**Accelerated versus Nonaccelerated Rehabilitation Following ACL Reconstruction**

The anterior cruciate ligament (ACL) provides stability to the knee joint as it projects from the anterior portion of the intercondylar area of the tibia to the posteriomedial aspect of the lateral femoral condyle surface1. Primarily the ACL resists anterior translation of the tibia on the femur, but also assists with restraining hyperextension, varus and valgus stress, and knee internal rotation2. The high level demands that are placed across the knee joint and the ACL make it vulnerable to injury during athletic participation.

In the U.S. alone, 200,000 or more ACL ruptures occur yearly in the general population3. A majority of the injuries occur in the athletic population with incidence being as high as 2.4 ACL ruptures per collegiate football team per year4. ACL injuries (including ruptures) may account for 100,000 ski injuries per year in the U.S. alone4.

Rupture of the ACL, in an athlete, means playing time missed due to surgery and rehabilitation. Surgery consists of either bone-patellar tendon-bone grafts or hamstring/gracilis grafts replacing the original tissue. Both types of grafts have shown positive outcomes, but that is not the intent of this paper. Following surgery the process of rehabilitation determines the athletes’ ability to return to play. Time until return to play may range from 4-6 months for elite athletes, and up to 12 months in some individuals5. Increased delay in return to sports is also associated with increased medical costs.

The rising occurrence for ACL ruptures and associated medical costs is a concern for both the individual and the medical field. Physical therapists are constantly searching for the highest quality of evidence and support for medical intervention with rehabilitating patients with ACL injuries. Thus, the purpose of this paper is to answer the question: For athletes, who underwent ACL reconstruction, is an accelerated rehabilitation protocol or nonaccelerated protocol associated with improved function and a quicker return to play? Accelerated protocol is defined as a program designed to return athletes to their sport in 4-5 months or less, compared to a nonaccelerated or traditional protocol that would delay return until 6 months or later.

In everyday practice physical therapists provide their own protocol to patients with ACL reconstructed knees. Evidence for intervention is based on educational background, clinical experience, and research literature. Literature review can be a weakness of clinicians due various reason, therefore, this paper will include a discussion of 8 articles to answer the debate of optimal protocols for earlier return to sport following ACL reconstructive surgery.

The research designs found during the literature review process consisted of 1 systematic review6, 2 randomized-control trials (RCT)7,8, 2 cohort studies9,10, 1 quasi-experimental design11, 1 case-control study12, and 1 case report13. The variance of study designs makes comparisons between them difficult but studies did have similar subjects, protocols, outcome measures, results, and clinical applications.

Beynnon et al produced a RCT of 36 subjects divided into either an accelerated group or nonaccelerated group8. Subjects completed the same exercise protocols with variance in the time frame, 19 weeks versus 32 weeks8. For example short arc quads were initial at 5 weeks in the accelerated group and 12 weeks for the nonaccelerated group8. Gerber et al also conducted a RCT with a group of early eccentric exercise (n=20) versus early concentric exercise (n=20)7. The intervention groups were required to only perform either eccentric or concentric exercise on an ergometer, and were provided a standard by which to progress duration7. Intervention concluded following week 15 and subjects were instructed to perform an independent home exercise program consisting of 2-3 days/week of progressive resistive exercise7. The systematic review performed by Wright et al, included the above Beynnon et al study, and added another study comparing “accelerated” versus delayed intervention6. The accelerated protocol for this study did not meet the definition of accelerated presented earlier in this paper, due to the earliest return of subjects to play was at 6 month6. A weak description of the protocol was described: the accelerated group was able to initiate isokinetic strength and jogging 4 weeks before the delayed group6. These three studies provided the highest level of evidence for this review; each with a unique approach for protocol and definition of accelerated.

Two cohort designs examined similar subjects with mean ages of 27.6±6.49 and 27.0±7.610. Karasel et al used a modified accelerated protocol from De Carlo et al12 that allowed early weight bearing, range of motion (ROM), and introduction of sports drills between 5-6 weeks post-operation9. Subjects were paced to return to sport between the 5-6 month mark9. Cardone et al introduced a protocol with their patients that also focused on early ROM and weight bearing without crutches10. Researchers also emphasized closed-chain exercises (calf raises, unilateral knee bends, leg press, and stair master) for the first 3 weeks of rehabiliation10. Subjects were introduced to sports specific drills between 6-8 weeks post-operation10, a few weeks behind the Karasel et al subjects9. Although, subjects of Cardone et al were introduced to sport specific drills later, return to sport was possible as early as 4 months post-operation10. Both of these cohort designs implemented protocols similar in subjects, intervention, and introduction of sport-specific training.

