CRITERION-BASED REHABILITATION PROGRAM AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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Traditional rehabilitation protocols consist of a progression of exercises and functional activities based on time frames that serve as strict guidelines for physical therapists and athletic trainers. Patients who have undergone reconstruction of the anterior cruciate ligament are guided through the process via written schedule which often overlooks their ability to master basic functional activities, such as walking. Basic science and joint kinematics certainly cannot be ignored when designing a rehabilitation program. Understanding tissue healing and the effects of exercise of soft-tissue integrity can enable the physical therapist or athletic trainer to safely and efficiently restore function to each patient. A rehabilitation program guided by criteria achievement based on patient presentation, and with respect to the healing soft-tissue structures, may be a more effective and successful means of returning an athlete or worker to their desired activity.

KEY WORDS: anterior cruciate ligament, postoperative, rehabilitation

Historically, management after surgical reconstruction of the anterior cruciate ligament (ACL) has been based on basic science research and clinical experience. Numerous research studies have been performed to help clarify the basic science involved in surgical reconstruction of the ACL.1-3 Results of these investigations as to soft-tissue healing, proper surgical placement of the graft, and postoperative graft strength have played an important role in the development of postoperative rehabilitation guidelines. This research has traditionally been used to establish time frames for the progression of rehabilitation. Programs considered to be accelerated4 have placed greater emphasis on clinical presentation to establish guidelines for progression of rehabilitation. In the rehabilitation program we use, progression of the patient is goal-directed with specific criterion for advancement. This approach integrates the basic science knowledge with the individual patient’s clinical presentation to establish criteria for advancement of rehabilitation.

This article presents a four-phased, criterion-based rehabilitation program for patients who have undergone ACL reconstruction. We use information that is known regarding soft-tissue healing and graft incorporation to guide the early phases. Results gained from research regarding the effects of closed and open chain exercises are used to develop the exercise progression.

INFLUENCES ON POSTOPERATIVE MANAGEMENT

Graft Selection

The graft selected to replace the absent ACL will influence postoperative management, especially during the initial phases of rehabilitation. Many orthopaedic surgeons are using allografts as an alternative graft source to autografts. The advantages of allografts are decreased surgical morbidity and availability of an alternative in cases of failed autograft reconstructions. It is important for the physical therapist or athletic trainer to understand the ramifications of graft selection to properly manage postoperative rehabilitation.

The physiological and biomechanical properties of various grafts used for ACL reconstruction have been studied by numerous investigators. Basic concerns for postoperative rehabilitation include revascularization and in vivo strength.

Both autografts and allografts must be fully revascularized if they are to survive and function in the long term.5 Animal studies of bone-patellar tendon-bone autografts have shown complete revascularization at 8 to 20 weeks, and normal histological appearance at 9 months after implantation.1,5 Studies on the revascularization of allografts have shown that revascularization occurs in the same manner as in autografts with complete revascularization observed from 20 to 36 weeks after implantation.6-8

Ultimate strength of the graft is another important consideration. Studies of autografts have shown an initial decrease in strength after implantation, reaching the weakest point at 6 to 8 weeks, followed by a gradual increase up to 50% of a control ACL at 1 year.1,3

Animal
studies of allografts have reached differing conclusions. Kirkpatrick et al\textsuperscript{19} showed decreased ultimate strength of allografts compared with autografts at 3 months after implantation in the dog, but at 6 months no significant differences were seen. Shino et al\textsuperscript{10} showed no significant differences in ultimate strength of autografts versus allografts at 30 weeks. However, Jackson et al\textsuperscript{11} found significant decreases in ultimate strength and stiffness at 6 months after implantation in allografts versus autografts in the goat. Both autografts and allografts are strongest at the time of implantation, then undergo a progressive weakening over the first 6 to 8 weeks.\textsuperscript{3,12,13} During this time, the weak link in the reconstructed ligament has been shown to be the fixation site.\textsuperscript{12,13} Bone-to-bone fixation, used for both autografts and allografts, has been shown to provide the strongest fixation.\textsuperscript{12}

Although many questions remain regarding the maturation process undergone by ACL grafts and resultant clinical implications following ACL reconstruction, certain conclusions can be drawn. Both autografts and allografts go through an initial strength loss after implantation, lasting about 8 weeks, possibly longer, for allografts. Improved fixation techniques performed with both types of grafts allow for early range of motion and weight-bearing. Strength differences noted in animal studies have not been shown to correlate with clinical problems encountered in humans, but performing more aggressive functional activities during this initial 8-week period may place the reconstructed ligament at risk. Although precise time frames are not known, it does appear that maturation of the allograft is delayed compared with autografts. Therefore, we feel it is warranted to delay return to functional activities for patients who have undergone allograft reconstruction. Criteria used to determine a patient's appropriateness for return to activity include graft tissue and fixation type, graft strength upon examination by the surgeon, and patient compliance with the rehabilitation process. Based on these criteria, patients undergoing ACL reconstruction return to full activity between 6 to 12 months postoperatively.

