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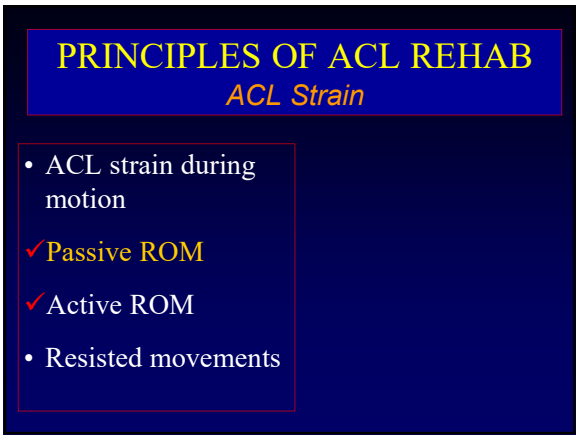

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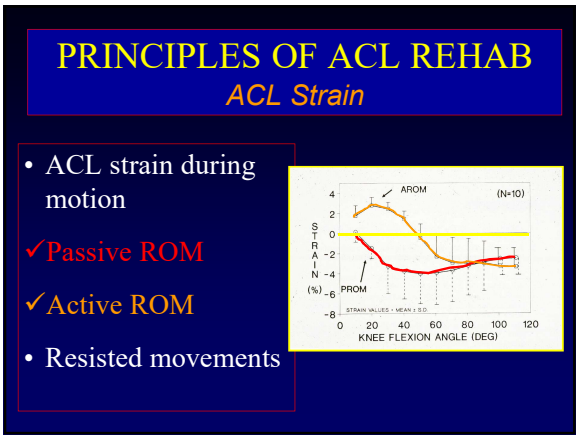

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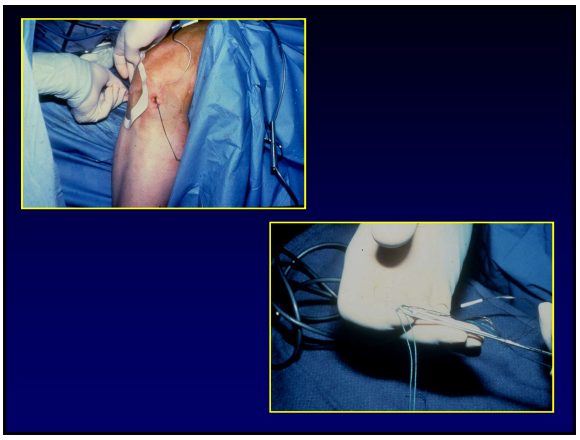

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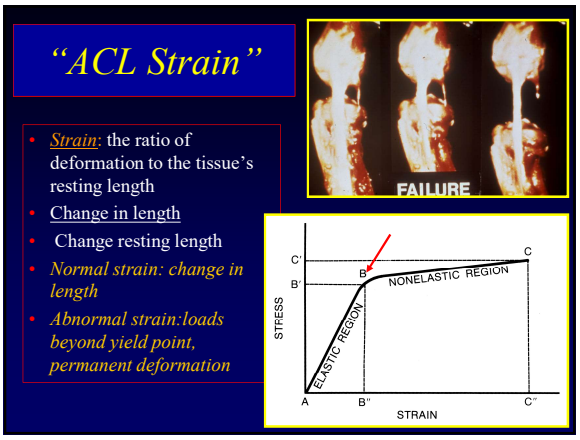

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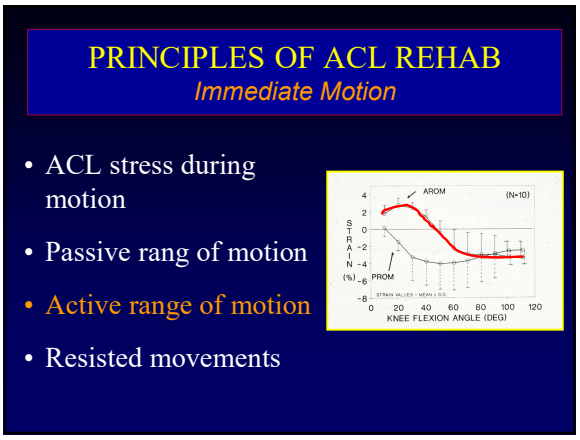

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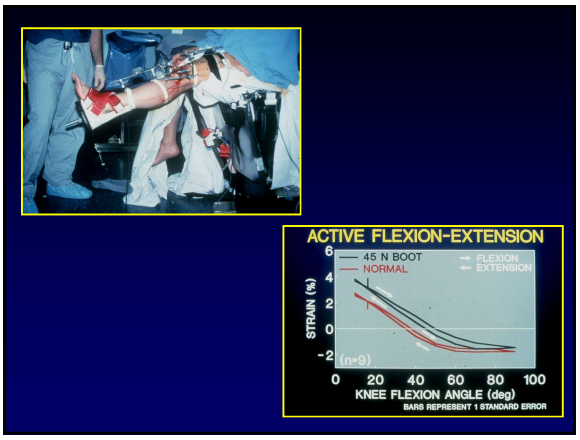

