Weight Bearing Vs Non-Weight Bearing Exercises for Anterior Cruciate Ligament (ACL) Injuries

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Weight Bearing Vs Non-Weight Bearing Exercises for ACL Injuries

- Safety Issues
  - ACL Strain
  - Patellar Tendon Autograft Donor Site
- Review of Randomized Clinical Trials
Safety Issues: Excessive Strain on Graft?

- NWB place excessive strain on the graft
- WB involves less anterior shear, therefore less strain on graft
- WB results in greater joint compression, adding stability to the joint during exercise

- Measured strain in ant. bundle of partially torn ACL (N=2)
- Strain measured during NWB and WB activities
- Strain measurements normalized to 80lb Lachman test
- NWB leg extensions through full ROM may be harmful to graft

- Strain behavior in injured ACL and ACL graft may not be the same
- Large variability in strain between 2 subjects
- Data has limited value

![Graph showing strain behavior in different activities and subjects.](image)
Anterior Tibial Translation As Indirect Measure of ACL Strain


- Measured tibial translation during quad MVIC at 15°, 30°, 45°, 60°, and 75° of knee flex
- 22 controls, 10 ACL deficient, 10 ACL reconstructed knees
- Translation occurred at 15 - 60° for all groups
- Significantly less when compared to 89N and Max Manual KT 1000 testing
- Amount of tibial translation during quad MVIC may not be clinically relevant.

- 11 subjects with ACLD
- Measured anterior tibial translation
- Leg extension vs squat
- Greater anterior tibial translation with leg extension exercise at knee flexion angles less than 64°

- Measured ant tibial translation during isometric leg extension and leg press at 30° and 60° of knee flexion
- 19 ACL deficient knees
- Greater anterior tibial translation during isometric leg extension at 30°
Anterior Translation Vs ACL Strain?

• Based on evidence, translation may be minimized if quad contractions are performed at angles greater than 60°

• Increased translation does not necessarily translate to harmful ACL or ACL Graft strain

- Review of a series of experimental studies measuring In-Vivo ACL strain during a variety of WB and NWB activities
- Strain gauge inserted into anterior-medial bundle of intact ACL during arthroscopy
- Strain measures were referenced to differential length of ACL between unloaded and 200N anterior shear load

<table>
<thead>
<tr>
<th>Rehab Activity</th>
<th>Type</th>
<th>Peak Strain</th>
<th># Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric Quad, 15° flexion, 30 Nm</td>
<td>NWB</td>
<td>4.4%</td>
<td>8</td>
</tr>
<tr>
<td>Squatting with Sport Cord</td>
<td>WB</td>
<td>4.0%</td>
<td>8</td>
</tr>
<tr>
<td>Isometric Gastr, 15° flexion, 15 Nm</td>
<td>NWB</td>
<td>3.5%</td>
<td>6</td>
</tr>
<tr>
<td>Squatting</td>
<td>WB</td>
<td>3.6%</td>
<td>8</td>
</tr>
<tr>
<td>Isometric Quad, 30° flexion, 30 Nm</td>
<td>NWB</td>
<td>2.7%</td>
<td>18</td>
</tr>
<tr>
<td>Stair Climbing</td>
<td>WB</td>
<td>2.1%</td>
<td>5</td>
</tr>
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<thead>
<tr>
<th>Rehab Activity</th>
<th>Type</th>
<th>Peak Strain</th>
<th># Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric Quad, 60° and 90° flexion, 30 Nm</td>
<td>NWB</td>
<td>0.0%</td>
<td>8</td>
</tr>
<tr>
<td>Isometric Hamstring, 15°, 10Nm</td>
<td>NWB</td>
<td>0.6%</td>
<td>8</td>
</tr>
<tr>
<td>Isometric Hamstring, 30°, 60°, 90°, 10Nm</td>
<td>NWB</td>
<td>0.0%</td>
<td>8</td>
</tr>
<tr>
<td>Isometric Gastr, 30° flexion, 15 Nm</td>
<td>NWB</td>
<td>0.2%</td>
<td>6</td>
</tr>
<tr>
<td>Quad/Hamstring Co-Contraction, 30°</td>
<td>NWB</td>
<td>0.4%</td>
<td>8</td>
</tr>
<tr>
<td>Quad/Hamstring Co-Contraction, 60 and 90°</td>
<td>NWB</td>
<td>0.0%</td>
<td>8</td>
</tr>
</tbody>
</table>

- Strain guage inserted into anterior medial bundle of ACL in 11 subjects
- Compression load of 40% body weight to simulate bilateral stance load
- Compared ACL strain between compression vs non-compression condition for:
  - Anterior-Posterior Shear
  - Internal and External Rotation Torques
  - Varus and Valgus Torques

- Weight bearing may not be as protective as we think.
- The rationale that weight bearing protects the ACL for supporting the use of WB exercise may be in error.
Implications from the Data

- The level of strain recorded in the various activities do not seem to be very high
- Greater external loads will result in greater strain
- Differences in ACL strain between WB and NWB may not be meaningful
- With properly placed ACL graft, strain patterns between WB and NWB exercise may be similar
- WB activities may not really reduce the strain in the ACL when other combined loads are applied
Should The Absence of Strain Really Be The Goal?

