kyphosis and Backpacks

- Spinal stress puts pressure on upper thoracic vertebrae
- Shift in center of gravity
- Produces a posterior moment by increasing moment arm
- Asymmetrical lumbar compression increases kyphotic angle from forward trunk lean & anterior head carriage
- Recommended: 10-15% BW & tighter straps
Previous Studies

Placement of load

- Back carry
- Asymmetric carry
- Head carry
Back Carry

- Commonly used by school students, hikers, travelers, etc.
- Biomechanically-favorable upgrades: hip & sternum straps
  - Reduce energy expenditure & distributes some of the load onto the hips & chest
  - Decrease the moment arm
- Negative moment on the spine counteracted by repositioning center of gravity
Asymmetric Carry

- Supplies a load that is not evenly distributed along the spine
- Wearer must lean to the unloaded side

<table>
<thead>
<tr>
<th></th>
<th>8 kg SYM</th>
<th>8 kg ASYM</th>
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</thead>
<tbody>
<tr>
<td>Trunk Rotation</td>
<td>0.003 ± 1.76</td>
<td>3.1 ± 3.4</td>
</tr>
<tr>
<td>Shoulder Asymmetry</td>
<td>-0.03 ± 7.2</td>
<td>18 ± 17.8</td>
</tr>
<tr>
<td>Frontal Plumbline</td>
<td>1.9 ± 6.5</td>
<td>28.3 ± 16.7</td>
</tr>
<tr>
<td>Sagittal Plumbline</td>
<td>73.8 ± 27.9</td>
<td>21.9 ± 18.1</td>
</tr>
<tr>
<td>Angle of lumbar Lordosis</td>
<td>-13 ± 16.5</td>
<td>-3.8 ± 5.7</td>
</tr>
<tr>
<td>Angle of Kyphosis</td>
<td>-5.9 ± 22.2</td>
<td>2.3 ± 4.7</td>
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Head Carry

- Carriage of up to 70% of body weight
- Little energy expenditure
- Aligns load’s center of mass with body’s
- Con: Stability only on flat surfaces
Head Carry

Unloaded

African woman

$E_{cm,k}$

$E_{cm,p}$

$E_{cm,tot}$

$30\% M_b$ load
Proposed Product: *The Balance-Carry Backpack*

- Back carry component

- Front carry with weighted strap pockets
  - HDPE cards used as inserts onto backside of strap to adjust weight
  - Wide straps to reduce nerve pain and circulation interference
  - Pockets on the front for water bottle, phone, etc.

- Maximize load while minimizing spinal strain

- Decreased moment arm reduces moment on spine
The Balance-Carry Backpack

\[ \Sigma M_{CM} = m_1 g \cdot r_1 \]

\[ \Sigma M_{CM} = 25\%BW\cdot9.81\cdot r_1 \]

\[ \Sigma M_{CM} = m_2 g \cdot r_2 - m_3 g \cdot r_3 \]

\[ = 20\%BW\cdot9.81\cdot r_2 - 10\%BW\cdot9.81\cdot r_3 \]

\[ = 10\%BW\cdot9.81(r_2-r_3) \]
Verifying our Proposed Product

<table>
<thead>
<tr>
<th>Interventions</th>
<th>Subjects</th>
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<tbody>
<tr>
<td>Without Backpack</td>
<td>200 (100 male and 100 female) students</td>
</tr>
<tr>
<td>With Backpack of 15% BW</td>
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<tr>
<td>With 10 minute walk with Backpack of 15% BW</td>
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<tr>
<td>Measurement of Craniovertebral Angle (CVA), and</td>
<td></td>
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<tr>
<td>Sagittal Shoulder Posture</td>
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Needs & Timeline Predictions

Backpack Design
6 - 12 Months
- High Density Polyethylene
- Pocket Strap Design and Construction
- Additional Backpack Materials
- Facility costs
- Research Staff Funding

Verification
3 Months
- CHEK Forward Head Caliper
- Student Subjects
- Facility costs
- Research Staff Funding

Mass Production & Marketing
6 - 12 Months
- Patent Approval
- Marketing Team
- Advertising Costs
References


