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# A Literature Review of the Results of Traditional versus Accelerated Anterior Cruciate Ligament (ACL) Rehabilitation in Treatment following ACL Reconstruction

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A LITERATURE REVIEW OF THE RESULTS OF  
TRADITIONAL VERSUS ACCELERATED ANTERIOR  
CRUCIATE LIGAMENT (ACL) REHABILITATION IN  
TREATMENT FOLLOWING ACL RECONSTRUCTION

by

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Bachelor of Science in Physical Therapy  
University of North Dakota, 1994

An Independent Study  
Submitted to the Graduate Faculty of the  
Department of Physical Therapy  
School of Medicine  
University of North Dakota  
in partial fulfillment of the requirements  
for the degree of  
Master of Physical Therapy

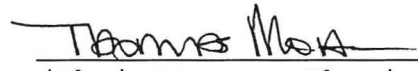


Grand Forks, North Dakota  
May  
1995

This Independent Study, submitted by Cara L. Conway in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

  
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(Graduate School Advisor)

  
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(Chairperson, Physical Therapy)

PERMISSION

Title                    A Literature Review of the Results of  
                             Traditional Versus Accelerated Anterior  
                             Cruciate Ligament (ACL) Rehabilitation in  
                             Treatment after ACL reconstruction

Department            Physical Therapy

Degree                   Masters of Physical Therapy

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Date April 1, 1995

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## ABSTRACT

In recent years, the rehabilitation of the anterior cruciate ligament (ACL) has undergone changes in its protocol. The changes in ACL rehabilitation protocol are due to clinical observations and trends in ACL rehabilitation across the country. The traditional and presently used accelerated ACL rehabilitation programs are not much different in the activities performed as in the time frames when each activity is permitted.

The main purpose of this literature review is to provide material for clinicians to have accurate and recent knowledge of ACL rehabilitation. This knowledge will allow the clinician to provide the best and most beneficial treatment to the patient. The traditional and accelerated ACL rehabilitation programs will be viewed separately and versus one another. Determinants of which ACL rehabilitation program to choose are stated to increase the clinicians' awareness of the proper treatment to choose for a patient.

Clinicians must continue to have present knowledge of sound basic science and recent research when treating a patient with a reconstructed ACL. ACL rehabilitation protocols are guidelines only, and a clinician must be aware of all of the factors present with a patient before slowing or speeding the rehabilitation process.



CHAPTER I  
INTRODUCTION

Ligaments were at one time thought to be inert structures.<sup>1</sup> Research has furnished a vast amount of evidence showing that ligaments are active bands of tough connective tissue, which display complex mechanical behavior in providing stabilization in each joint.

The anterior cruciate ligament (ACL) is an essential structure on which all human beings depend for knee joint stability.<sup>2</sup> The ACL is the key control to static and dynamic stability in the knee and is also the most injured structure of the knee.<sup>3</sup>

The patient usually describes the mechanism of injury of the ACL as one of three ways: (1) deceleration, flexion, and rotation of the knee, (2) hyperextension of the knee, or (3) hyperflexion of the knee with a violent contraction of the quadriceps.<sup>4</sup> The injury usually takes place in a noncontact sport. A loud "pop" may be heard or a tearing of the tissue may be felt by the patient. Knee joint effusion is present within hours after the injury and the patient is unable to continue with his or her activity or work. The patient commonly complains of pain, limited range of motion,

loss of knee control, and lack of patient confidence with knee activity.

Clinical signs of ACL injury include a swollen knee, which is slightly flexed due to spasm of the hamstrings and an inability of the patient to actively flex or extend the injured knee.<sup>4</sup> The Lachman, pivot shift, and anterior drawer tests are performed by the clinician to determine whether there may be damage to the patient's ACL. Only arthroscopic surgery can actually diagnose the ACL injury. The literature stated that patients with a functional disability of the knee, or who have recurrent episodes of lost knee control, pain, and swelling of the knee should undergo ACL reconstruction.

Since the ACL is frequently injured, rehabilitation after ACL reconstruction has received a vast amount of attention.<sup>3</sup> The differences in protocols and outcome between the traditional and accelerated ACL rehabilitation programs are probably more apparent in this decade due to the increased participation in and volume of sport activities, and the anticipation of the patient to return to activity early.

The post operative traditional and accelerated rehabilitation programs are believed to influence clinical outcomes. A large amount of research has been conducted to determine the outcome of each ACL protocol.

Physical therapists are sometimes confused regarding the ACL rehabilitation program to choose for treatment. The confusion that exists causes therapists to question their own judgement, and may also cause possible setbacks when trying to obtain the patient's and therapist's goals of treatment.

The purposes of this literature review are: (a) to review the literature to outline the differences between the traditional and the accelerated ACL rehabilitation programs, (b) to report the advantages and disadvantages of each ACL rehabilitation program, (c) to review the outcome and efficacy of ACL rehabilitation results, and (d) to define the determinants which may be utilized in selecting an ACL rehabilitation program. The overall purpose of this literature review is to provide material for clinicians to eliminate the confusion regarding which ACL rehabilitation program to choose for each individual patient.

## CHAPTER II

### ANATOMY AND BIOMECHANICS

The knowledge of the knee joint anatomy and biomechanics is essential for surgeons to devise and perform a reconstructive procedure that does indeed restore knee joint stability. This knowledge is also necessary for physical therapists to have in order to provide the proper rehabilitation for a patient with a reconstructed ACL.