• Some tension and strain may actually enhance the histological quality and tensile strength of the healing ligament

• What is not known is the critical value between helpful vs harmful strain
Safety Issues: B-PT-B Donor Site
Implications in Post-op B-PT-B Autograft Reconstruction Rehab

- Careful not to overload the quadriceps in positions of greater knee flexion (>60 degrees) in early stages of rehab following B-PT-B autograft.
- Donor site may need about 6-8 weeks to heal before it can tolerate aggressive loading.
- Can initiate resistance exercises early but provide enough time for donor site healing before aggressive progression is initiated.
Clinical Trials Comparing WB and NWB Exercise in Post ACL Reconstruction Rehabilitation

Bynum, et al, 1995
Morrissey, et al, 2000
Mikkelsen, et al, 2000

- 97 Subjects, B-PT-B, autograft
- Randomly assigned to NWB (N = 47) or WB (N = 50) group.
- 1 year follow-up
- Laxity, Lysholm and Tegner Scores, Knee Motion, Patellofemoral Pain, Satisfaction Rating

<table>
<thead>
<tr>
<th>NWB</th>
<th>WB</th>
</tr>
</thead>
</table>
| **0-8 weeks** | - Cocontraction isom  
- Low resistance leg ext  
- Low resistance cycling  
- Isokinetic hamstrings  
- Proprioceptive Training? | - Knee bends, Leg Press  
- Hamstring curls  
- Low resistance cycling  
- Proprioceptive Training?  
- Fwd/Bwd walking against - Sportcord  
- Slow motion jogging against Sportcord |
| **12 weeks** | Unrestricted Quadriceps PRE’s | Side-to-Side jumping against Sportcordon |

<table>
<thead>
<tr>
<th></th>
<th>NWB</th>
<th>WB</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 weeks</td>
<td>- Treadmill jogging</td>
<td>- Sport specific exercises with Sportcord</td>
</tr>
<tr>
<td></td>
<td>- Fwd/Bwd running,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Single leg deep knee bends</td>
<td></td>
</tr>
<tr>
<td>24 weeks</td>
<td>- Isokinetic quads</td>
<td>- Progressive running and Sport specific training</td>
</tr>
<tr>
<td>9 months</td>
<td>- Non-cutting, jumping, pivoting sports</td>
<td>- Non-cutting, jumping, pivoting sports</td>
</tr>
<tr>
<td>12 months</td>
<td>- Unrestricted activity</td>
<td>- Unrestricted Activity</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>TABLE 5</th>
<th>Postoperative comparison of study groups</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Group&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lysholm score&lt;sup&gt;b&lt;/sup&gt;</td>
<td>86</td>
</tr>
<tr>
<td>Tegner activity level&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6</td>
</tr>
<tr>
<td>Subjective rating&lt;sup&gt;b&lt;/sup&gt;</td>
<td>86%</td>
</tr>
<tr>
<td>Patellofemoral pain&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10 (24%)</td>
</tr>
<tr>
<td>Extension deficit (&gt;5°)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Flexion deficit (&gt;10°)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0</td>
</tr>
<tr>
<td>Lachman 0/1 +&lt;sup&gt;c&lt;/sup&gt;</td>
<td>28 (88%)</td>
</tr>
<tr>
<td>Pivot shift 0/trace&lt;sup&gt;c&lt;/sup&gt;</td>
<td>29 (90%)</td>
</tr>
<tr>
<td>KT-20 mean side-to-side difference&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.2 (mm)</td>
</tr>
<tr>
<td>KT-max mean side-to-side difference&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.3 (mm)</td>
</tr>
</tbody>
</table>

<sup>a</sup> OKC, open kinetic chain; CKC, closed kinetic chain.

<sup>b</sup> *N = 41 for OKC, 44 for CKC, 85 for combined group.*

<sup>c</sup> *N = 32 for OKC, 32 for CKC, 64 for combined group.*

**TABLE 6**

Postoperative KT-1000 arthrometer differences (in millimeters) among chronic subgroups

<table>
<thead>
<tr>
<th>Time</th>
<th>Group&lt;sup&gt;a&lt;/sup&gt;</th>
<th>OKC</th>
<th>CKC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>KT-1000 (20 pound)</td>
<td>KT-1000 (max)</td>
</tr>
<tr>
<td>4–12 weeks</td>
<td>11</td>
<td>1.8</td>
<td>3.0</td>
</tr>
<tr>
<td>13–52 weeks</td>
<td>6</td>
<td>2.0</td>
<td>3.1</td>
</tr>
<tr>
<td>&gt;12 months</td>
<td>15</td>
<td>2.6</td>
<td>3.5</td>
</tr>
</tbody>
</table>

<sup>a</sup> OKC, open kinetic chain; CKC, closed kinetic chain.
Sooner than expected return to ADLs was only item on survey favoring WB training. Return to sport not different between groups.

