

Wilk - ACL Strain Values During Specific Movements/Exercises



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**PRINCIPLES OF ACL REHAB**  
*ACL Strain*

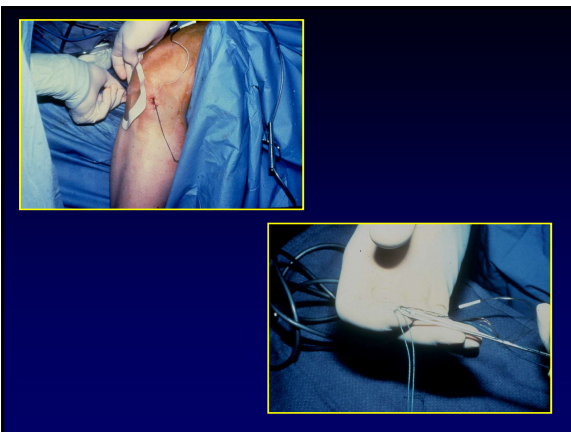
- ACL strain during motion
- ✓ Passive ROM
- ✓ Active ROM
- Resisted movements

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**PRINCIPLES OF ACL REHAB**  
*ACL Strain*

- ACL strain during motion
- ✓ Passive ROM
- ✓ Active ROM
- Resisted movements

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**"ACL Strain"**

- *Strain*: the ratio of deformation to the tissue's resting length
- Change in length
- Change resting length
- Normal strain: change in length
- Abnormal strain: loads beyond yield point, permanent deformation

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# Wilk - ACL Strain Values During Specific Movements/Exercises

## PRINCIPLES OF ACL REHAB

*Immediate Motion*

- ACL stress during motion
- Passive rang of motion
- **Active range of motion**
- Resisted movements

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## OKC vs CKC

### OKC vs CKC With Resistance

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## Increased Resistance during OKC & CKC Exercises & Its Effect on ACL Strain

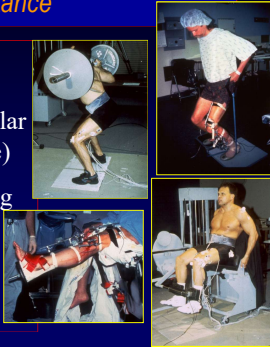
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### CKC & OKC Exercises *Resistance*

- Squats with resistance (sportcord) & without resistance resulted in similar strain patterns (magnitude)
- Knee extension: increasing resistance resulted in an increase in ACL strain

*Beynnon: AJSM '95*



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### ACL *In Vivo* STRAIN DURING BICYCLING

*Fleming, et al ORS 1996*

- No significant difference for 6 riding conditions
- Relatively low compared to other rehab
- Greatest strain when knee has reached greatest extension

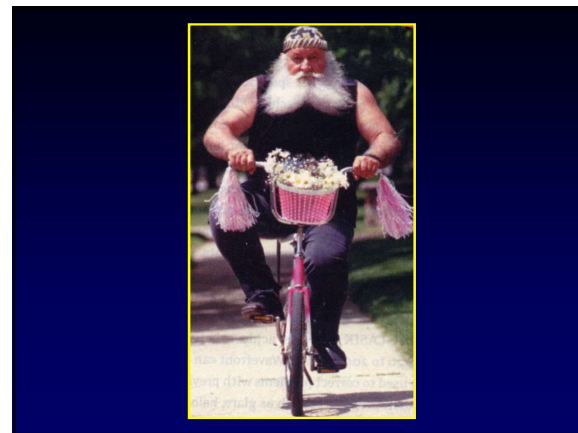


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### ACL *In Vivo* STRAIN DURING BICYCLING

RPMS	Power	Strain
60	75	2.6%
60	125	2.8%
60	175	2.2%
90	75	2.4%
90	125	1.8%
90	175	1.6%

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*Fleming, Beynnon, Renstrom, et al: Arthroscopy '99*

