Russ Paine, PT
Memorial Hermann Ironman
Sportsmedicine Institute
Houston, Texas

CU connection
- Spencer Dinwiddie

Disclosure
- Lite-cure
- mTrigger

Texas Medical Center
Houston
- 21 academic institutions
  14 hospitals
- 33.8 million sq. ft.
  patient care
- 20K MD’s, scientist,
  advanced degreed
- 14 billion annual
  economic impact
- 93,500 employees
- 6.0 million patient visits

Objectives
- Review current trends in ACL rehabilitation
- Review science of ACL rehabilitation
- Demonstrate exercise and functional progression
- Discuss functional testing and return to play criterion

Incidence of ACL Tears NCAA
- Dragoo AJSM 2012
- Artificial turf = 1.4 x higher than grass
- Players 10x more likely to tear ACL during game than practice
- Scrimmages resulted in greater injury than regular practice
**ACL: Return to Play American Football Collegiate and HS Level**

- McCollough AJSM 2012
- 65% able to return
- Subjective questionnaire:
  - 43% able to resume pre-injury level
  - 27% returned, but lower level
  - 30% unable to return (67% other interests
  - 50% feared re-injury)
- 165 players

**Risk of re-injury to ACL**

- 78 patients followed 2 years after ACL Rec.
- 47 controls
- 27 of 125 = ACL tears
- 23 of 27 in ACL Rec. grp.
- 29% = 2nd ACL tear
  - 20% = opposite limb
  - 9% re-tear of graft
    - Female = 24%, Male = 11%
  - Opposite leg injury
    - 24%
  - Paterno AJSM 2014

**Familial Predisposition to ACL Tears**

- Flynn AJSM 2004
- 171 ACL reconstructed pts.
  - 171 normal control
- Parents siblings children (first degree) 2x more likely to have ACL tear than non ACL family history

**Return to Sports 1 year Factors**

- Lentz AJSM 2015
- ACL return to sports:
  - fear factor, quad function, other
- 1 year s/p ACL 73 pts.
  - 46 YRTS 27 NRTS
  - 13 NRTS = other
  - 14 NRTS – Fear confidence
  - Quad weakness assoc. with
    - NRTS – Fear, lack of confidence

**Trend is all functional rehabilitation Don t forget to strengthen!**

- Quad weakness may be masked with functional rehabilitation exercise
- Return to sports develops PF pain, tendinopathy, effusion
- Don’t drop strengthening

**NFL ACL injuries return to play**

- Shah, Andrews AJSM 2010
- 63% returned to play 10.8 mos. After reconstruction
- High draft pick (4th round or higher)
- Greater than 4 years of play in NFL
- Greater odds to RTP
ACL Rehabilitation
Adrian Peterson NFL Running Back

- NFL MVP 2012
- 2,097 yds.
- 6th fastest player to reach 8,000 rushing yards
- 150 yds. 7 games
- ACL PTG, MCLIII 8 mos prior to begin of season
- Joint condition/intensity genetics

Phase I ACL Rehab. ROM and Strength

- ACL/MCL injury on December 24, 2011
- Grade III MCL
- Surgery: Dec. 30, 2011 Dr. Andrews
- Returned to Houston for rehab on January 10

ACL/MCL
Combined ligament injury

- Limits ROM and WB 1st 4-6 weeks
- Locked in extension for 2 weeks, increased flexion 30d per week
- WB with crutches gradual increase, D/C crutches 4-6 weeks

Revascularization of ACL Graft
4 phases

- Avascular graft necrosis
- Revascularization
- Cellular repopulation
- Remodeling & Reorganization collagen fibers (ligamentization Arbel'86 AJSM)
- Recent studies = intraarticular portion revascularizes faster than bone interface sites - diffusion Ntoulia AJSM 2011

Early Phase Motion?
The more you know the more your patient knows

- Inflammatory response: macrophages, cytokines produce scar between graft and bone – 4-10 days
- 6 weeks graft has vascular synovial envelope
- 6 weeks BPig
- 8 weeks Tendon
- Tomita Arthroscopy 2001 dog model
- 20 weeks intrinsic graft revascularization
- Fat pad, synovial tissue, bone tunnels - vascularity

Animal Studies

- Bone Tunnel Healing
- 12 weeks Sharpey's fibers into graft = bone healing
- Pull out failure prior to 12 weeks = tunnel failure, after 12 weeks = midsubstance Rodeo JBJS '93
- BPTB 6 weeks complete incorporation soft tissue incomplete Papageorgiou AJSM 2001
- Bracing 4-6 hyper flexion
**Passive ACL Strain**

- Passive ROM 0% strain 0-60, 70-120 1-2% strain in normal ACL
- Push extension **wait on flexion** (swelling)
- Renstrom AJSM ’86

**Steps To Avoid Extension LOM with quad inhibition/splinting**

- Recognize early factors:
  - Poor quad function – no SLR
  - Flexed knee ambulation
  - Poor pain tolerance
  - MCL/Meniscus repair
- Reversing Lack of Extension
- 1cm = 1° HHD Daniel AJSM ’89

**Biofeedback mTrigger**

**mTrigger Biofeedback**

**Motion Complications**

- Increasing flexion
- Restricted flexion – increased PF Compression
- Flexionator
- Provides hydraulic resistance
- 5 min. on 5 min.off, repeat
- 6 x per day
- HS Biofeedback Prone Hangs

**Laser Therapy**

- Use all modalities, US, topical anti-inflammatory cream
**Immobilization**

- Decrease in proteoglycan content
- Reduces stiffness of cartilage
- Can’t withstand shearing forces

**Compression & Fluid Flow**

- As compression increases, resistance to fluid flow in matrix increases
- GAG’s slow down fluid flow in & out of matrix
- Result = increased stiffness of cartilage
- Stiffness = allows resistance to compression
- Status of articular cartilage determines for return to activity

**Quad Atrophy Still Enigma**

- AJSM March 2005
- VL, VI smaller in ACL def. knee
- VMO – still difficult to activate

**Pre op and Immediate Post op**

- Quad Recruitment biofeedback 10-
- Stimulate Proprioception (gait training, balancing activities) cone amb.
- Extension ROM techniques ERMI device
- SLR’s up to 105°
- Flexion contracture = locate pain
- Ant. Or Post.
- Ant = fat pad impingement
- Post = capsular scarring or h.s. spasm

**ACL Tear**

- Loss of Proprioceptive Function must be Restored before return to sports

- Primary goal – Rehabilitation
- Enhance muscle reaction time
- Stabilization/Recruitment

**Proprioception**

- Loss of proprioception after ACL rupture
- Roberts et al, J Orthop Res, 2000
- Loss of proprioception after ACL reconstruction
Gait Abnormalities

Acute ACL Tears

- Decreased NM input
- Delayed quad firing – heel strike
- Result = flexed knee gait pattern
- Increased PFJRF
- Force patient to squeeze quad at heel strike

Treadmill amb.

Stability

No DJD?

- In a 2004 study of male former soccer players 14 years after an ACL injury, Swedish investigators found no difference between surgically treated and conservatively treated athletes with regard to radiographically detected OA
- ACL reconstruction did not affect prevalence of knee OA in female soccer players 12 years after ACL injury


ACL Deficient Rehabilitation

Risks

- Increased articular cartilage loss long-term
- Murrell – AJSM ’01
  - 130 pts. ACL tears
  - ATS exam. – Reconstruction
  - Time = increased cartilage & meniscus loss
  - 9 x greater cartilage damage – 2 yrs.
  - Vs. 1 mo. ACL rec.

Step 2

Begin Gradual Loading Exercises

Leg Press Best

- MR functional squat
  supine squat low load
  high endurance activity 60 second contractions
- Begin with 5Kg

Ligament loading exercises

- Knee extension 30 to 0 degrees with resistance
- Pivoting, twisting activities - Markolf - JBJS - no protection
- Squatting - Beynon - ’97

AJSM - loads comparable to open chain - no increase in strain with increased load during squat. Knee extension = increased strain with increased load

Quad EMG

WB & NWB

- Wilk AJSM – knee extension = highest EMG = 25 degrees
- Wilk AJSM – leg press = highest EMG = 85 degrees
- Knee extension = requires high EMG due to lack of patellar height near extension
- Huberti = Fpt > Fquad 1st 20d.
  45d Fquad > Fpt = Careful with minisquats
Step 3
Body Weight Control
Functional Squat

- MR Systems Squat Control
- Chair Squats 3x20 D & SL
- Speed Squats 20 sec. 5 sets
- Technique = chest toward ceiling on way up

New Device
Primal 7

- Allows patient to assume normal body positions early using assisted strapping

Testing Functional Hip Abductor Strength

- Crossley AJSM 2011
- A- participant demonstrates good performance
- B- participant demonstrates poor overall and trunk performance
- C- participant demonstrates poor pelvis and hip performance
- D- participant demonstrates poor hip and knee performance

Chris Powers JOSPT 2003

- Controlling femoral position
- Hip ABDuctor, G.Max, Lateral Rotation,
- NWB routine
- Hewitt AJSM ’07 – pelvic control - ACL

Powers: Controlling Hip Internal Rotation, Knee Adducton

- WB routine
- ABD, GMAX, Lateral rotation

Core Strengthening Strengthens Kinetic Chain

- Rotational plyoball: hold VMO contraction
- Lower Abdominal Trunk flexion/extension using Swiss Ball
- Hewitt AJSM ’07 – Core control may be assoc. with ACL tear = pelvic control = kinetic chain = PF control
Hip Flexor Stretch/Strengthening

ACL tear    loss of HS reflex
Rehab.   re gain

• Tsuda – AJSM ’01
• Stim. ACL = reflex HS activity
• Response = Humans versus Solomonow = animal model

High Speed Biodex

• Speeds 180-300 deg./sec.
• May stimulate NM control
• Rapid reversal from ext./flexion
• HS curls, good mornings

Strength

• Preparation for plyometrics and sport specific skills
• Vary Load and Volume
• Involve The Core
• MAKE IT PROPRIORCEPTIVELY CHALLENGING!!!!!

Phase II Functional Strengthening

Strength Load and Volume

• Set load and volume to meet goals of phase
• Periodization Model
• Strength and conditioning
Runners Pose

Cone Reach

When to Run?
- PTG 2 ½ - 3 mos. Treadmill
- Allograft ACL 3-4 mos.
- Timeframes dependent on quad strength and symptoms

ACL Knee Bracing
- Used primarily during rehabilitation
- Ave. time for use after return = 8 weeks

Combination Core/LE/UE Slide Board End Stage Rehab

Phase III Plyometrics and Sports Specific Training
- Plyometrics Develop:
  - Strength
  - Speed
  - Power
- Good Proprioceptive Training
- Injury Prevention
- Not everyone needs to jump!
Plyometrics

- Jumps
  - 2 footed landing
- Hops
  - 1 foot landing
- Bounds
  - Jumping form one foot to the other
- Proprioceptive

When To Start

- Full PROM
- Normalized Quadriceps Control
- Appropriate Time Period
- Controlled Joint Effusion
- Normal Ligamentous Exam

Quad Re education Take Off

- Recruitment = plyometric routine, single leg plyo's
- Sportsmetric
- Functional Drills
- Isokinetic strength, leg press 90-40

Bilateral Cone Hop Stick

Broad Jumps

- Maintain mechanics
- Must undergo double leg jumps
- Must have adequate core/quad control
Agilities/Sports Specific

- The ability to change direction rapidly without loss of body control
- Uses

Return to Play
Objective Measures
SL Squat reach

Most Functional Tests: Quad Function
Acceleration  no Deceleration

Jump tests, running pivoting tests require minimum deceleration
Quad functions most heavily during deceleration
“Brakes” are vital to function

SL Hop for Distance

Functional Assessment
50n High School FB Paine, Chicas, Harari

- Skilled vs Non-skilled positions
- Skilled demonstrated strong correlation (r=.70) 60d isokinetic & SLBJ
- Non-skilled low correlation (r=.30) 60d isokinetic & SLBJ

<table>
<thead>
<tr>
<th>Correlation</th>
<th>60d Flexion</th>
<th>60d Extension</th>
<th>240 Flexion</th>
<th>240 Extension</th>
<th>Average Flexion</th>
<th>Average Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.608</td>
<td>0.438</td>
<td>0.484</td>
<td>0.617</td>
<td>0.649</td>
<td>0.588</td>
<td>0.599</td>
</tr>
<tr>
<td>0.406</td>
<td>0.535</td>
<td>0.699</td>
<td>0.512</td>
<td>0.512</td>
<td>0.599</td>
<td>0.599</td>
</tr>
</tbody>
</table>

Fig. of eight 40 yd. run 9.5s
Paine et al IJSPT Nov 2015
Conclusions: Functional Testing HS Football Players

- Skilled versus Non-skilled positions will have effect on strength to function correlations
- Body type has an effect on functional performance during function testing

Panel discusses treatment of ACL injuries in athletic patients:

- Roundtable discussion
- Wilk Moderator
- Current trends in ACL early, late rehabilitation

James Cooper, Eric Sugarman

- Functional Exercise
- Must have adequate strength

ACL follow up Day

- Tracking post-op patient rehabilitation is critical to successful outcome.
- Each patient is objectively measured
- Y Balance

Return to full competition in NFL

- Timetables were not unusual
- Level of play was very unusual
- Skill position, ability to cut/pivot with no fear – superhuman effort
Conclusions

- Rehabilitation = team effort
- Must know healing constraints
- Progression = strength, proprioception/balance, plyometrics/agilities
- Never progress patient until ready for next phase