Symmetric or Sufficient for Return-to-Sport after ACL Injury?
Science Meets Practice Session
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INTRODUCTION:

ACL Reconstruction after ACL Injury

- Standard of care for ACL injuries in the United States
- Generally expected to:
  - Restore joint stability
  - Allow for return to preinjury activity/sport

Poor RTS Outcomes after ACLR:

- Meta-analysis findings:
  - When examining return to any level of sport over any period of time:
    - 82% return
  - When examining return to preinjury level of sport participation:
    - only 63% return
  - When examining return to competitive sports:
    - only 44% return

Associated Sequelae:

Decreased Patient-Reported Knee Function

- Approximately one-third of individuals report an outcome of “less than acceptable” 2 years after ACLR
- 30% of individuals demonstrate KOOS-QOL scores <44/100 at 2 years

Increased Risk of 2nd ACL Injury

- High school age athletes: ~30% sustained 2nd ACL injury within 2 years of RTS
- Recent meta-analysis data: 23% of athletes <25 years old sustained 2nd ACL injury after RTS
What Typically Guides RTS Decisions?

- Post-operative timeline
- Medical team/surgeon opinion
- Objective measures of function/performance
- Of objective measures, most used:
  - Strength
  - Performance measures
  - Often evaluated using symmetry measures:

Debate Regarding Symmetry Measures after ACLR:

- Appropriate comparison for involved limb?
- Uninvolved limb de-conditioning?
- Bilateral injury effects?

Purpose:

- To examine the evidence in support of evaluating symmetry measures (strength, performance, movement) vs. evaluating absolute performance measures (sufficiency) after ACLR
- Make clinical recommendations for practical use of symmetry and “sufficiency” measures in RTS decision-making after ACLR

Symmetric:

Symmetry and Additional Knee Injury

Grindem 2016, Br J Sports Med

- RTS test battery completed at 6 and 12 months post-ACLR including:
  - Isokinetic quadriceps strength
  - SL hop tests
  - Self-reported function
- Tracked additional knee injuries over 24 months
- Lower quadriceps strength symmetry in those with reinjury (75.0% vs. 84.4%)
- When grouped by quadriceps LSI> or < 90%:
  - Quadriceps LSI >90%: 12.5% sustained reinjury
  - Quadriceps LSI <90%: 33.3% sustained reinjury

Kyritsis 2016, Br J Sports Med
• 158 male professional athletes tested prior to RTS
  • Isokinetic strength, hop and agility tests
  • Tracked over time for occurrence of graft rupture
• Discharge criteria:
  • Isokinetic quadriceps symmetry: >90% LSI
  • Single hop, triple hop, crossover hop: >90% LSI
  • Running t test: <11 seconds
  • Completed on-field sport-specific rehab
• Met all discharge criteria: 10.3% sustained graft rupture
• Did not meet discharge criteria: 33.3% sustained graft rupture

• Drop landing mechanics tested at time of RTS in 56 young athletes
• 2nd injury surveillance over 1 year post-RTS
• Side-to-side asymmetries in sagittal plane knee moment
  • Approximately 3 times higher odds of 2nd ACL injury (OR=3.3)

_Symmetry and Return-to-Sport Success_
_Tool 2017, J Orthop Sports Phys Ther_
• 115 young athletes previously cleared to RTS
• How many met recommended RTS criterion cutoffs?
  • Strength LSI, hop test LSI, IKDC scores
• Association between meeting cutoffs and continuing in sport participation over 1 year post-RTS
• Only 28% met both quadriceps and hamstring LSI >90%
• Those that met both quadriceps and hamstring LSI >90%:
  • Continued in sports participation over the year post-RTS at higher proportions (81%) than those that did not meet both cutoffs (60%)

_Symmetry and Knee Function_
_Schmitt 2012, JOSPT_
• 55 young athletes previously cleared to RTS after ACLR and 35 healthy controls
• Quadriceps strength tested at RTS
• Symmetric (HQ; Quad LSI≥90%), Asymmetric (LQ; Quad LSI<90%)
• Compared IKDC scores and hop test performance
• Asymmetric quad strength group – Lower IKDC scores at time of RTS
• Asymmetric quad strength group – Worse hop test performance at time of RTS