- Strain gauge implanted in anteromedial bundle of the ACL
- 5 subjects tested with normal ACL (intact)
- Stairmaster 4000PT performed at 80 & 120 steps per minute cadence
- *Results: 80 steps cadence :2.69 %  
120 steps cadence :2.76 %*
- *No significant difference between 2 speeds*

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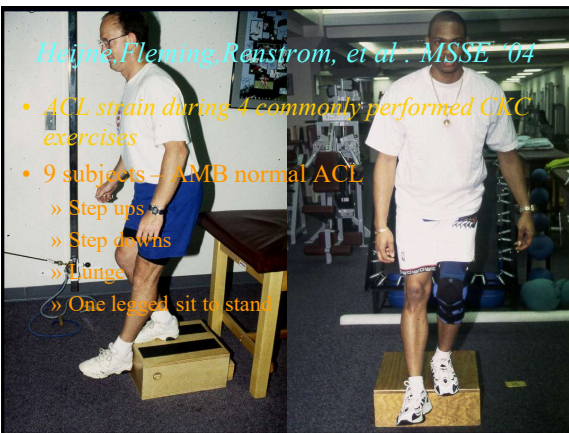


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*Fleming, Renstrom, et al: J Orthop Res '01*

- Strain gauge implanted within AM bundle of ACL
- 6 subjects tested with EMS applied to gastroc
- Tested at various knee flexion angles
- *Results: 5 degrees of flexion: 2.8 %*  
*15 degrees of flexion: 3.5%*  
*30 & 45 deg flexion: no strain on ACL*  
*co-contraction of Q & G: higher strain values*  
*co-contraction of H & G: higher than isolated H*

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*Heijne, Fleming, Renstrom, et al : MSSE '04*

- ACL strain during 4 commonly performed CKC exercises
- 9 subjects – AMB normal ACL
  - One legged sit to stand 2.8 + 0.27
  - Step downs 2.6 + 0.34
  - Step ups 2.5 + 0.36
  - Lunge 1.9 + 0.50

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**ACL In Vivo STRAIN**  
*Johnson, Beynnon, et al*

• Isometric quads @ 15 deg. (30 Nm)	4.4%
• Squat w/ sportscord	4.1%
• AROM 45N boot	3.8%
• Lachman test (150N)	3.7%
• Squat w/o sportscord	3.4%
• AROM	2.8%
• Co-contraction Q/H at 15 deg.	2.8%

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**ACL In Vivo STRAIN**  
*Johnson, Beynnon, et al*

• Isometric quads @ 30 deg. 30NM	2.7%
• Anterior drawer (150N)	1.8%
• Isometric hams @ 15 deg.	0.6%
• Co-contraction Q/H at 30 deg.	0.4%
• Passive ROM	0.1%
• Isom quads @ 60°, 90° (30 Nm)	0.8%

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### ACL Strain References

Beynnon,Johnson,Fleming,et al: *AJSM* '01  
Fleming,Renstrom,Beynnon,et al: *J Biomech* '01  
Fleming, Renstrom, Ohlen, et al: *J Orthop R* '01  
Fleming, Beynnon, Renstrom: *Arthroscopy* '99  
Fleming,Beynnon,Renstrom,et al: *AJSM* '98  
Beynnon,Johnson,Fleming,et al: *JBJS* '94  
Beynnon,Howe,Pope,et al: *Int Orthop* '92

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### ACL In Vivo STRAIN During Walking

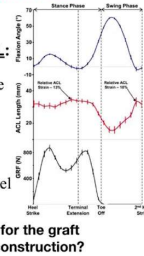
**In vivo measurement of ACL length  
and relative strain during walking**

Taylor et al *J Biomech.* 2013

**Relative strain in the ACL:**

✓  $13 \pm 2\%$  during mid-stance  
when the knee was near full  
extension

✓  $10 \pm 7\%$  near the end of  
swing phase, just prior to heel  
strike



Should we be concerned for the graft  
with walking post ACL reconstruction?

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