Structural Properties of the Intact Proximal Hamstring Origin and Evaluation of Varying Avulsion Repair Techniques: An In Vitro Biomechanical Analysis

Mark G. Hamming, MD
Sports Medicine Fellow

Co-Authors:
Marc J. Philippon, MD
Matthew T. Rasmussen, BS
Fernando P. Ferro, MD
Travis L. Turnbull, PhD
Christiano A. C. Trindade, MD
Robert F. LaPrade, MD, PhD
Coen A. Wijdicks, PhD
Disclosure

• No personal financial conflicts to report

• Study funded by Smith & Nephew

• Institute receives research support from the following companies:
  o Acumed
  o AlloSource
  o Arthrex
  o Biomet
  o Ceterix Orthopaedics
  o ConMed Linvatec
  o DePuy Synthes
  o OREF
  o Össur
  o Smith & Nephew
  o Sonoma Orthopedics
Background

Anatomy of the Attachments of the Proximal Hamstrings

Conjoined (5): Biceps Femoris & Semitendinosus
3.6 cm x 2.1 cm

Semimembranosus (7)
3.3 cm x 1.5 cm

Proximal Rupture: Poor healing potential without surgery → Pain, muscle retraction, loss of strength

Net force (N/kg) experienced by hamstrings during different activities

<table>
<thead>
<tr>
<th></th>
<th>Walking (N/kg)</th>
<th>Jogging (N/kg)</th>
<th>Sprinting (N/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal Swing</td>
<td>9.60</td>
<td>15.16</td>
<td>46.54</td>
</tr>
<tr>
<td>Foot Strike</td>
<td>9.55</td>
<td>5.28</td>
<td>31.30</td>
</tr>
<tr>
<td>Stance</td>
<td>20.17</td>
<td>21.23</td>
<td>31.89</td>
</tr>
</tbody>
</table>

This information guided the development of the loading protocol designed to be representative of functional activities for a 80 kg individual during rehabilitation.

Schache et al. 2010.
Clinical Relevance

• Debilitating injury if untreated

• Repairs often heal, but are rehab protocols overly conservative?

• Knowledge of forces & repair strength at time zero can better guide rehab
  - weight-bearing, hip/knee flexion angles, range of motion (ROM)

Purpose

1. Determine structural properties of intact proximal hamstrings

2. Test common repair techniques to determine optimal repair strategies
Materials

24 Fresh-frozen human cadaveric hemi-pelvises
   Mean Age: 54.5 yrs, (range, 34-63)
   Mean BMI: 25.8, (range, 14.8-43.5)
   All Male

Two groups of anchors
   Small – 2.9 mm OSTEORAPTOR
   Large – 5.5 mm HEALICOIL PK
Methods

1. Intact Origin
2. 2L: Two, Large 5.5 mm anchors.
3. 2S: Two, Small 2.9 mm anchors.
4. 5S: Five, Small 2.9 mm anchors.

2L, 2S, 5S Groups:
- All anchors double-loaded
- All stitches loaded in anchors with #2 Ultrabraid
- All stitching passed using Modified Kessler stitching
Methods

• Specimens randomly assigned to groups
• Ischial tuberosity potted in poly(methyl methacrylate) and underwent one of two conditions (intact or repair) based on group assignment
• Cryoclamps attached to the actuator of a dynamic tensile testing system used for fixation
• Subjected to a progressive cyclic loading protocol
Data Analysis

- One-way analysis of variance (ANOVA)
  - Number of cycles to failure
  - Maximum cyclic load

For ANOVA's that demonstrated a statistically significant difference, a post hoc Games-Howell test was conducted to determine statistical significance between groups.
Results