#### ANATOMY

The knee is the largest joint in the human anatomy and is comprised of bone, muscles, and ligaments (Figure 1).<sup>5</sup> The bony structures, which help form the knee, consist of the femoral condyles, the patella, and the tibial plateaus. The knee musculature mainly consists of the quadriceps and hamstring muscles, which help to stabilize the knee joint. The ligaments of the knee include the anterior cruciate ligament, the posterior cruciate ligament, the lateral collateral ligament, and the medial collateral ligament.<sup>6</sup> The anatomy and biomechanics of the ACL will be the focus of this review.

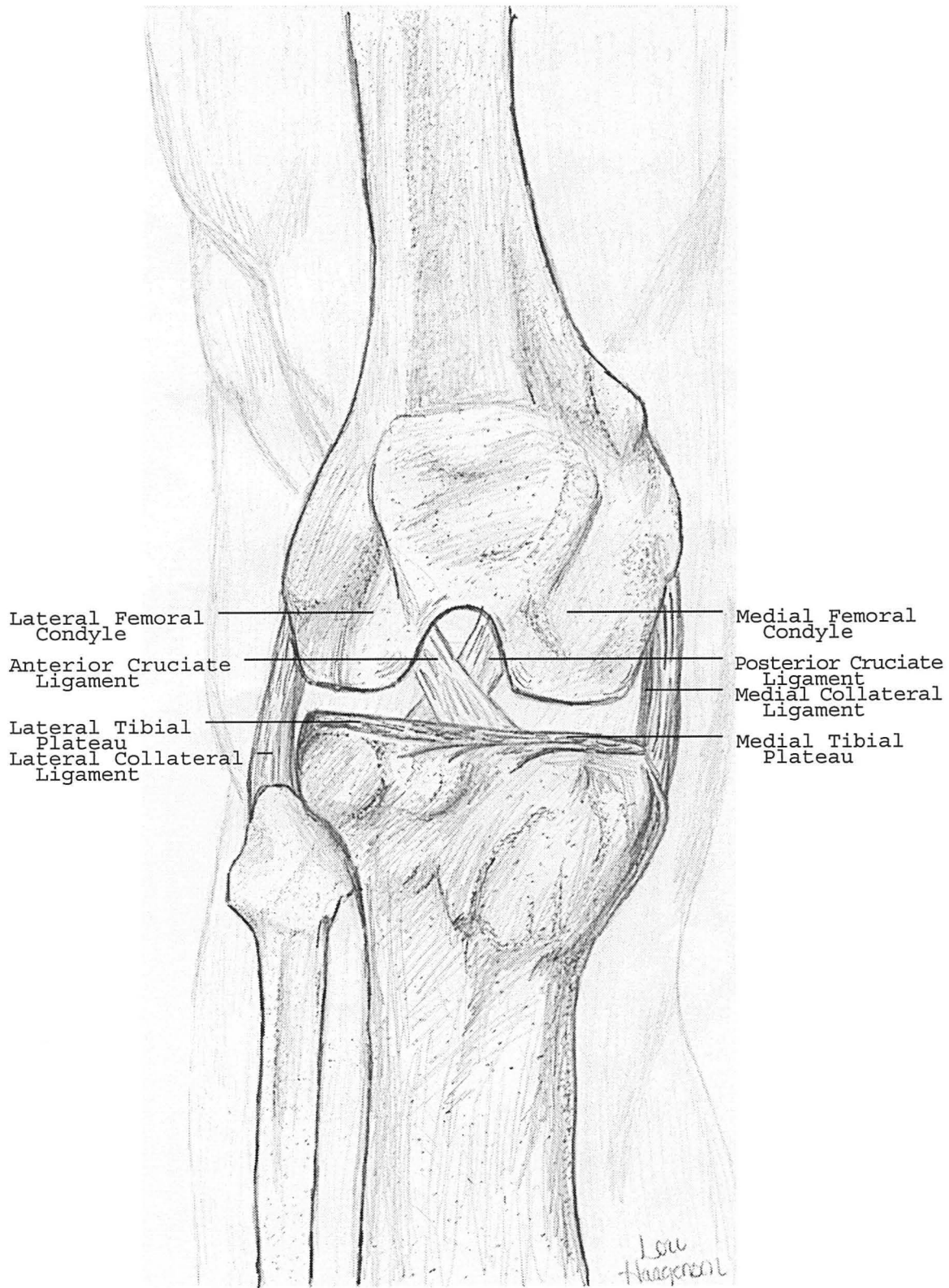


Figure 1. Illustration of the anatomy of the knee.

The ACL is named by its location and appearance. The ACL is located toward the anterior portion of the knee joint<sup>5</sup> and appears to be crossed with the posterior cruciate ligament upon anteriorly viewing the knee, thus the name cruciate is used.<sup>6</sup> The term ligament originated from the Latin word "ligare", which means to bind.<sup>7</sup>

The ACL is an intracapsular, extrasynovial ligament.<sup>6</sup> Structurally, approximately 90 percent of the ACL is composed of well oriented collagen fibers with the other 10 percent comprised of elastic fibers.<sup>2</sup> Collagen fibrils together form the well oriented collagen fibers.<sup>1,6,8</sup> A great number of collagen fibers unite to make the subfascicular unit. The endotenon, a thin band of loose connective tissue, encloses the subfascicular unit. The endotenon is enclosed by epitenon, a more dense tissue, and is directly followed by the paratenon, which blends with the epitenon. The ligament is then covered by the synovium causing the ligament to be extrasynovial.

The ACL is described as a fan-shaped structure constructed by the interlacing collagenous fascicles. These fascicles have their origin on the posterolateral view of the femoral condyle within the intercondylar notch.<sup>1</sup> The collagenous fascicles proceed obliquely to their insertion on the anteromedial portion of the tibia between the tibial spines.<sup>1,8</sup> A portion of the ACL also attaches to the anterior horn of the lateral meniscus. The average length

of the ACL is reported to be approximately 31-38 millimeters.

The fascicular arrangement of the ACL allows for a separation between two "bands" of the ACL.<sup>1</sup> These two "bands" have been presented by researchers as the anteromedial and the posterolateral bands, designated so by the attachment of the tibial insertion.

#### **BLOOD AND NERVE SUPPLY**

The ACL synovial membrane surrounding the ACL may assist in protecting the ligament.<sup>1</sup> This synovial membrane surrounds the ligament and is vascularized by vessels that originate primarily from the middle genicular artery and secondarily from smaller vessels of the lateral inferior genicular artery.<sup>1,2</sup> The blood supply is reported to originate from soft tissues and not from bone structures at the ligament ends. Thus, bone-ligament junctions are not thought to be a major source of blood supply to the ACL.

The tibial nerve supplies the ACL.<sup>1</sup> Through histologic examination of the neural anatomy of the ACL, researchers have found that several morphologic mechanoreceptor types exist in the ACL. These mechanoreceptor types include the Golgi tendon organ, Ruffini and Pacinian corpuscles, and free nerve endings.

## BIOMECHANICS

The ACL is a structure that possesses both a great deal of tensile strength as well as a degree of elasticity.<sup>2</sup> The nonparallel arrangement of the multiple collagenous fibers along with some associated elastin seems to account for the biomechanical properties of the ACL.

The ACL is a very important component that acts to (a) stabilize the knee joint, (b) guide knee joint motion, and (c) to prevent excessive joint motion in the knee.<sup>2,8</sup> The ACL is the primary component that controls flexion and rotational motions of the healthy knee.<sup>2</sup> The ACL prevents excessive anterior translation of the tibia, knee hyperextension, and excessive axial tibial rotations of the knee. The ACL is a secondary prevention to excessive varus-valgus motions of the knee.

The ACL is able to prevent excessive knee joint motion because of its fascicular nature.<sup>2</sup> It has been observed that the fibers within the ACL have a unique point of origin and of insertion, that the fibers are not exactly parallel or of equal length, and that each individual fiber is not under the same tension throughout knee range of motion.<sup>8</sup> Researchers emphasize that portions of the ligament appear to remain taut throughout the full range of motion with continuous control of femorotibial position. Posterolateral fibers of the ACL are described as being taut in extension and are, perhaps, the primary component that resists



hyperextension. The fibers that are found in the anteromedial region of the ACL are thought to be taut in flexion. The anteromedial fibers are thought to be the primary components that resist an anterior displacement of the tibia in flexion.

In ambulation, other factors provide stability to the knee joint besides the ACL.<sup>8</sup> These factors include osseous configuration, meniscal integrity, proper sequential muscle tension, and the load placed on the knee joint. In the ACL-deficient knee, these factors must help to control knee stability. Loss of terminal control of femorotibial contact will be evident in the ACL-deficient knee. Even with the help of other knee joint structures, the loss of the ACL will cause the tibial plateau to sublux anteriorly in extension with a tendency toward sudden reduction with flexion.

The loss of an ACL may result in disruptive kinematics and subsequent degenerative changes, which may be due to a lack of structural integrity and a disruption of proprioceptive function.<sup>8</sup> Research shows that the natural history of ACL-deficient patients displays a definite tendency for subsequent meniscal injury and possible later degenerative changes.

**ACL RECONSTRUCTION**

Reproduction of the exact anatomy of the ACL by surgical reconstruction is difficult because of the multifascicular structure of the ligament.<sup>1</sup> The goal of surgical ligament reconstruction is to restore some measure of joint stability and to prevent secondary damage to other knee structures and the onset of degenerative changes in the injured joint.<sup>2</sup>

**MATURATION OF THE AUTOGRAFT**

The maturation of the ACL graft has four distinct stages: (1) avascular necrosis (in autograft only), (2) revascularization, (3) cellular proliferation, and (4) remodeling.<sup>9</sup> The graft is strongest directly after surgery and then weakens until approximately the sixth week after surgery.<sup>6</sup> The graft becomes revascularized at approximately six weeks after surgery.<sup>3</sup> Full maturation of the graft will be reached around one year after surgery, but the graft may not be at 100 percent strength at one year following surgery.

CHAPTER III  
TRADITIONAL REHABILITATION

The traditional ACL rehabilitation program of patients with a reconstructed ACL was first outlined by Paulos et al<sup>10</sup> in 1982. This rehabilitation program is outlined in Table 1 on pages 12 and 13. Directly following surgery, the patient is casted in a long leg cast at 30 degrees of flexion for two weeks. At two to three days following surgery, the patient is taught to begin ambulating with crutches with a non-weight bearing status. The long leg cast is removed at the patient's initial visit to the clinic at two weeks after surgery and is replaced with a long leg hinged brace. The long leg hinged brace is set at 30 to 60 degrees of range of motion.

The patient is allowed to begin weight bearing as tolerated and progress to full weight bearing at eight to ten weeks.<sup>10</sup> During this time, the patient is fitted with a custom molded polycentric brace, which is to be worn at all times. Ten to ninety degrees of knee range of motion is achieved at eight to ten weeks. Closed kinetic chain exercises are initiated at 12-14 weeks when the patient is of full weight bearing status. The patient is allowed to

Time after Surgery	
2-3 Days	Casted at 30° flexion Ab/adduction straight leg raises (SLR) Extension SLR Gluteal sets NWB ambulation with crutches
6-7 Days	Discharge from hospital
2-4 Weeks	Cast removed, hinge brace applied at 30-60° ROM Passive ROM exercise Hamstring curls Ab/adduction and extension SLR Toe touch weight bearing
4 Weeks	Motion from 20-70° add weights with SLR
8-10 Weeks	FWB as tolerated ROM 10-90° Passive stretching to increase ROM SLR with increased weight Eccentric knee extension Short arc knee extension 90-45° Hamstring curls Bicycling, swimming
12-14 Weeks	ROM 0-110°, FWB Continue with previously prescribed exercises, start knee bends, step-ups and calf raises
4 Months	ROM 0-120° Discontinue brace for ADL if good quad tone Increase intensity of exercise with higher weight and more sets and reps
6 Months	Isokinetic evaluation at 180,240°/sec with 20° block Ligament stability test Jump rope, lateral shuffles Walking up to 2 miles Short arc knee extensions to full knee extensions Squats, brace for activity
7 Months	Isokinetic evaluation Ligament stability test 1/4 mile walk/jog progression

**TABLE 1.** Summary of Traditional Postoperative ACL Reconstruction Rehabilitation Protocol Used From 1982-1986 in the Study by Paulos et al.<sup>10</sup> (Table 1 continued on page 13)

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Time after Surgery	(Table 1 continued)
8 Months	Agility drills including large figure-eights, lateral shuffles, backward running Isokinetic strengthening at slow and fast speeds Ligament stability test
9-12 Months	Return to normal activity levels if strength is greater than 80%, full ROM, no pain or swelling, and successful completion of functional progression

---

discontinue the use of the custom molded polycentric brace for daily activities at 12-14 weeks.

Six months following surgery, the patient is given an isokinetic evaluation at 180 and 240 degrees per second with a 20 degree extension block and an anti-shear accessory applied to the patient.<sup>10</sup> The KT 1000 arthrometer (MedMetric Corporation, San Diego, CA) is used to test stability of the reconstructed ACL to quantify tibial displacement relative to the femur at known sources. Finally, at nine to twelve months after surgery, the patient can progress to full unrestricted activity when full range of motion is achieved and the patient successfully completes the functional program.

The traditional ACL rehabilitation program focuses on protection of the new ligament with blocking of full extension, and avoidance of active quadriceps function in the terminal degrees of extension.<sup>11</sup> Brewster et al<sup>12</sup> stated that clinicians are always striving to achieve the optimal trade-off between immobility, which facilitates soft tissue repair, and early exercise, which facilitates tissue revascularization and nutrition, when using the traditional ACL rehabilitation program.

Rehabilitation by Brewster et al<sup>12</sup> consisted of casting the reconstructed knee in 35 to 45 degrees of flexion for four to six weeks. Brewster et al<sup>12</sup> stated that the ACL remains under tension throughout range of motion, but

tension is greatest from 30 degrees of flexion to full extension. Casting the knee at 35 degrees should slightly relieve the tension on the ACL. The patient remains nonweight-bearing for four to six weeks and the cast is replaced with a hinged brace locked at 35 degrees of flexion during week four.

Exercises focus on hamstring strengthening throughout rehabilitation by Brewster et al.<sup>12</sup> Other exercises included in this rehabilitation program are: (a) hip abduction to strengthen the iliotibial band, which contributes to lateral stability of the knee, (b) isometric adduction, because clinically, patients with patellar tracking problems are able to perform quadriceps sets much easier after performing isometric adduction sets, (c) hip extension to increase the strength of the gluteus maximus since it is part of the ilio-tibial band and will contribute to knee stability, (d) wall slides to increase knee flexion, and (e) quadriceps sets to help increase quadriceps strength and to prevent atrophy.

In this rehabilitation program, the patient is not allowed to progress to full weight-bearing status until week eleven after surgery.<sup>12</sup> The patient's hinged brace is set at 20 degrees of flexion at week eleven post-surgery and then at 15 degrees of flexion at 15 weeks post-surgery. The patient is not allowed full knee extension until 18 weeks post-surgery. During week eleven through week 28, the

patient continues a progression of resistive strengthening of the original exercises, and at week 30 post-surgery, the patient begins to perform agility exercises, such as figure-of-eights, backward running, rope skipping, vertical jumps, lateral running, and crossovers. By week 32 post-surgery, the patient will have started practicing the skills of his or her sport. The patient is allowed to return to his or her sport or regular activities at one year post-surgery.

As knowledge increases in relation to the change in the ACL reconstruction surgery techniques and ligament healing, revisions take place in the ACL rehabilitation program.<sup>13</sup> Podesta et al<sup>13</sup> designed a rehabilitation program that focused mainly on allowing adequate tissue healing time and protected muscular conditioning. The early phases of this ACL rehabilitation program (0-12 weeks) are to control translational forces across the new graft to provide adequate time for the new graft to properly revascularize and to allow for soft-tissue healing. In this phase, hamstring and quadriceps exercises are performed isometrically and isotonicly in a restricted range of motion. Passive range of motion is encouraged, and a progression from partial to full weight-bearing is permitted. During the advanced stages (12-31 weeks), isotonic muscle strengthening exercises are performed throughout full range of motion. Dynamic stability is achieved by increasing strength, coordination, and



endurance. The preinjury level of function is usually achieved one year after surgery.

Four important issues are stressed by Whittington et al<sup>14</sup> in the rehabilitation of the reconstructed ACL. They consist of:

1. Clinical treatment of the ACL
2. Biomechanical principles
3. Tissue healing data
4. The effects of immobilization

Whittington et al<sup>14</sup> also feel that the most important consideration in the rehabilitation of the reconstructed ACL is one that corresponds activity of the operative knee with definite time limits to maximize the healing of the ligament graft.