Ithurburn 2018, Knee Surg Sports Traumatol Arthrosc

• 76 young athletes tested at time of RTS clearance and 1 year later
• Quadriceps strength symmetry at RTS
  • Symmetric (HQ; Quad LSI≥90%)
  • Asymmetric (LQ; Quad LSI<90%)
• KOOS and IKDC at 1 year
• Asymmetric quad strength group at RTS – Lower KOOS-Sport and IKDC scores at 1 year
• Asymmetric quad strength group at RTS – Lower proportions of “functional recovery” at 1 year


• 85 patients after ACLR were tested at 6 months and 1 year post-surgery
• 4 single-leg hop tests at 6 months (single, triple, crossover, 6m-timed)
• IKDC at 1 year
• IKDC scores categorized as within/outside normal range of age- and sex-norm values
• Higher SL hop test symmetry at 6 months = increased odds of normal IKDC scores at 1 year

SUFFICIENT:

Review of Meta-Analyses:

• When examining return to competitive sports: only 44% return (Ardern 2011, Br J Sports Med)
  • Ipsilateral reinjury rate: 10%
  • Contralateral reinjury rate: 12%

Limb Symmetry Indexes (LSI’s): Reasons for concern
• Uninvolved limb de-conditioning
• Bilateral injury effects
  • Is the function of the uninvolved limb adequate for comparison?

**Uninvolved limb de-conditioning**

*Appell 1993, Sports Med*
• Muscle atrophy
• Immobilization: lose 3-6% strength/day

*Thom 2001, Acta Physiol Scand*
• Up to 40% decrease of initial 1 RM strength in 10 days

**Bilateral injury effects – Neuromuscular alterations**

• Lower neural excitability in **BOTH** limbs after ACL reconstruction compared to healthy control subjects

• Spinal-reflexive excitability and corticospinal excitability lower in both limbs compared to controls at 2 weeks post-ACLR

*Pietrosimone 2015, J Athl Train*
• 4 years post-op ACLR
• Hoffmann reflex higher **bilaterally** compared to controls (p=0.03)
  • Injured: 0.27 ± 0.12; Uninjured: 0.28 ± 0.16; Control: 0.20 ± 0.13
• Active motor threshold (AMT) higher in injured limb vs. controls
  • No difference in uninjured limb
• Lower quadriceps muscle activation in **BOTH** limbs after ACL injury

*Lynch 2013, J Orthop Sports Phys Ther*
• 49% with lower quad activation 1 months after ACL injury

*Urbach 1999, Med Sci Sports Exerc*
• 4 months post-injury (N=22 ACL, 21 healthy, all men)
• Quadriceps activation lower **bilaterally** compared to controls (p=0.026-0.031)
  • Injured: 83.9 ± 2.3%; Uninjured: 84.7 ± 2.2%
  • Controls: 95% CI: 90.0-93.7%

*Pietrosimone 2015, J Athl Train*
• 4 years post-op ACL reconstruction
• Quadriceps activation lower bilaterally compared to controls (p=0.002)
  • Injured: 88 ± 12%; Uninjured: 88 ± 12%; Control: 96 ± 4%

_Hart 2011, Knee Surg Sports Traumatol Arthrosc_

• 4 years post-op ACL revision
  • 76% with activation failure (<95%) in both reconstructed and contralateral limb
  • Injured: 83.9 ± 12.0%; Uninjured: 85.5 ± 9.5%

**Bilateral injury effects – Quadriceps Strength**


• 4 months post-injury (N=22 ACL, 21 healthy, all men) Urbach 1999 (Med Sci Sports Exerc)
  • Quadriceps strength (MVIC) lower bilaterally compared to controls
    • Injured: 153 ± 9.6 Nm (p < 0.001)
    • Uninjured: 189 ± 12.4 Nm (p = 0.057)
    • Controls: 216 ± 9.5 Nm


• Quadriceps LSI:
  • Presurgery: 80.4%
  • 6 months post-ACLR: 92.5%
  • Insufficient (per healthy controls) at 6 months post-ACLR despite acceptable LSI > 90%

_Hiemstra 2007, Clin Biomech (Bristol, Avon)_

• 3.5 years post-ACLR
  • Symmetric at all eccentric and concentric velocities
  • Insufficient (per healthy controls) at all eccentric and concentric velocities