The final three studies included a quasi-experimental design, a case-control, and a case study. Melegati et al focused on early retention of knee extension through examining the effects of initial bracing position for post-operative patients with bone-patellar tendon-bone grafts11. A total of 36 males were split into two groups: Group A had their braces locked 0-90 degrees flexion for the first week, while Group B had their braces locked in full extension for the same period11. The intervention groups were similar for all other aspects of rehabilitation11. De Carlo et al took a retrospective approach to their case-control design and compared over 1,500 previous patients12. The investigators split the study population based on when the patients had surgery because the rehabilitation protocol changed from a traditional protocol to an accelerated protocol in 198712. The traditional protocol included a period of 2-4 weeks of non-weight bearing, controlled bracing (30-90 degrees flexion) initially, full ROM by 4 months, sports specific training at 6 months, and return to play between 9-12 months12. The accelerated group, which today would be considered nonaccelerated or traditional, concentrated on early weight bearing, early ROM, sport specific drills by 5-6 weeks, and return to play at 4-6 months12. The final study, by Roi et al, presented a case of an elite, male, Italian soccer player and his recovery process13. The authors used a criterion-based progression rather than the time-based progression that the above studies used13. Aquatic therapy and treadmill training were introduced in the first two weeks and sport specific drills were performed on the field just 39 days after surgery13. The subject was able to return to limited play in 77 days and full return was seen at 90 days post-operation13.

Each study was designed independently, making the choice of exercises, time frame, and results vary. Outcome measures are a way of being able to compare and contrast results from studies on similar subjects. The eight studies in this review each contained multiple outcomes for their patients including one or more of the following: Laxity, Tegner Score, Knee Injury and Osteoarthritis Outcome Survey (KOOS), one-leg hop or triple hop, ROM, strength, muscle volume, torque, and total work.

Laxity of the knee ligaments is a major concern to physical therapists, patients, and physicians because of the chance that a ligament becomes overstretched and unable to perform its function of stability and protection. Six of the eight studies reported statistics for laxity in patients. Beynnon et al reported statistically significant values (p<0.05) for knee laxity in the accelerated group compared to nonaccelerated group8. Subjects of the accelerated protocol had significantly lower laxity in the anterior-posterior and varus rotation directions, as well as, decreased laxity in the medial-lateral and absolute displacement categories8. De Carlo et al found similar results, reporting a statistically significant (p<0.05) lower mean for the accelerated group in knee laxity compared to the traditional group mean12. Positive results showing decrease laxity of the involved knee following intervention were noted by three additional studies6,7,11. Roi et al was the only study to show increased laxity of the knee compared to the subject’s contralateral knee (0.5mm difference)13. The outcomes for reported laxity appear to favor the inclusion of an accelerated protocol to prevent excessive motion.

Three studies administer the Tegner Activity Scale, a scale measuring the highest level of activity participation a patient is currently and previously participated in prior to injury. Beynnon et al reported statistically significant (p<0.05) improvement by the accelerated protocol group, who increased by 1.5 points on average8. Gerber et al declared statistically significant (p<0.05) improvements in both the eccentric and concentric exercise groups7, while Karasel et al found no significant difference in Tegner Activity Scale score9. Activity participation of subjects following ACL reconstruction appears to improve without dependence on a specific protocol.

The KOOS is a patient survey of pain, function, sports/recreation participation, quality of life, and symptoms. Beynnon et al and Gerber et al both administered the KOOS to subjects and found that all groups showed statistically significant (p<0.05) improvements on the scale, but no significant difference reported between groups7,8.

Function was tested in 4 studies by way of the single-leg hop test, triple hop test, or vertical jump test. Beynnon et al found statistically significant (p<0.001) improvements on the single-leg hop test for both accelerated and nonaccelerated groups8. The accelerated group produced a mean different to the contralateral limb of only 4.0±13.2cm, while the nonaccelerated group had a mean difference of 9.6±18.5cm8. Gerber et al echoed these results showing statistically significant (p<0.05) improvements in the single-hop test for the eccentric exercise group7. Karasel et al found no significant results for the single-hop test, triple hop test, or the crossover hop test9, when comparing to contralateral limb. Finally, Roi et al found a 0.5mm difference between involved and uninvolved limb in one elite soccer player13. Return to full function in an accelerated protocol may be possible or minimal differences between limbs may still persist.

All but one study examined strength as an outcome measure. Beynnon et al found a statistically significant (p<0.05) increase of quadriceps strength at 3 months post-operation, and all other strength measures showed no difference8. De Carlo et al found statistically significant (p<0.05) results for increased quadriceps and hamstring strength in the accelerated group at 3,6, and 12 months for quadriceps and 3 and 6 months for hamstrings12. Gerber et al also found peak quadriceps torque to be statistically significant (p<0.05) in the eccentric group when compared to the concentric group7. Cardone et al reported statistically significant (p<0.05) deficits in knee extensor peak torque, as well as, decreased knee extensor total work throughout the intervention10. Roi et al found quadriceps strength to be 95% of the athlete’s contralateral limb at 90 days post-operation, and quadriceps and hamstring strength exceeded contralateral limb strength at follow-up (517 days post-operation)13. Wright et al reported an increase in quadriceps strength at 6 month follow-up for the 6-month rehabilitation group, but the difference dissolved by 12 months post-operation6. Karasel et al reported no significant results in terms of strength for the modified accelerated protocol except for a significant (p<0.05) deficit in quadriceps strength at 60deg/sec9. Strength deficits appear to remain following rehabilitation, but the addition of an accelerated or eccentric protocol appears to decrease this deficit.