Six general phases of the traditional rehabilitation program utilized by Whittington et al<sup>14</sup> include:

1. Phase I (0-3 weeks): This phase consists of maximum protection and controlled exercise. A straight leg brace is worn with early weight-bearing and discarding of crutches during week three. Range of motion and hamstring strengthening are emphasized.
2. Phase II (3-12 weeks): This phase consists of moderate protection, controlled motion during activity, and a strengthening progression.
3. Phase III (3-4 months): This phase consists of minimal protection during daily activities with

increased protection during rehabilitation exercises.

4. Phase IV (4-8 months): The patient is allowed to continue on his or her own, working to achieve the goals of full strength, equal quadriceps girth, and active and passive range of motion measurements.
5. Phase V (8-12 months): Sports-specific training is begun in this phase.
6. Phase VI (beyond one year): The patient can return to full sports participation.

A delayed return of the patient to his or her normal activity is often seen in the traditional ACL rehabilitation program. Some advantages of the traditional ACL rehabilitation program consist of: (a) proper healing time for the graft, (b) no unnecessary stretching of the graft, and (c) time for appropriate re-education of the patient in knee joint proprioception.<sup>15</sup>

Some disadvantages associated with the traditional ACL rehabilitation program are: (a) intra-articular adhesions, (b) infrapatellar adhesions, (c) patellofemoral crepitation, (c) joint stiffness, (d) profound quadriceps atrophy,<sup>15</sup> (e) extensor mechanism disruption, (f) chronic knee effusion, and, (g) donor site pain.<sup>16</sup> ACL injury is the number one joint stiffness producing injury.<sup>17</sup> Scientific evidence shows that ten to fifteen percent of patients have complications with joint stiffness following surgery.

Arthrofibrosis prevents the patient from regaining full knee range of motion, especially the terminal five degrees of extension.<sup>18</sup> Sachs et al<sup>19</sup> reported a 24 percent incidence of a knee flexion contracture greater than five degrees following ACL reconstruction. Immobilization causes a rapid decline in the biomechanical properties of ligament and bone.<sup>20</sup> Exercise has been shown to increase the strength and stiffness of ligaments and the ligament-bone unit.

The rehabilitation of a repaired ACL is a lengthy process.<sup>12</sup> Careful attention is paid to strengthening musculature around the knee without placing excessive stress on the healing tissues. Controlled weight bearing, careful attention to knee position and proprioception, and a specific strengthening program yields the best results in the traditional ACL rehabilitation program.

CHAPTER IV  
ACCELERATED REHABILITATION

Shelbourne et al<sup>21</sup> discussed that the development of the accelerated rehabilitation program during the mid 1980s came about from the observation that noncompliant patients did better than those patients who were very compliant. The noncompliant patients had shown no signs of knee instability or any complications such as decreased range of knee motion or anterior knee pain in the area of the graft. The main point of the accelerated rehabilitation program is the short term goal of full knee extension and the long term goal of maintaining that knee extension.

The summary of the accelerated postoperative ACL reconstruction rehabilitation program used from 1987 to 1989 is found in Table 2 on page 21.<sup>21</sup> In the accelerated rehabilitation program, the patient is seen before surgery for evaluation and instruction on the rehabilitation process. The patient is informed of the preoperative goals, which consist of regaining full range of motion, near normal strength, and unassisted gait without analgesia. The pre-evaluation includes bilateral ligament stability testing,

Time after Surgery	
2-3 Days	CPM and Cyro/Cuff Passive ROM exercise for terminal extension and 90° flexion WB as tolerated
2-3 Days	ROM terminal extension--prone hangs and towel extensions Wall slides, heel slides, active assisted flexion
5-6 Weeks	ROM, terminal extension to 130° flexion Isokinetic evaluation with 20° block at 180, 240°/sec If greater than 70%, start lateral shuffles, cariocas, and jumping rope Continued weight room activities Continue bicycling, swimming
10 Weeks	ROM full Isokinetic eval at 60, 180, and 240°/sec Ligament stability test Increase agility workout
16-24 Weeks	Isokinetic eval Ligament stability test Return to sports if strength is greater than 80% and successful completion of functional progression

**TABLE 2.** Summary of Accelerated Postoperative ACL Reconstruction Rehabilitation Protocol Used From 1987-89 by Carlo et al.<sup>3</sup>

isokinetic strength evaluation, and goniometric measurements of the knee.

Directly after surgery, the patient is placed in a continuous passive motion (CPM) unit with a cold compression unit placed on the knee.<sup>21</sup> The CPM unit is set at equal extension of the opposite limb to 30 degrees flexion during the entire hospital stay.

While in the hospital, range of motion exercises are performed by the patient two to three times a day.<sup>21</sup> Range of motion exercises strive for full terminal extension and 90 degrees of flexion. The patient's operative leg is placed in a long leg immobilizer at this time, and ambulation is initiated with crutches and weight bearing as tolerated. The patient is discharged two to three days after surgery.

The patient's initial post-surgery visit is at seven to ten days.<sup>21</sup> Physical therapy is started at this time with terminal extension, defined as extension equal to the opposite leg, as the main focus. Flexion is also achieved with wall slides, heel slides, and active-assistive knee flexion in sitting. The goal in the early stage of accelerated rehabilitation is to gain terminal extension to 90 degrees of flexion in the operative knee. The patient is also encouraged to move from partial to full weight bearing without crutches.

Closed kinetic quadriceps exercises are strongly enforced to gain early leg control and quadriceps strength in the accelerated ACL rehabilitation program.<sup>21</sup> Weight room exercises are started three to four weeks after surgery, and swimming and stationary bicycle exercises are started at this time to help regain knee flexion.

The first isokinetic testing of the reconstructed knee is performed five to six weeks after surgery.<sup>21</sup> If the patient's isokinetic quadriceps strength ratio is 70 percent or greater of the opposite limb, the patient is started on agility exercises, which include cariocas, lateral shuffles, and rope jumping. The exercises become much more rigorous as the patient improves in quadriceps strength. The patient is allowed to return to full activity, including contact sport, at four to six months. Criteria for return to full activity is an isokinetic quadriceps strength ratio greater than 80 percent of the opposite leg. The patient is requested to return for re-evaluations to test range of motion, isokinetic strength, and ligament stability measurements.

Besides patient noncompliance, advances in the surgical technique, which has facilitated more accurate graft placement, and stronger graft fixation due to advances in instrumentation has increased the use of the accelerated ACL rehabilitation.<sup>16</sup> Arthroscopically assisted ACL reconstruction has increased the use of the accelerated ACL

rehabilitation program because this surgical technique has decreased tissue morbidity. The accelerated rehabilitation program is more accepted by the patient and clinicians because the early return to range of motion, weight-bearing, and functional activities has shortened the traditional ACL rehabilitation program.

The accelerated ACL rehabilitation program of Wilk and Andrews<sup>16</sup> is based on five basic principles of rehabilitation:

1. Healing tissue should never be overstressed.
2. The negative effects of immobilization must be prevented.
3. The patient must meet certain goals to be advanced to the next stage of the rehabilitation program.
4. The rehabilitation program must be based on current and sound science.
5. The team effort is necessary to provide a successful outcome.

The most fundamental principle of the accelerated rehabilitation program is the amount of stress that a reconstructed ACL can withstand during different stages of healing.<sup>15</sup> Once clinicians can understand these limitations, the optimal rehabilitation program can be used that will insure proper healing of the ACL graft.

The ACL rehabilitation treatment program at the Mayo Clinic in Rochester, MN consists of five functional



stages.<sup>22</sup> The entire rehabilitation program usually lasts one year, with the patient progressed through the five stages after different time limits depending on the patient's initial injury, the surgical procedure performed, and the motivation of the athlete.

The five stages consist of early protected mobilization, kinetic chain strength training, neuromuscular-proprioceptive training, sport-specific agility training, and a maintenance program.<sup>22</sup> Regardless of the rehabilitation program used, the clinician must understand what steps must be taken to protect the healing of the graft and provide nutrition to the graft. The clinician must also understand the stress that the new graft can withstand under certain loads.

Four phases of the accelerated rehabilitation program described by Shelbourne et al<sup>11</sup> are shown in Table 3 on page 26. The ACL accelerated rehabilitation program continues to be re-evaluated and changed. The accelerated rehabilitation protocols act as only a guide for the clinician to follow. The amount of swelling and range of motion determine the speed at which the patient is allowed to proceed through the stages of the rehabilitation process.

A pilot study was performed by Barrett et al<sup>23</sup> to discover the effect of a straight leg immobilizer compared to a hinged brace in treatment of a patient with a reconstructed ACL directly following surgery. Measurements

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Phase I:	Regain full ROM Resolve swelling Review postoperative rehabilitation program Mental preparation for surgery Arrange school, work, family schedule for elective reconstruction
Phase II:	Obtain full hyperextension Allow wound healing Maintain active quadriceps leg control Minimize swelling Achieve 90° of flexion
Phase III:	Resume a normal gait pattern Improve flexion to 135° Increase knee bends, step-ups, calf raises, leg press, Stairmaster, bicycle
Phase IV:	If strength is adequate, start lateral shuffles, cariocas, jumping rope, light running program Start sport-specific activities and return to competition as rehabilitation progress allows

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**TABLE 3.** Four Phases of Accelerated Rehabilitation Program by Shelbourne et al.<sup>27</sup>

of range of motion were taken during the first week of rehabilitation. Patients that were placed in the straight leg immobilizer had a five degree range of motion improvement compared to the patients placed in the hinged brace. It was noted that there was no loss of flexion of the patients treated in the straight immobilizer. Barrett et al<sup>23</sup> proposed that this is a significant statistic due to the fact that extension is usually the most difficult motion to replace during the ACL rehabilitation process.

Draper et al<sup>24</sup> surveyed 180 patients that had previously undergone a bone-patellar-bone autograft reconstruction procedure 12 to 21 months prior to the survey. Questions pertaining to the long-term affects of early weight-bearing, immediate full weight-bearing, early advancement to closed chain exercises, and an early return to athletic activities, usually by four to six months, were administered to the former patients. Of the 180 patients, 58 patients completed the survey. The Lysholm Knee Scoring Scale and a questionnaire were completed by these 58 former patients. The results showed that the majority of these patients had returned to their former level of activities with minimal complaints.

Functional rehabilitation has been incorporated into the ACL rehabilitation over the past few years.<sup>25</sup> Functional rehabilitation concentrates on returning the patient back to his or her normal activities by performing

exercises which simulate the actions used by the patient in his or her normal activity. Concepts of agility, proprioception, and patient confidence are combined to reach the goals of the functional rehabilitation. Different goals are determined for each individual patient.

Markey<sup>25</sup> explained three different categories of rehabilitation based upon the patient's individual goals and functional performance expected by the patient. These three categories consist of the nonathletic level, the athletic level, and the athlete level. The determinants in reaching the goals of each patient's ACL rehabilitation program include the patient's motivation, the type of injury, the stability regained in the knee, and the innovation of the clinician. Constant monitoring of the vigorous rehabilitation by the clinician is necessary to prevent reinjury.

Tegner et al<sup>26</sup> created a test that patients with ACL reconstruction are required to pass in order to return to their normal level of activities when treated at his facility. This test consists of a one-leg hop, running in a figure-of-eight, running up and down a spiral staircase, and running up and down a slope to test proprioception and stability of the reconstructed knee. This test was also used to monitor the ACL rehabilitation process.