Biomechanics of Exercise

Numerous studies have shown that lower extremity exercises performed in a closed kinetic chain (eg, leg press, minisquat) result in less translation at the tibiotalar joint than exercise in an open kinetic chain.\textsuperscript{14-16}

Arms et al\textsuperscript{14} studied strain on the normal and reconstructed ACL in cadaver specimens during active open kinetic chain isometric quadriceps contraction. Their results showed similar increases in ligamentous strain for both groups with isometric quadriceps contraction from 0° to 45° of knee flexion. Conversely, there was little strain on the ACL with open chain quadriceps activity at a knee flexion angle greater than 60°.

Beynon et al\textsuperscript{17} showed similar results by observing a large increase in strain on the anteromedial bundle of the ACL during isometric quadriceps contraction at 30° of knee flexion. During active open chain extension of the knee the anteromedial portion of the ACL was strained between 48° and 10°, and was unstrained between 50° and 110° of knee flexion.

Lutz et al\textsuperscript{15} compared tibiotalar joint shear forces and electromyographic (EMG) activity of the quadriceps and hamstrings during open and closed kinetic chain exercises. The results showed significantly less anterior and posterior tibiotalar shear with closed chain exercise compared with open chain. Additionally, results of EMG patterns and tibiotalar forces during closed chain exercise produced greater joint compression and quadriceps/hamstring muscular cocontraction at the same knee angles at which open chain exercise produced maximum shear force and minimal muscular cocontraction.

Though a majority of research has shown closed kinetic chain exercise to produce significantly less strain on the ACL, recent studies\textsuperscript{18,19} have yielded results that show some level of strain on the ACL during closed chain leg exercises. Data suggest that an anterior tibial force is greater during squat-type exercise at knee flexion angles less than 50°, than anterior shear produced with isometric quadriceps contraction at 15° and 30° of knee flexion.\textsuperscript{18} These studies do not suggest a risk to healing tissue, but simply warn clinicians that with closed, as well as open-kinetic chain quadriceps exercise, there are varying amounts of soft-tissue strain that occur with common exercises performed during rehabilitation.

Protecting the patellofemoral joint from irritation after ACL reconstruction is important for establishing a strong and stable foundation for exercise progression. Hungerford and Barry\textsuperscript{20} compared open and closed chain (squat) exercise and the resultant stress on the patellofemoral joint. Contact stress per unit area during open chain knee extension against a 9-kg weight was exceeded that which occurred by squatting under body weight from 0° to 50° of knee flexion. Closed kinetic chain exercise performed in this range reduces patellofemoral stress and may be included in early stages of the rehabilitation process. Closed chain exercise can be incorporated into a rehabilitation program as early as a few days postoperatively through weight-bearing during ambulation as tolerated by the patient.

Pain, quadriceps weakness, and/or knee range of motion should determine a patient's gait limitations. A weak quadriceps, which is quite common after surgery, can lead to patellofemoral irritation if weight-bearing, as well as non-weight-bearing exercises are progressed too rapidly. Additionally, loss of motion, especially lack of full knee extension results in a bent-knee gait, and can result in patellar immobility, patellofemoral joint irritation, and continued quadriceps weakness. Failure to address quadriceps strength, patellar mobility, and range of motion deficits results in propagation of quadriceps weakness and patellofemoral pathology. Aggressive attempts to accelerate the early weight-bearing phase after surgery may lead to increased effusion and pain which interferes with normal muscular activation and joint kinematics, and ultimately hinders recovery. Educating the patient to the importance of the early protective phase of rehabilitation and the adverse effects of prolonged effusion and patellofemoral irritation is vital to allow them to take an active role in their postoperative care.

Though data regarding the effects of open versus closed chain exercise on knee joint shear is inconclusive, we favor early initiation of closed chain exercise after
ACL reconstruction. The protection of the patellofemoral joint, cocontraction of the quadriceps and hamstrings, and more functional positions that closed kinetic chain exercise offers, provides patients with a generally safer and more efficient rehabilitation progression.

