Dynamics of the meniscus under the weight-loading condition: investigation using special upright magnetic resonance imaging

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I have no financial conflicts to disclose
Introduction

- Meniscal extrusion is related to knee malalignment, tibiofemoral cartilage loss, and meniscal injury, leading to osteoarthritis\(^1\).

- Previous studies which investigated meniscus dynamics using a special loading device with magnetic resonance imaging (MRI) in a supine position have been conducted\(^2,3\).

- Another study showed the large meniscus movement in knee ROM exercise under loading\(^4\).

Evaluation of meniscal morphology under upright physiological load condition is not done.
Introduction

Because weight loading during MRI is rarely performed, Meniscal morphology under the upright weight-loading condition remains unknown.

Purpose

To investigate the meniscal shift of the medial and lateral meniscus in healthy adults under full weight loaded and unloaded conditions using both supine and upright MRI
Methods

- Eighteen adult volunteers without previous medical history of the right knee
- 13 males and 5 females with a mean age of 21.8±3.1 years
- Using special MRI which is capable of imaging in any position (Gravity MRI, 0.4T, Hitachi, Japan)
- The examination positions of MRI:
  - supine position, double-leg upright (DLU) position and single-leg upright (SLU) position with full extension of knee

MRI apparatus  | Supine position  | Upright position
---|---|---

T1-weighted images in the coronal and sagittal plane with a slice thickness of 2 mm.
The evaluation slice of medial meniscus

coronal

The evaluation slice and measurement method of coronal plane

- At the midpoint of the anterior- posterior diameter of the medial tibia on sagittal plane and where medial collateral ligament (MCL) is best depicted on coronal plane.

- The medial shift rate \((a/A \times 100\%)\) was measured.

  \[A: \text{overall width of the medial meniscus (mm)}\]
  \[a: \text{medial shift of medial meniscus against the tibial wedge (mm)}\]

sagittal

The evaluation slice and measurement method of sagittal plane

- At the midpoint of the medial femoral condyle on coronal plane.

- The anterior shift rate \((b/B \times 100\%)\) and posterior shift rate \((c/C \times 100\%)\) were measured.

  \[B: \text{overall width of the medial meniscus of anterior part (mm)}\]
  \[b: \text{anterior shift of medial meniscus against the tibial wedge (mm)}\]
  \[C: \text{overall width of the medial meniscus of posterior part (mm)}\]
  \[c: \text{posterior shift of medial meniscus against the tibial wedge (mm)}\]
The evaluation slice of lateral meniscus

The evaluation slice and measurement method of coronal plane

- At the midpoint of the anterior- posterior diameter of the lateral tibia on sagittal plane.

- The medial shift rate \((d/D \times 100\%)\) was measured.

  \(D\): overall width of the lateral meniscus (mm)
  \(d\): lateral shift of the lateral meniscus against the tibial wedge (mm)

The evaluation slice and measurement method of sagittal plane

- At the midpoint of the lateral femoral condyle on coronal plane.

- The anterior shift rate \((e/E \times 100\%)\) and posterior shift rate \((f/F \times 100\%)\) were measured.

  \(E\): overall width of the lateral meniscus of anterior part (mm)
  \(e\): anterior shift of the lateral meniscus against the tibial wedge (mm)
  \(F\): overall width of the lateral meniscus of posterior part (mm)
  \(f\): posterior shift of the lateral meniscus against the tibial wedge (mm)
Statistical analysis

- Medial and lateral meniscal shift rates (%) between supine, DLU and SLU conditions were compared using analysis of Variance (ANOVA).