Training programs, by design, not equivalent in progressing functional retraining. Progression favored WB. Might explain survey result.

No difference in functional outcome measures.

Concluded there was more laxity in OKC group but data did not indicate any real change in laxity from early rehab to 1 year. Variable subject numbers also minimize credibility of data.

- 36 subjects, B-PT-B autograft
- Randomly assigned to NWB or WB group
- Groups differed in type of hip and knee strengthening exercise
- Laxity measured with Knee Signature System arthrometer after 4 weeks of training

- **WB group**: Leg Press, supine position, 90° to 0°, no description of load amount
- **NWB group**: Leg extensions, hip extensions, cuff weights, machines, no description of load amounts
- Balance and proprioception in both groups, no description of the activities
- Both groups allowed stationary cycling
Morrissey MC, Hudson ZL, Drechsler WI, et al.  

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWB</td>
<td>9.46mm</td>
<td>10.25mm</td>
</tr>
<tr>
<td>WB</td>
<td>9.87mm</td>
<td>9.98mm</td>
</tr>
</tbody>
</table>

- No difference in laxity between groups
- Not certain if intensity of exercise was what is typically done in clinical practice
- Pain and Function scores not reported in this study
- Stated no difference in these variables, cited other unpublished work

- 44 subjects, B-PT-B autografts
- Randomized to WB Vs WB+NWB
- Following randomization, matched based on age, gender, activity level
- Laxity with KT-1000, isokinetic quad and hamstring strength
- Proportion of subjects returning to pre-injury activity level

<table>
<thead>
<tr>
<th>Time</th>
<th>Exercises</th>
</tr>
</thead>
</table>
| 0–2 weeks     | Passive knee extension exercises  
                 Active knee flexion exercises  
                 **Electrical muscle stimulation (if unable to contract quadriceps and/or hamstrings)** |
| 2–6 weeks, add: | Patella mobilization (if needed)  
                 Gait training  
                 Closed kinetic chain exercises (quadriceps and hamstrings)  
                 Hamstring training (gradually isokinetically)  
                 Proprioceptive and balance training  
                 Stationary biking (when 100° of knee flexion) |
| 6–12 weeks, add: | Functional exercises *(stair walking, skip the rope, “skating” on a slide board)* |
| 3–4 months, add: | Jogging straight ahead on an even surface |
| 4–6 months, add: | Jogging and running on an uneven surface  
                 Jogging with turns 90°, 180°, 360°  
                 Cutting with 45° changes of direction  
                 Acceleration and deceleration running  
                 Sport-specific exercises |

**WB + NWB group**

- isokinetic concentric/eccentric leg extensions, 90°-45°, initiated 6 weeks following surgery
- progress to 90°-10° over 6 week period

**Table 3** Mean values ±SD of anterior knee laxity (mm), KT-1000-max, preoperatively and 6 months postoperatively in the ACL injured and healthy contralateral knee (n=22 in each group)

<table>
<thead>
<tr>
<th></th>
<th>CKC only</th>
<th></th>
<th>CKC + OKC</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preop</td>
<td>Postop</td>
<td>Preop</td>
<td>Postop</td>
</tr>
<tr>
<td>Injured knee</td>
<td>15.5±3.6</td>
<td>9.1±3.2</td>
<td>15.6±2.9</td>
<td>8.5±2.2</td>
</tr>
<tr>
<td>Healthy knee</td>
<td>7.7±1.9</td>
<td>7.4±2.1</td>
<td>7.8±2.4</td>
<td>7.3±2.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quadriceps Strength Index (% of uninvolved limb), 6 months post-op</th>
<th>WB</th>
<th>WB + NWB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Con: 30/sec</td>
<td>65.7</td>
<td>78.8</td>
</tr>
<tr>
<td>Ecc: 30/sec</td>
<td>65.7</td>
<td>83.2</td>
</tr>
<tr>
<td>Con: 120/sec</td>
<td>72.2</td>
<td>79.7</td>
</tr>
<tr>
<td>Ecc: 120/sec</td>
<td>69.8</td>
<td>79.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Subjects Returning to Pre-injury Level of Sports Activity</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>(9.5 months)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WB + NWB</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>(7.5 months)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$X^2$ test significant, $p < .05$, NNT = 3
Summary of RCT’s

- Adding NWB exercises do not appear to increase laxity or cause injury
  - Manner in which NWB exercise is applied may be a factor (delay aggressive resistance, use protected ranges)
- Two studies do not report differences in outcome measures between groups
- Mikkelsen indicates that adding NWB resistance training in a controlled manner to a well rounded WB and functional retraining program can improve quad strength and return to pre-injury sports activity without increasing laxity