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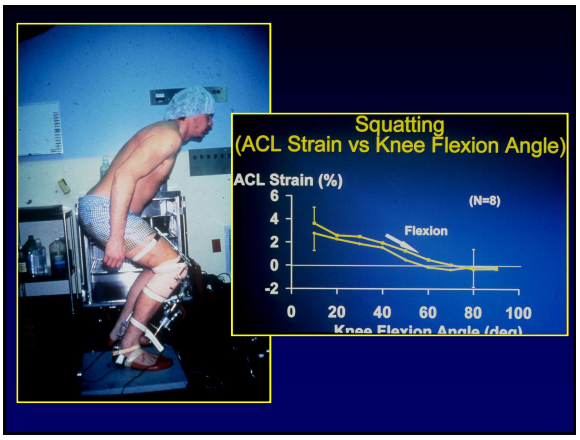

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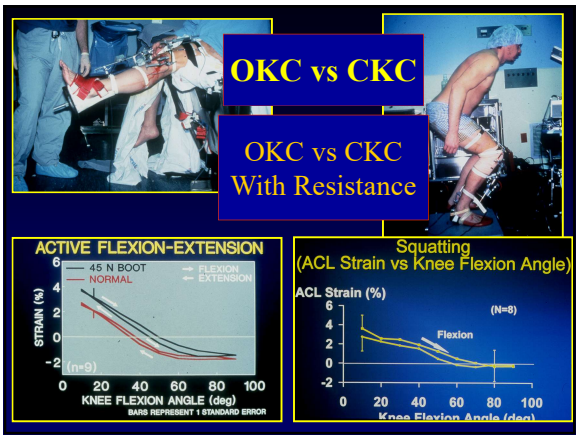

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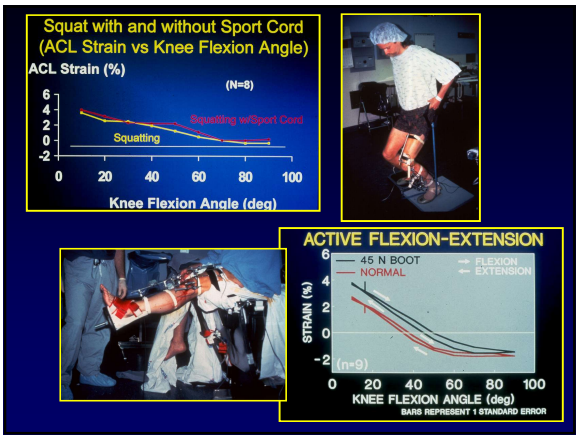

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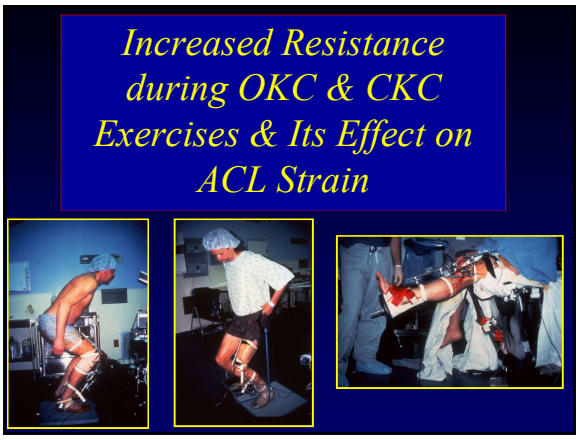

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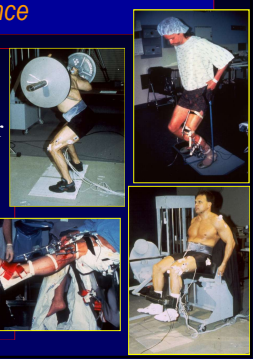
CKC & OKC Exercises
Resistance

- 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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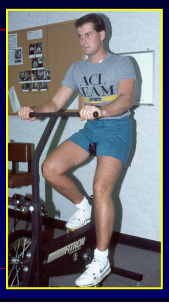
ACL *In Vivo* STRAIN DURING BICYCLING
Fleming, et al ORS 1996

- 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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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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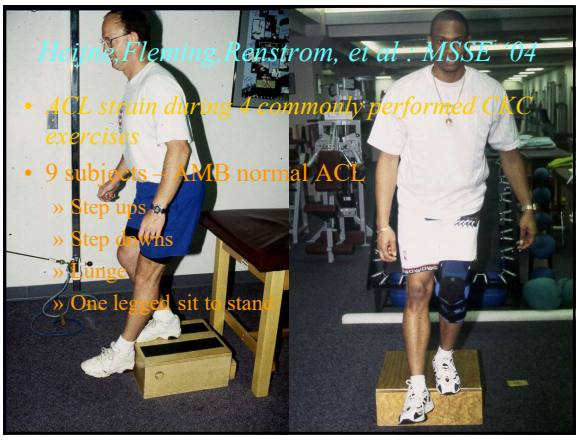

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Heijne,Fleming,Renstrom, et al : MSSE '04

- *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^{o}, 90^{o} (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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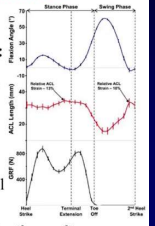
ACL *In Vivo* STRAIN
During Walking

In vivo measurement of ACL length and relative strain during walking

Taylor et al J Biomech. 2013



Relative strain in the ACL:

✓ 13±2% during mid-stance when the knee was near full extension

✓ 10±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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