- Significant outcomes ($P < 0.05$) in ANOVA were further examined using a multiple comparisons test.
Results: medial meniscus using ANOVA

<table>
<thead>
<tr>
<th>shift rates (%)</th>
<th>Supine</th>
<th>DLU</th>
<th>SLU</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>[amount of shift (mm)]</td>
<td>7.3±5.8</td>
<td>20.0±8.8</td>
<td>21.5±7.6</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Medial shift rate (%)</td>
<td>[0.6±0.5]</td>
<td>[1.8±0.8]</td>
<td>[2.0±0.6]</td>
<td></td>
</tr>
<tr>
<td>Anterior shift rate (%)</td>
<td>33.8±5.9</td>
<td>35.1±7.3</td>
<td>33.1±7.6</td>
<td>0.61</td>
</tr>
<tr>
<td>[amount of shift (mm)]</td>
<td>[3.8±1.0]</td>
<td>[3.7±1.1]</td>
<td>[3.6±1.0]</td>
<td></td>
</tr>
<tr>
<td>Posterior shift rate (%)</td>
<td>-25.3±8.5</td>
<td>-27.1±9.6</td>
<td>-26.8±8.2</td>
<td>0.41</td>
</tr>
<tr>
<td>[amount of shift (mm)]</td>
<td>[-4.7±1.5]</td>
<td>[-4.5±1.6]</td>
<td>[-4.2±1.3]</td>
<td></td>
</tr>
</tbody>
</table>

The difference among the three conditions for medial shift rate of the medial meniscus was significant. Contrally, no significant differences were observed for the anterior and posterior shift rates of the medial meniscus.
**Results: lateral meniscus using ANOVA**

<table>
<thead>
<tr>
<th>shift rates (%) [amount of shift (mm)]</th>
<th>Supine</th>
<th>DLU</th>
<th>SLU</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral shift rate (%) [amount of shift(mm)]</td>
<td>-1.2±11.8</td>
<td>2.7±11.1</td>
<td>4.5±10.8</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Lateral shift rate (%) [amount of shift(mm)]</td>
<td>[-0.1±1.0]</td>
<td>[0.2±1.0]</td>
<td>[0.5±1.1]</td>
<td></td>
</tr>
<tr>
<td>Anterior shift rate (%) [amount of shift(mm)]</td>
<td>-20.6±14.3</td>
<td>-14.7±12.2</td>
<td>-8.9±14.9</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Anterior shift rate (%) [amount of shift(mm)]</td>
<td>[-2.5±1.5]</td>
<td>[-1.4±1.7]</td>
<td>[-1.1±1.8]</td>
<td></td>
</tr>
<tr>
<td>Posterior shift rate (%) [amount of shift(mm)]</td>
<td>-78.0±19.6</td>
<td>-63.7±18.7</td>
<td>-57.8±19.2</td>
<td>0.001</td>
</tr>
<tr>
<td>Posterior shift rate (%) [amount of shift(mm)]</td>
<td>[-7.1±1.5]</td>
<td>[-5.8±1.8]</td>
<td>[-5.4±1.7]</td>
<td></td>
</tr>
</tbody>
</table>

In the lateral meniscus, there are significant difference about lateral, anterior and posterior shift rates among the three conditions.
Multiple comparison test in medial meniscus

The medial shift rate was significantly greater in DLU and SLU positions than in the supine position.

No significant difference was observed between the DLU and SLU.

<table>
<thead>
<tr>
<th>Position</th>
<th>Medial shift rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine</td>
<td>7.3</td>
</tr>
<tr>
<td>DLU</td>
<td>20</td>
</tr>
<tr>
<td>SLU</td>
<td>21.5</td>
</tr>
</tbody>
</table>
Multiple comparison test in lateral meniscus

The lateral shift rate was significantly greater in the SLU position than in the supine position, but no significant difference was observed in the DLU position (P=0.21).

Anterior and posterior shift rates in the lateral meniscus were significantly greater in DLU and SLU positions than in the supine position.
Conclusions

In the upright weight-loading condition for healthy adults

- In medial meniscus, significantly medial shift was shown but anterior and posterior shift were not.
- In lateral meniscus, significantly lateral, anterior and posterior shift was shown although there was no significant difference between double-leg upright and single-leg upright positions.

References