Effect of Posture on Lumbopelvic Muscle Morphometry and Geometry in Adult Spinal Deformity Patients from Upright MRI

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Adult Spinal Deformity (ASD)

- Previously thought primary causes were degenerative changes in intervertebral discs or facet joints leading to asymmetric collapse and deformity [1]

- Recent work highlights importance of lumbopelvic muscle [2] – however all supine imaging

Goal:
To assess the effect of **upright postures, in comparison to supine**, on **lumbopelvic musculature** & geometry in pre-operative **ASD** patients using upright magnetic resonance imaging (MRI)
Methodology – Imaging & Postures

- 0.5T upright MRI (MROpen, Paramed)
  - T1-weighted Spin Echo sequences, 5 postures (Fig. 1)

- Measures:
  - **Muscles**: multifidus/ erector spinae, psoas major, gluteus, iliopsoas (Fig. 2)
  - **Muscle parameters**: muscle cross-sectional area (CSA), position (radius & angle) (Fig. 2)
  - **Bony geometry parameters**: pelvic tilt (PT), pelvic incidence (PI), sacral slope (SS), L3-S1 lumbar lordosis (LL)

Fig 1. Four of five postures, supine not shown.

Fig 2. Lumbar and pelvic parameters, muscle CSA (yellow, red outlines), radius (mm), angle (degrees), pelvic tilt, pelvic incidence, sacral slope, L3-S1 lumbar lordosis. A) Lumbar measures. B) Pelvic measures. C) Pelvic bony geometry measures. D) Lumbar bony geometry measures
Study Design

Aim 1) Effect of posture on pelvic muscle & geometry parameters
   
   Repeated Measures
   
   ANOVA

Aim 2) Relationships between muscle & geometry changes with posture
   
   Coefficient of Determination
   
   $R^2$

Aim 3) Upright MRI relative to radiographic measures
   
   ICC (3,1) & Pearson’s Correlation

Aim 4) Intra- and inter-rater repeatability
   
   Intra-class correlation coefficient
   
   ICC(3,1)

**Study Design**

3 Raters

Subset (275 scans)

8 Pre-operative ASD Patients

5 Posture Scans

2 Regions: Lumbar & Pelvic

1 Rater

2 Segmentations
Results – Muscle

**Standing to supine had few effects** & interactions, standing to **flexion had more notable effects** on lumbopelvic muscle parameters

**Gluteus**: level dependent effects
- Ex: Standing to supine CSA (S4/S5) increased 17% (Fig 1)

**Multifidus/erector spinae**: flexion to other postures
- Increase CSA up to 11%, radius up to 4% (Fig 2, 3)

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Fig 1. Increase in gluteus CSA at S4/S5, increased 17% from standing (A) to supine (B)

Fig 2. Decrease in multifidus/erector spinae CSA at L4/L5, decreased 11% from standing (A) to flexion (B).

Fig 4. Multifidus/erector spinae CSA by side and level, shown by posture
Results – Geometry

Posture affected PT (Fig 1 A), SS, and L3-S1 LL, but not PI (Fig 1 B)

Results – Correlation

Positive correlation expected between changing muscle CSA & bony geometry → passive muscle deformation with changing posture

However, lack correlation in 60-75% of measures
  • Between CSA & L3-S1 LL, or CSA & PT (Fig 2)
  • Correlations present were muscle, level, and individual specific
Results – Correlations

Relationships between muscle CSA & bony geometry tended to be **stronger with supine CSA**, compared to standing CSA

• Ex. Cobb angle more strongly correlated with supine muscle CSA side difference

Results – Repeatability

<table>
<thead>
<tr>
<th></th>
<th>Lumbar ICC(3,1)</th>
<th>Pelvic ICC(3,1)</th>
<th>Bony Geometry ICC(3,1)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
<td>Average</td>
</tr>
<tr>
<td>Intra-Rater</td>
<td>0.93</td>
<td>0.89-0.97</td>
<td>0.74</td>
</tr>
<tr>
<td>Inter-Rater</td>
<td>0.79</td>
<td>0.53-0.93</td>
<td>0.65</td>
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<tr>
<td>Upright MRI &amp; X-ray</td>
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</tbody>
</table>

**Fig 1. Example plot of lumbar muscle side-to-side CSA versus Cobb angle, for standing CSA (top), and supine CSA (bottom)**

<table>
<thead>
<tr>
<th>ICC(3,1)</th>
<th>Interpretation</th>
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<tbody>
<tr>
<td>0.90-1.00</td>
<td>excellent</td>
</tr>
<tr>
<td>0.80-0.89</td>
<td>good</td>
</tr>
<tr>
<td>0.70-0.79</td>
<td>fair</td>
</tr>
<tr>
<td>0.00-0.69</td>
<td>poor</td>
</tr>
</tbody>
</table>

3) **Aim**

4) **Aim**
Discussion

• Study confirms previous supine findings (Fig 1)
  • Flexion reduced extensor CSA [1] – observed MF/ES

• Lack difference muscle measures standing to supine
  • Suggests supine MRI representative of standing morphometry
  • Exceptions: gluteus CSA & radius, psoas major radius & angle
    • Important for biomechanical modeling

• Effect of posture on PT, SS, and L3-S1 LL but not PI - aligns with clinical expectation (Fig 1)
  • Standing to flexion, larger changes PT (18° decrease) & smaller change L3-S1 LL (5° decrease)
  • Suggests preferentially flexing from hips, rather than lumbar [2,3]

• Relationships
  • Changing muscle CSA & geometry patient & level specific – unable to assume relationships across groups
  • Supine vs. standing muscle CSA & bony geometry – stronger relationships supine, standing may enable uncovering more nuance around lumbopelvic muscle

• Promising repeatability - feasibility of ASD upright imaging of lumbopelvic muscle & geometry in tandem

Conclusion

• **Supine MRI is generally representative** of upright muscle morphometry, except for certain instances
  • Notable **effects of flexion** on muscle morphometry & bony geometry

• **Promising repeatability**
  • Upright imaging of muscle morphometry & bony geometry, in tandem

• Work helps lay foundation for furthering understanding of ASD upright muscle morphometry
  • Could help inform future biomechanical modeling, mitigation, and treatment of ASD