Table 1. Results of Cyclic Testing

<table>
<thead>
<tr>
<th></th>
<th>Intact</th>
<th>2S</th>
<th>2L</th>
<th>5S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displacement (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ 50th Cycle of 25-200 N</td>
<td>1.14 ± 0.57</td>
<td>17.36 ± 4.71</td>
<td>6.52 ± 3.92</td>
<td>4.44 ± 2.72</td>
</tr>
<tr>
<td>@ Maximum Cyclic Load</td>
<td>22.34 ± 6.51</td>
<td>21.99 ± 6.67</td>
<td>20.11 ± 7.86</td>
<td>32.64 ± 7.99</td>
</tr>
<tr>
<td>Stiffness (N/mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ 1st Cycle of 25-200 N</td>
<td>104 ± 47</td>
<td>45 ± 10</td>
<td>49 ± 14</td>
<td>47 ± 17</td>
</tr>
<tr>
<td>@ 50th Cycle of 25-200 N</td>
<td>127 ± 48</td>
<td>91 ± 22</td>
<td>89 ± 24</td>
<td>99 ± 13</td>
</tr>
<tr>
<td>Number of Cycles to failure</td>
<td>326 ± 43</td>
<td>81 ± 39</td>
<td>98 ± 70</td>
<td>259 ± 80</td>
</tr>
<tr>
<td>Maximum Cyclic Load</td>
<td>1405 ± 157</td>
<td>474 ± 145</td>
<td>543 ± 245</td>
<td>1164 ± 294</td>
</tr>
</tbody>
</table>

1 One specimen failed prior to 50th cycle. Result is for n=5.
2S = repair with two small anchors; 2L = repair with two large anchors; 5S = repair with five small anchors

For maximum cyclic load, there is no statistically significance difference between intact and 5S or between 2L and 2S. There is a statistically significant difference between intact/5S and 2L/2S.
Results

Table 2. Mechanism of cyclic failure for each specimen

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Mechanism of Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact No. 1</td>
<td>Tendon-bone interface</td>
</tr>
<tr>
<td>Intact No. 2</td>
<td>Musculotendinous-clamp interface</td>
</tr>
<tr>
<td>Intact No. 3</td>
<td>Musculotendinous-clamp interface</td>
</tr>
<tr>
<td>Intact No. 4</td>
<td>Tear of semitendinosus</td>
</tr>
<tr>
<td>Intact No. 5</td>
<td>Tendon-bone interface</td>
</tr>
<tr>
<td>Intact No. 6</td>
<td>Tendon-bone interface</td>
</tr>
<tr>
<td>2S No. 1</td>
<td>Suture anchor pullout</td>
</tr>
<tr>
<td>2S No. 2</td>
<td>Suture-tissue interface</td>
</tr>
<tr>
<td>2S No. 3</td>
<td>Suture anchor pullout + suture-suture anchor interface</td>
</tr>
<tr>
<td>2S No. 4</td>
<td>Suture anchor pullout + suture-suture anchor interface</td>
</tr>
<tr>
<td>2S No. 5</td>
<td>Suture anchor pullout</td>
</tr>
<tr>
<td>2S No. 6</td>
<td>Suture anchor pullout</td>
</tr>
<tr>
<td>2L No. 1</td>
<td>Suture anchor pullout + suture-suture anchor interface</td>
</tr>
<tr>
<td>2L No. 2</td>
<td>Suture anchor breakage</td>
</tr>
<tr>
<td>2L No. 3</td>
<td>Suture anchor breakage</td>
</tr>
<tr>
<td>2L No. 4</td>
<td>Suture anchor breakage + suture anchor pullout</td>
</tr>
<tr>
<td>2L No. 5</td>
<td>Suture anchor breakage</td>
</tr>
<tr>
<td>2L No. 6</td>
<td>Suture anchor breakage + suture anchor pullout</td>
</tr>
<tr>
<td>5S No. 1</td>
<td>Suture anchor pullout + suture-suture anchor interface</td>
</tr>
<tr>
<td>5S No. 2</td>
<td>Suture anchor pullout</td>
</tr>
<tr>
<td>5S No. 3</td>
<td>Suture anchor pullout</td>
</tr>
<tr>
<td>5S No. 4</td>
<td>Suture-tissue interface</td>
</tr>
<tr>
<td>5S No. 5</td>
<td>Tear of semitendinosus</td>
</tr>
</tbody>
</table>

2S = repair with two small anchors; 2L = repair with two large anchors; 5S = repair with five small anchors

Intact/5S groups had more intrinsic tendon failures as denoted by blue box

2L group predominantly failed by suture anchor breakage/pullout as denoted by red box
Discussion/Conclusion

• First study to investigate structural properties

• (Intact ~ 5S )>>( 2L ~ 2S)
  – Difference may be underestimated due to mode of failure of intact/5S

• More progressive rehab appears permissible with 5S repair

• Clinical trials needed to assess outcomes with immediate full active hip & knee ROM
References Cited