Regaining full ROM is a priority in most ACL rehabilitation protocols and patients generally continue to see improvement over time in ROM measurements. In the accelerated group of De Carlo et al, ROM was significantly better than the traditional group at 3,6 and 12 months for both knee flexion and knee extension (p<0.05)12. Melegati et al found a significant increase of knee extension at 4 and 8 weeks post-operation, for the group that had their braces locked in full extension11. The group that was allowed 0-90 degrees of knee flexion in their braces had more trouble regaining full extension11. Karasel et al reported difficulty regaining full extension following their modified protocol, with subjects still 10.1±0.8 degrees from extension9. Roi et al were able to achieve full ROM in their patient before 38 days post-operation13. ROM can be a challenging feat during the rehabilitation process, therefore the use of a brace locked in extension initially, and early ROM exercises appear to provide the best outcome for patients.

 Only one study provided data for muscle volume, finding that quadriceps, hamstring, gracilis, and gluteus maximus volumes significantly increased for the group performing eccentric ergometer exercise7. Gerber et al reported that gains by the eccentric exercise group in quadriceps and gluteus maximus volumes exceeded volumes in the concentric group by more than 50%7. The use of eccentric exercise may provide the best outcome for increasing muscle volume and muscle strength in the lower extremity musculature.

The difference in protocols and outcome measures makes generalization of results difficult. A trend towards early weight bearing and ROM appears to be optimal for the first few days to weeks. Inclusion of closed-chain exercises has been shown by several authors to be safe and provide optimal outcomes in strength deficits7,8,13. The major concern of excessive strain on the ACL graft and increased laxity may actually decrease with protocols that require increased force production early and often7,8,11,12. Additionally, the concept of criterion-based progress may prove to be more appropriate than a time-based progression13. The protocols that used criterion-base progression, included early weight bearing and ROM, and initiated sport specific drills sooner, provided subjects with a quicker return to sport.

A review of the literature for accelerated rehabilitation following ACL reconstruction yielded only 2 RCTs, making the level of evidence available weak. Positive results were found throughout the research and pointed in the direction of using accelerated protocols over nonaccelerated protocols. Each study produced protocols that required time lengths from 90 days to 1 year, meaning there is not a clear-cut length of time for recovery. Roi et al suggest that time-based progression is not the route for clinicians to take, but rather a criterion-based progression allows for treatment on an individual basis13. De Carlo et al and Karasel et al both produced studies off similar protocols, yet De Carlo et al showed significant improvements in strength, laxity, and ROM, while Karsel did not9,12. Only 3 studies released subjects to return to sport before the 5-month mark7,8,13, indicating further research needs to evaluate the effectiveness of protocols that can safely return athletes to sport before 5 months. Finally, only 1 study exclusively focused on accelerated versus nonaccelerated protocols for the entire duration of the study8. Other studies examined types of exercise7 (eccentric versus concentric) or brace application11 (flexed versus extended) in relation to ACL rehabilitation, but did not apply accelerated protocols. Further development of RCTs that focus solely on accelerated versus nonaccelerated rehabilitation in athletes, following ACL reconstruction, must address earlier return to play and specific time-based or criterion-based measures. At this point in time it is not clear if an athlete can return to play safely before 4 months of rehabilitation. The current evidence supports the use of an accelerated protocol that would return an athlete to play between 4-6 months post-operation.

Due to the inconclusive evidence that the literature presents, it is suggested that further research fill in the gaps on criterion-based versus time-based protocols and progression. Information in this area would greatly influence clinical practice and provide support for intervention. From the literature we can gather the importance of early weight bearing and ROM following ACL reconstruction8,12. Emphasis on maintaining or achieving full knee extension has also been associated with improved outcomes11. Eccentric exercise is safe and should be incorporated into a strengthening program in order to maximize muscle volumes, improve strength, and maintain laxity7. Protocols that emphasize sport specific exercises earlier in the protocol (i.e. 5-6 weeks or earlier) have shown the ability to safely return athletes to participation in as early as 90 days13 and on average 4-66,8,12 months following ACL reconstruction.

 With the information from this literature review I plan to apply it to the formation of a presentation and protocol design to share with other DPT students and colleagues. Given that DPT programs allocate more time to the evaluative and differential diagnosis realm of patient care, I believe that students would benefit from treatment protocols or ideas to use as a base for intervention. I plan to add more to the presentation about knee anatomy, mechanism of injury, evaluation, outcome measures, and perhaps expand upon a criterion-based theory of progression.

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