Shelbourne and Nitz<sup>27</sup> found that patients with a reconstructed ACL who were treated more aggressively

experienced advantages such as: (a) improved muscular strength, (b) greater range of motion, (c) better knee stability, (d) decreased incidence of arthrofibrosis, (e) less joint stiffness, less patellofemoral pain, and other symptoms, and (f) were more satisfied with the outcome of their rehabilitation. According to the literature, an early return to activity does not make the patient prone for reinjury.<sup>28</sup> Subjective assessment and knee arthrometric tests showed that patients who follow the accelerated ACL rehabilitation program are satisfied with the outcome.

Disadvantages of the accelerated ACL rehabilitation program include: (a) inadequate time allowed for healing of the graft, (b) unnecessary stretching of the graft, and (c) inadequate time for the therapist to detect complications associated with the accelerated ACL program.<sup>27</sup> Long-term research of the outcome of the accelerated ACL rehabilitation program is unavailable since the program has slowly evolved over the last seven years.

The return of the patient to his or her full functional activity after ACL reconstruction is a long hard process. The ACL rehabilitation program has been able to change because information collected over the years has given the medical community the opportunity to continuously update the knowledge linked with the biomechanics of the ACL. Seto et al<sup>29</sup> have been able to modify their ACL rehabilitation program to reflect the changes made by the medical community

based on clinical experience and research results by using their ACL rehabilitation program as a guide and not as a strict format for patient progression.

The clinician must avoid the errors of the accelerated ACL rehabilitation program such as ignoring pain, which will decrease muscle strength and knee range of motion, tendinitis, and exercises which aggravate a pre-existing arthritic-type condition.<sup>25</sup> Regardless of the ACL rehabilitation program used, the knowledge of the protection of the graft during muscular strengthening, and endurance and coordination training is necessary for the patient to achieve the maximal benefits from the reconstructed ACL.<sup>22</sup>

Progression of the ACL rehabilitation program is no longer based on time constraints.<sup>30</sup> The healing of the graft and the loads that the graft can withstand at certain points in time are not clearly understood. The clinician must be careful not to completely ignore sound basic science to rush the rehabilitation process.

CHAPTER V  
TRADITIONAL VERSUS ACCELERATED  
ACL REHABILITATION PROGRAMS

Since surgeons have been mainly performing the bone-patellar tendon-bone reconstruction for ACL replacement, research has transferred to the area of rehabilitation.<sup>3</sup> The two ACL rehabilitation programs compared in this research are the traditional and accelerated ACL programs.

Shelbourne and Nitz<sup>3</sup> compared two groups of patients who underwent two different ACL rehabilitation programs. The traditional ACL rehabilitation program was followed by those patients who were treated from 1984 to 1987. The accelerated ACL rehabilitation program was followed by those patients who were treated from 1987 to 1989. In this research, range of motion, strength, and stability were measured and recorded. Measurements taken of each group showed that the accelerated ACL rehabilitation program had increased range of motion, increased isokinetic strength, and better joint stability compared to those patients belonging to the traditional ACL rehabilitation program.

Encouragement of early passive terminal extension, early weight-bearing, and quadriceps control allowed the patient to progress through the postoperative rehabilitation

program at a faster pace.<sup>3</sup> The patients in the accelerated ACL rehabilitation program were able to achieve full range of motion by six to eight weeks and strength was gained earlier than the group treated with the traditional ACL rehabilitation program without compromising knee joint stability. The accelerated ACL rehabilitation program allowed these patients to return to competition at four to six months after surgery compared to six to nine months for the traditional ACL rehabilitation program.

Wilk and Andrews<sup>16</sup> compared the results of their rehabilitation program to the results noted by Shelbourne and Nitz.<sup>27</sup> The two rehabilitation programs were similar in form and were of the accelerated ACL rehabilitation form. The muscular strength and knee stability test results were comparable. Overall, the results of the two programs appeared similar.

Conclusions of a study comparing the two ACL rehabilitation programs by Glasgow et al<sup>28</sup> show that early return to activity following ACL reconstruction does not make the patient prone to reinjury. They also stated that an early return to activity does not create a less desirable outcome, such as decreased knee joint stability.

Anderson and Lipscomb<sup>31</sup> compared five different types of groups following different ACL rehabilitation programs.

1. Group I was treated with a knee immobilizer set in extension with quadriceps sets and straight leg raises performed twice daily.



2. Group II was treated with a knee immobilizer set in extension with quadriceps sets, straight leg raises, and TENS performed twice daily.
3. Group III was treated in 60 degrees of knee flexion with TENS, quadriceps sets, and straight leg raises performed twice daily with the immobilizer locked in 60 degrees of flexion.
4. Group IV was treated in 60 degrees of knee flexion with electrical stimulation applied for ten hours a day and quadriceps sets and straight leg raises performed twice daily with the immobilizer locked in 60 degrees of flexion.
5. Group V was treated in 60 degrees of knee flexion. The CPM, which was set at 35 degrees of knee extension to 70 degrees knee flexion, was performed twice daily. TENS, quadriceps sets, and straight leg raises with the immobilizer locked in 60 degrees of knee flexion were also performed twice daily.

Results of this research show that immobilization in flexion was favored because three of the patients treated in extension required manipulations to regain flexion.<sup>31</sup> Stability of the knee joint of those treated in extension and flexion were similar. Electrical muscle stimulation (EMS) did not reduce muscle atrophy, but it did decrease the strength deficit that occurred with immobilization. EMS did

increase range of motion and decrease patellofemoral crepitation. It was stated that CPM reduced the need for manipulation compared to immobilization in extension, but was not as effective as early limited range of motion. It was concluded that the optimal rehabilitation program included EMS and immobilization in flexion with early limited range of motion.