**CRITERION-BASED REHABILITATION PROGRAM**

This rehabilitation program is used for patients receiving either an allograft or autograft ACL replacement. Patients undergoing concomitant meniscal repair or transplantation or multiple ligamentous reconstruction (eg, posterior cruciate ligament/ACL), are progressed slower in the initial phases of the program. Each patient is guided through the four phases of the program based on a frequent assessment of their condition, known principles of tissue healing and biomechanics of exercise, and the achievement of certain criteria to advance to each subsequent phase. Progression through each phase should take into account patient status, their ability to safely advance to the next phase, and physician advisement. The referring physician should be consulted if there is any uncertainty concerning advancement of a patient to the next phase of rehabilitation. Attendance in a formal physical therapy setting ranges from 1 to 3 times a week. During the initial phases of the program, “difficult” patients (eg, patients having difficulty achieving full knee extension or lacking adequate quadriceps contraction) are identified and the frequency of supervised physical therapy sessions is increased.

**Phase One**

Goals during this phase are to protect graft fixation, minimize effects of immobilization, control inflammation, maintain full knee extension, and educate the patient regarding the rehabilitation process. After surgery, the patient is placed in a long leg immobilizer that is locked in full extension for 1 week. Sutures are removed 7 to 10 days postoperatively, and at that time the brace is unlocked to allow range of motion between 0° and 90° of knee flexion. Patients are instructed to use crutches for gait and bear weight on the involved extremity as tolerated. We believe that the use of crutches is necessary until a normal gait pattern is achieved for patient safety and to avoid patellofemoral irritation resulting from a weak quadriceps. Therapeutic exercise focuses on early protected range of motion and restoration of quadriceps control in preparation for weight-bearing activities. Continuous passive motion (CPM) is often used to provide early, safe motion for patients after knee surgery. Research has not proven CPM to be a necessity to prevent loss of flexion following surgery. We do not commonly use CPM postoperatively, however, patients identified preoperatively as being at risk for loss of flexion are issued a CPM machine after surgery. Joint compression and shear forces are kept to a minimum to prevent insult to healing soft tissue. Patellar mobilization is performed if indicated. Flexibility of the hamstring and gastrosoleus muscle groups is maintained. Criteria that a patient must achieve before advancing to the second phase are a good quadriceps contraction, straight leg raise performed without an extension lag, approximately 90° of knee flexion, full knee extension, no signs of active inflammation, and patellar mobility within normal limits.

**Phase Two**

Functional goals during phase two include restoration of normal gait and the initiation of closed kinetic chain exercises. Additional goals are to protect graft fixation and the patellofemoral joint. Emphasis is placed on restoration of a normal gait pattern through aquatic therapy or visual feedback. Use of the brace and crutches depends on patient status and graft healing studies. Within the 4- to 6-week postoperative period, patients are allowed to ambulate without assistive devices when they can exhibit full knee extension, can perform a straight leg raise without an extension lag, and can exhibit a normal gait pattern without assistive devices. Patients undergoing allograft reconstruction may be kept in the postoperative immobilizer longer secondary to delayed revascularization compared with autografts. Closed chain exercise is initiated during this phase to restore lower extremity strength and proprioception, while minimizing tibial translation. Basic cardiovascular exercises such as stationary bikes and stairclimbers are used. The criteria for advancement to phase three includes patient performance of a normal gait pattern, no complaints of patellofemoral joint pain, and an appropriate cardiovascular fitness level to support aerobic exercises.

**Phase Three**

During this phase of rehabilitation the patient wants to achieve full range of motion, improve strength, endurance, and proprioception, and at the same time avoid excessive stress on the graft and patellofemoral joint. Closed kinetic chain exercises are progressed through a greater range of motion and patients begin integration of sports/occupation specific tasks (eg, ball pass with balance exercises, box lift with partial squat). Before advancing to the fourth and final stage of rehabilitation, a patient must not have any patellofemoral or soft-tissue complaints and have the necessary joint range of motion, strength, proprioception to begin preparation for a safe return to work or athletic participation.

**Phase Four**

This final phase of rehabilitation focuses on advancement of the functional progression in preparation to return to sport or work. Sports or occupation-specific activities are integrated into the rehabilitation program, still maintaining strength, endurance and proprioception. A walk/jog/run progression and cutting and jumping activities are incorporated as well. As stated previously, allografts may need to be delayed in return to full function caused by prolonged graft maturation. Recommendation for discharge from structured physical therapy is made when the patient is able to safely return...
to their desired activity level and resume full unsupervised participation.

This program is used for the progression of patients after ACL reconstruction. Frequent reevaluation of the patient by the physical therapist or athletic trainer is necessary to monitor progress. Without periodic examination, the clinical decision-making process, and necessary rehabilitation program adjustments cannot be adequately performed to ensure quality care to all patients.

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