_Lynch 2013, J Orthop Sports Phys Ther_

• 1 month post-injury
  • N=188; 63% men
  • Normal quad index (>90%) but bilateral quad activation failure

**Performance Measures**

• No worsening of uninvolved limb measures between 4 months and 6 months post-ACLR
  • Limitation: Fails to account for uninvolved limb changes between ACL injury and 4 months post-ACLR

**Gokeler 2017, Orthop Traumatol Surg Res**
• N=52; 7 months post-ACLR
  • 38 men (23.9±3.5 years); 14 women (21.7±3.5 years)
  • Compared both limbs to previous normative data (Myers 2014; Gustavsson 2006)
    • Matched for sex, age, type of sport
    • Interlimb differences for single hop (men & women) and triple hop (men only)
    • Both limbs lower than norms for single and triple hop

**Performance Measures & Quadriceps Strength**

**Wellsandt 2017, J Orthop Sports Phys Ther**
• 57% achieved 90% LSI’s (quad + hops)
• 29% achieved 90% of pre-operative uninvolved limb function (EPIC)
• 34% who met 90% LSI’s did not meet 90% EPIC measures
• 8 of 11 (4 ipsi, 4 contra) second ACL injuries achieved 90% LSI’s
• 6 of these 8 failed 90% EPIC

• 45 female patients (15 ACLR-U, 15 ACLR-B, 15 controls)
  • Completed testing after RTS clearance
  • Both limbs in ACLR-B and involved limb in ACLR-U had significantly lower quad strength than the uninvolved limb in ACLR-U and both limbs of control subjects

**Alternate RTS Benchmarks:**
• Collection of pre-injury data
  • Provides patient-specific data of functional and performance levels before injury
  • Limitations:
    • Time
    • Equipment and resources
    • Determination of important measures
  • Unrealistic in most practice settings
• Normative data:
  • Limitations:
    • Not widely developed
    • Lack comparisons for body size, sport position, etc.
    • De Carlo 1997 (J Sport Rehabil): Hop tests in high school athletes
    • Myers 2014 (Int J Sports Phys Ther): Hop tests in high school and collegiate basketball and soccer players
  • More stringent than 90% LSI's
    • Does 90% equal sufficient?
    • 10% considered to account for normal interlimb asymmetry Myer 2011 (J Orthop Sports Phys Ther), Wilk 1994 (J Orthop Sports Phys Ther)
  • Schmitt 2016 APTA-CSM Proceedings
    • N=97 patients (91% female); mean 17.2 years
    • Successful Sports Participation: 1 year post-RTS Tegner score >RTS Tegner score
    • IKDC > 95% & Single Hop for Distance > 95%
      • 5.4 times more likely to achieve successful sports participation
      • 6.9 times more likely in female patients

• RTS Test Battery
  • No single test encompasses all domains needed for return to sport (Adams 2012 J Orthop Sports Phys Ther)
  • Additional measures beyond strength & hops may be needed
  • Lentz 2012 (J Orthop Sports Phys Ther): 55% return to sports at 1 year post-ACLR
    • No knee effusion, no instability episodes, IKDC >93% had greatest likelihood to return to sport
  • Paterno 2017 (Sports Health): Activity and 2nd ACL injury after RTS
    • TSK-11 ≥ 17: 4X more likely to have lower activity levels
    • TSK-11 ≥ 19: 13X more likely to have 2nd ACL injury within 24 months

• Post-Operative ACL Protocols
  • Include bilateral strengthening and performance training
  • Progressive and targeted bilateral training, especially after symmetry attained
• Longer return-to-sport progressions
• Reinjury rate decreased 51% for every month RTS was delayed (up until 9 months) Grindem 2016 Br J Sports Med

CONCLUSIONS:
• Both symmetric and sufficient strength and performance are important
• Both limbs need to be trained during post-operative rehab
• Optimal Return-To-Sport Criteria???
  o Goal: Successful return to sport without further injury
  o Exact benchmarks to aim for still unknown
  o BUT-----Objective testing works!
    ▪ Minimum: Strength and hop performance testing

REFERENCES:


