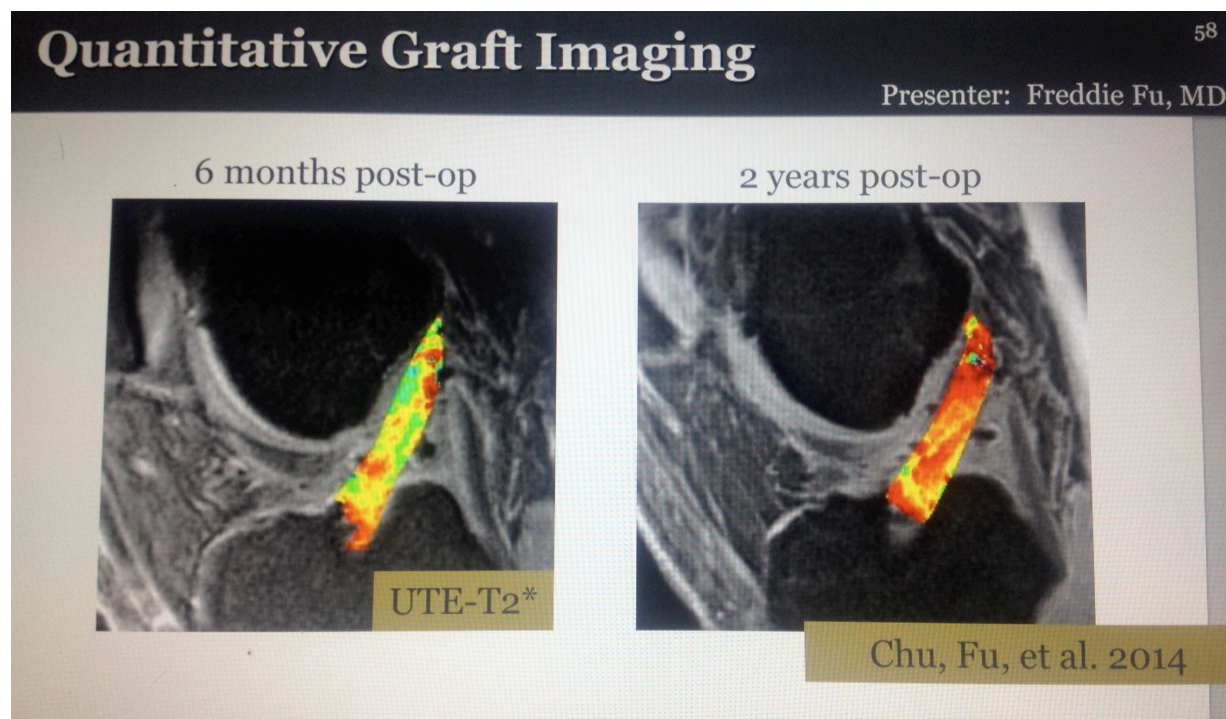


Introduction.

Current Anterior Cruciate Ligament Reconstruction Rehabilitation protocols often focus on three major tenets: 1) protection and facilitation of the graft, 2) improving knee range of motion and strength to “within normal limits” 3) passing of “established” return to sport testing, most notably single-leg hop testing, quad strength greater than 85% of uninvolved limb, etc. Despite hundreds of articles highlighting these points, incidence of re-injury continues to be high and further, it has been demonstrated that even if there is no re-injury, only 63% of athletes return to their pre-injury level of performance (Arder CL, 2011). This suggests that current rehabilitation models and return to sport parameters may not be addressing the appropriate deficits. At Nevada PT we are evidence-*led* and the evidence at this time suggests that the key to successful rehab lies in improved hamstring strength (in addition to established quadriceps protocols), *equal* lower extremity activation during athletic movements such as jumping, cutting, etc., improved core strength and possibly more stringent return to sport benchmarks. Additionally, the timeline of graft healing may be **much longer** than previously thought as some grafts show healing continuing past the two year mark.



(Rabuck SJ, 2013 Jan).

While the following protocol borrows many tried and true rehabilitation theories from the best in sports medicine, it also incorporates new progressive models to address the above mentioned goals.

Phase 1 Progressions: The patient needs to be seen frequently and aggressively immediately after surgery to facilitate the completion of phase 1 goals. It is imperative to manage inflammation and swelling as early as possible post-op while progressing extension as tolerated. Symmetrical extension should be achieved *as early as possible*, with a goal of achieving equal bilateral hyperextension within the first 1-2 weeks. Additionally, normalizing patellar mobility and preventing “patella contracture syndrome” should be pursued aggressively as tolerated by the patient. Not only to minimize scar tissue formation but also to facilitate improved quadriceps activation (Wilk KE, 2012 Mar). If scar tissue is allowed to form, extension deficits persist or the inflammatory cycle is allowed to continue after the first few weeks, the patient will have continued difficulty throughout the ACL rehabilitation program.

Improved Hamstring Activation/Decreased Hamstring Laxity: Hamstring laxity has been suggested as a primary indicator for ACL injury susceptibility, specifically in the female population (Hewett TE, February 2006). Additionally, hamstring activation unloads shear on the ACL, especially during athletic movements such as cutting and sidestepping (Weinhandl JT, June 2014) and it would follow that a program based around ACL repair protection would have a heavy hamstring component while continuing the well-established quadriceps and hip musculature strengthening. The following protocol addresses this in multiple directions, primarily in the form of deadlift progressions (Escamilla RF, 2002 Apr) such as assisted bandwork, bodyweight and single-leg movements, kettlebells and finally barbell work as appropriate. While squat progressions are well known, very few protocols incorporate deadlifts and if they do, it is often in a single-leg platform with a balance emphasis. Additionally, hamstring weakness when matched to their male counterparts, not quadriceps weakness, *may be a bigger predictor for ACL injury* and subsequent re-injury in females (G.D. Myer, 2009). Not only is the deadlift, when performed correctly, safe for ACL repairs, it is a compound multi-joint hamstring dominant movement requiring strong core activation. Hamstring and core weakness are well-documented risk factors for ACL injury and are often underemphasized components of many rehabilitation programs.

Improved Core Strength: It has been theorized that poor core strength translates to poor lower body control, specifically when change of direction occurs. The deadlift (and barbell squat) addresses core strength to a greater extent than conventional “core” exercises (Hamlyn N, 2007 Nov) but in addition, the Selective Functional Movement Assessment has created a platform on which to progress core stability. In short, the SFMA maintains that functional movement is built on developmental layers: rolling supine to prone, prone to supine; quadruped movement, high kneeling stability, and finally, bipedal movement. Gray Cook and the SFMA suggest many protocols skip over the normal developmental progressions and this, in turn, translates to dysfunctional athletic movement. This protocol incorporates these theories in an attempt to approach core strength as more than sit-ups on a BOSU ball but rather as facilitating and strengthening the core itself on a pattern consistent with our biological development.

Symmetrical Lower Extremity Activation: Isokinetic testing has long been the norm for measuring lower extremity strength, specifically with return to sport following ACL repair. Consistent decrease in knee extension values are shown as far as 12-24 months after surgery (Xergia SA, 2013 Mar) suggesting current quadriceps-specific directed therapeutic exercise is falling short. The problem with this type of testing, in our opinion, is that it is single-joint and as such, provides little information on athletic

movements and the multi-joint systems they require. While the single-leg hop test offers a more complete picture of return to sport deficits in the ACLR athlete, specifically decreased knee flexion angles in load production and increased plantar flexion angles in load absorption (Xergia SA, 2013 Mar), again current rehab protocols may not be addressing the complete athlete. We use a platform equipped with load sensors to track single leg output during barbell movements such as squats and deadlifts (both of which are well-studied as translating to vertical jump height, core control etc.) which will allow a progression of this rehab model in the future. Compound multi-joint training with an objective measure on individual leg output may address the above mentioned deficits with return to sport.

In summary, Nevada Physical Therapy and the University of Nevada-Reno Sports Medicine Department hope to *advance* the “ACL rehabilitation for athletes” conversation by adding a deadlift progression model to facilitate appropriate hip musculature activation and functional hamstring strengthening while protecting the graft, an evidence-based core/functional movement assessment and exercise prescription consistent with the Selective Functional Movement Assessment, and prioritizing equal lower extremity output during compound multi-joint movements more consistent with strengthening the platforms all athletic movements require. The goal of this rehab program, as Kevin Wilks would say, is to “do better.” These athletes not only need to return to their previous level of function but beyond it as their pre-existing risk factors need to be identified, addressed and corrected.



Bone-tendon-Bone Anterior Cruciate Ligament Rehabilitation Protocol for Athletes

Common Risk Factors for ACL Injury

- **Hamstring Weakness/Decreased Hamstring to Quad Strength ratio (>66% for males, >75% for females)**
- **Valgus collapse/Poor Jumping and Landing Mechanics**
- **History of ACL injury (contralateral/ipsilateral)**
- **Core Weakness**

Pre-Operative Status. (21 days post-op)

“Because of the large impact that quadriceps strength may have on knee function, the identification and treatment of quadriceps weakness prior to ACL reconstruction are paramount in maximizing patient outcomes (Adams D, 2012 Mar 8. See also Tables 1 and 2).”

The primary goals of the pre-operative patient are as follows:

- Decrease knee effusion and pain to within normal levels
- Improve Range of Motion to uninvolved limb
- Normalize gait
- Maximize voluntary quadriceps contraction and strength

Therapeutic Exercise

- Wall slides
- Isometric Quad sets/Straight leg raises
- Supine hamstring curls
- 4-way hip strengthening
- Clamshells/lateral theraband shuffle
- Double-leg/Single-leg leg press as able

PO Days 1-6:

Goals

- Protect Graft Fixation
- Control inflammation.
- **Facilitate full extension**
- Gait Training
- Rehab progression education

Therapeutic Exercise

- Weight bearing as tolerated.
- Supine Wall Slides, limited to 90° degrees flexion first 2 weeks, 130° first 4 weeks.
- Quad Sets with small towel under knee
- 4-way ankle theraband strengthening
- Hip abduction if able to achieve appropriate quad contraction
- Standing Hamstring curls if no pain reported

End of Week	AROM:	PROM:
1	0-80°	0-90°
2	0-105°	0-120
3	0-120°	0-125°

Weeks 2-4

Goals

- Continue to facilitate normal gait.
- VMO activation improvement/Normalize Straight Leg Raise
- **Avoid knee over toes in all closed-chain exercises.**
- Do not progress flexion greater than 125°
- Weight-bearing exercises should only be progressed once adequate quad function is restored!
- Normalize Patella Mobility

Therapeutic Exercise

- Bike as ROM allows, use for ROM facilitation if flexion less than 100°
- Straight leg raise if able to perform with no extensor lag
 - Begin core cue work, TA/oblique activation in conjunction
- 4-way hip strengthening
 - Avoid lax VMO activation with accessory planes (abd, add, ext)

- Bilateral balance/weight shift work.
- Standing Terminal Knee Extension
- Single-leg balance work, progress as able
- Hamstring bridging if ROM permits
- Double-leg squats 0-30°
- Stool scoots
- Step-ups/downs (week 3-4) with attention to minimal anterior translation of tibia over toes.

SFMA/Accessory Work:

- Initiate upper extremity (2x1) rolling patterns
- Assisted (2x1) hip flexion with SLR
- Assisted hamstring/glute bridge (2x2) as appropriate
- Assisted Squat and deadlift patterns as appropriate with ROM limitations

Weeks 4-8

Remember: Progressions to weight bearing activities should come only after full extension and adequate quad function have been achieved!

Goals

- Decrease knee pain and effusion.
- ROM within Normal limits
- Goals as above.

Therapeutic Exercise

- As above, progressed as appropriate
- Single-leg squats 0-45° with forward trunk flexion.
- Progressive Knee extension with cuff weights, maintain greater than 80° flexion
- Single leg deadlifts (with trunk flexion) with can touch, progress weight as appropriate
- Romanian Deadlifts with PVC, avoid tibial translation as mentioned
- Single-leg balance work with external stimuli
- May begin swimming (week 6), avoid whip kick
- Begin leg press/hip sled 0-70°
- Lateral shuffle (week 7-8)

SFMA/Accessory Work:

- Quadruped work as appropriate
- Bridge progressions.

- Lower Extremity rolling patterns

Weeks 8-12

Goals

- Progress gait to include stair-climbing
- Increase lower extremity strength
- Increase proprioception
- Optimize force production/absorption

Therapeutic Exercise

- Progressive bike resistance/intensity
 - Single-leg squats, deep wall squats, partial lunges, step-up height etc
- Nordic Trac/Elliptical
- Initiate anterior/lateral lung work, attention to limit tibia over toes
- Progress previous therapeutic exercise above
- Begin pool running (10-12 weeks)
- Light leg sled plyometrics (30% of body weight)

SFMA/Accessory Work:

- Progress above
- Initiate kettlebell deadlift patterns

Month 3-4

Progression Criteria:

- No patella-femoral pain
- 0-120 degrees of motion
- Sufficient strength and proprioception to initiate running.
- Minimal swelling/inflammation.

Goals

- Full Range of Motion
- Begin sport-specific strength training
- Strength 70% of uninvolved lower extremity.
- Avoid unnecessary graft strain.

Therapeutic Exercise

- As above
- Leg press to 90°
- Knee extension progression 90-30°, progress to eccentrics
- Begin swimming

- Advanced proprioception exercises.

SFMA/Accessory Work

- Front planks/plank progression
- High Kneel Chops/Lifts
- Kettlebell box squats/front squats
- Kettlebell rack walks/core work/suitcase carry

Months 4-6

Goals

- Symmetric performance of basic and sport specific agility drills
- Single hop and 3 hop tests 85% of uninvolved lower extremity (if able to demonstrate greater than 90% uninvolved leg strength symmetry)
- Quadriceps/Hamstring strength at least 85% of uninvolved lower extremity

Therapeutic Exercise

- Agility Progressions
 - Side steps/crossovers/shuttle run/single leg and double leg jumping
 - Ladder drills/acceleration/deceleration sprints
- Side plank progressions
- Begin level-ground running (see progression/soreness models)

Months 6-Return to Sport

- Begin barbell squat and deadlift training
 - Patient should demonstrate greater than 75% of uninvolved limb by month 7 as measured on force plate during barbell movements.
 - Patient should demonstrate greater than 85% of uninvolved limb by month 8 as measured on force plate during barbell movements.
 - Single Hop (single hop, Crossover hop, triple hop) testing greater than 85% of uninvolved limb by month 9.

Additional Considerations:

<u>Athlete Progression Timeline</u>	
Weeks 1-8 (Or Until Phase 1 goals Achieved)	Nevada Physical Therapy
Weeks 9-16	Co-treat Nevada PT/Sports Medicine (monthly check-ups with NVPT)

Weeks 17-24	Nevada Sports Medicine/Strength (monthly check-ups with NVPT)
Months 6-9	UNR Strength and Conditioning (monthly check-ups with NVPT)

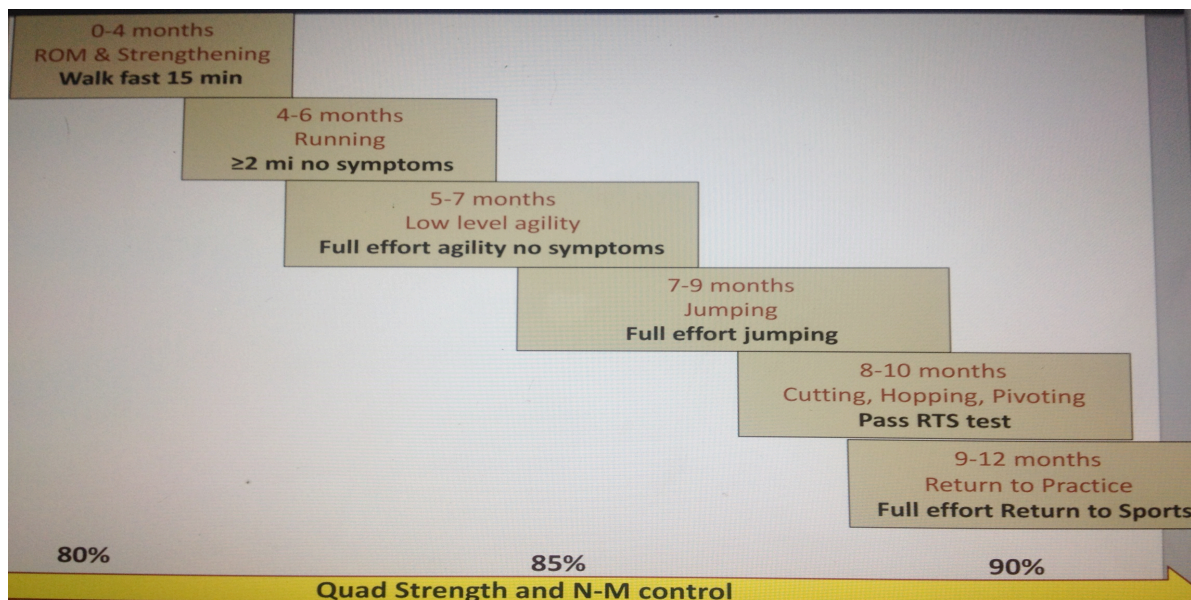
Table 1 Soreness Rules*		
Soreness during warm-up that continues days off, drop down 1 level	2	Soreness during warm-up that goes away Stay at level that led to soreness
Soreness during warm-up that goes away but redevelops 2 days off, drop down 1 level during session		Soreness the day after lifting (not muscle soreness) 1 day off, do not advance program to the next level
No soreness Advance 1 level per week or as instructed by healthcare		professional
*Reprinted with permission from SAGE Publications: Fees M, Decker T, Snyder-Mackler L, Axe MJ. Upper extremity weight-training modifications for the injured athlete. A clinical perspective. Am J Sports Med. 1998;26(5):735. Copyright ©1998 SAGE Publications.		

Table 2 Running Progression*		
Level 1	0.1-mi walk/0.1-mi jog, repeat 10 times	Jog straights/walk curves (2 mi)
Level 2	Alternate 0.1-mi walk/0.2-mi jog (2 mi)	Jog straights/jog 1 curve every other lap (2 mi)
Level 3	Alternate 0.1-mi walk/0.3-mi jog (2 mi)	Jog straights/jog 1 curve every lap (2 mi)
Level 4	Alternate 0.1-mi walk/0.4-mi jog (2 mi)	Jog 1.75 laps/walk curve (2 mi)
Level 5	Jog full 2 mi	Jog all laps (2 mi)
Level 6	Increase workout to 2.5 mi	Increase workout to 2.5 mi
Level 7	Increase workout to 3 mi	Increase workout to 3 mi
Level 8	Alternate between running/jogging every	Increase speed on straights/jog curves

	0.25 mi	
<p>*Progress to next level when patient is able to perform activity for 2 mi without increased effusion or pain. Perform no more than 4 times in 1 week and no more frequently than every other day. Do not progress more than 2 levels in a 7-day period. Conversion: 1 mi = 1.6 km. Reprinted with permission from Tara Manal, University of Delaware Physical Therapy Clinic.</p>		

Return to Sport Criteria for Division I athletes:

Dr. Freddie Fu recently presented MRI studies documenting graft type healing rates and makes the argument that early return to sport clearance should be supported by imaging to support an adequately healed graft. The below images were give during a recent webinar (Freddie Fu, MD, 2014):



Keeping this new information on graft healing rates and the above timeline progression in mind, we are able to form a more complete return to sport model. The following parameters use established return to sport baselines as well as goals unique to Nevada Physical Therapy, the University of Nevada-Reno Sports Medicine Department and Great Basin Orthopedics.

1. Full, symmetrical range of motion compared to contralateral limb.
2. Single-leg hop testing (single hop, triple hop, crossover hop) should be greater than 90% of non-surgical limb.
3. Single-leg strength (both hamstring and quadriceps) should be greater than 90% of non-surgical limb. Tested either isokinetically and/or during compound movements such as squat and deadlift with unilateral limb feedback, e.g. force plate scales).
4. Restored Quad:Hamstring strength ratio (>66% for males, >75% for females (Wilk KE, 2012 Mar))
5. Subjective Knee assessment testing with the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC) greater than 85 for athletes 18-24 years of age (Anderson AF & Committee., 2006 Jan)
6. No asymmetries or 0-1 scores on FMS testing.

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