Malone and Garrett<sup>32</sup> have similar ACL rehabilitation protocols to Shelbourne and Nitz.<sup>27</sup> Malone and Garrett<sup>32</sup> do have progression criteria for the patient, but feel that the patient must be provided with flexible time limits to allow for individualization for success in the ACL rehabilitation program. According to Malone and Garrett,<sup>32</sup> patients need approximately two to three months to regain a normal functional level of activity. If the patient is looking to return to his or her competitive sport by six to eight months, the functional exercises of the patient's sport must be started at approximately four to six months.

Advantages of the accelerated ACL rehabilitation program consist of:<sup>32</sup>

- a) Increased patient cooperation and compliance.
- b) Earlier return to normal function and athletic activities.
- c) A decrease in the incidence of patellofemoral joint symptoms.
- d) A decrease in the number of procedures required to obtain full knee extension.

The accelerated ACL rehabilitation program resulted in an earlier and more complete restoration of extension and an earlier return of final flexion without compromising knee stability.<sup>30</sup> Early increased range of motion, strength, and function can be achieved with the accelerated ACL rehabilitation program without putting the graft at risk or jeopardizing knee stability.<sup>27</sup>

Early motion decreased arthrofibrosis as well as the need for postoperative manipulation.<sup>33</sup> Early motion had no detrimental effect on outcome when compared with six weeks of knee immobilization. Many authors agree that if early motion is allowed, it should be passive, or within a limited range of motion.

Patients with a reconstructed ACL have received better results from the current accelerated ACL rehabilitation program than from the traditional ACL rehabilitation program.<sup>3</sup> By encouraging early passive terminal extension, early weight-bearing, and quadriceps control while emphasizing closed kinetic chain exercises, the patients were able to progress through the postoperative rehabilitation at an accelerated pace. Full range of motion and full strength were gained earlier in ACL rehabilitation without compromising knee stability, and the patient was able to return to his or her normal activities as soon as four to six months following surgery. The clinician must keep in mind that the design of the ACL rehabilitation

program is based on the most current scientific information, sound therapeutic principles, and clinical experiences.<sup>9</sup>

CHAPTER VI  
DETERMINANTS OF WHICH ACL REHABILITATION  
PROGRAM TO CHOOSE FOR TREATMENT

Although treatment of the patient with a reconstructed ACL has recently shifted from the traditional ACL rehabilitation program, not all patients will highly benefit from the accelerated ACL rehabilitation program. Many factors must be accounted for when choosing the ACL rehabilitation program that is the most beneficial for each individual patient.

Certain variables will affect the outcome of the ACL rehabilitation process. These variables include: (a) the type of surgical approach,<sup>16,34</sup> (b) the type of graft used, (c) the method of graft fixation, (d) the method of graft placement, and (e) patient related variables.<sup>3,16,25,35,36</sup> Patient related variables include age,<sup>3,12,35</sup> body type,<sup>16</sup> patient activity level,<sup>16,25,35</sup> patient motivation, and other associated or pre-existing injuries of the knee.<sup>3,35</sup> The time from the initial injury to the time of surgery is a critical determinant of the outcome of the ACL rehabilitation program also.<sup>18</sup> Research shows a better outcome of ACL rehabilitation if reconstructive surgery is

performed two weeks or more after injury to allow knee joint effusion to disperse.

Arthroscopically assisted ACL reconstruction decreases tissue morbidity and allows faster progression of the patient in the ACL rehabilitation program. The accelerated ACL rehabilitation program is usually performed by those patients who have undergone the bone-patellar tendon-bone ACL reconstruction because research shows that the patellar tendon has the greatest biomechanical properties like the original ACL.<sup>34</sup> The allograft is also a very good substitute for the original ACL, but the sterilization technique of the allograft has a negative effect on the biomechanical properties of the graft, so ACL rehabilitation may need to be progressed slowly for proper graft healing. An allograft is usually used if the previous autograft has failed, if there is a malalignment of the extensor mechanism, if there is marked patellofemoral arthrosis, if the patient has a narrow patellar tendon, or if the patient desires not to sacrifice his or her own tissue.<sup>21</sup> Surgeons usually perform ACL reconstruction surgery on those individuals who are 30 years old or younger.<sup>17</sup> If the patient is very active, the surgeon and patient will determine whether or not to reconstruct the ACL. The therapist must evaluate the patient's body type, activity level, and motivation to determine whether to accelerate or slow the ACL rehabilitation program. Associated injuries,

such as meniscal tears, and pre-existing injuries of the patient's knee will slow the rehabilitation process.

Exercise progressions must be flexible.<sup>21</sup> The clinician must not get trapped into an automatic progression of exercises. It is necessary to evaluate each activity before progressing the patient to a more difficult activity.<sup>25</sup> When implementing a functional rehabilitation program, the clinician must not focus on time limits. In general, the clinician must apply specific guidelines for treatment of the patient with a reconstructed ACL using his or her knowledge of the surgical procedure and ligament healing, and his or her ability to individualize the rehabilitation program as needed.<sup>3</sup>

CHAPTER VII  
SUMMARY AND CONCLUSION

The rehabilitation management of the patient with a reconstructed ACL has changed over the past few decades.<sup>34</sup> The literature presented a variety of protocols, which are to be used as guidelines for the treatment of a patient with a reconstructed ACL. Advances in basic science research and new surgical procedures have allowed for accelerated ACL rehabilitation.

Although time constraints for healing and maturation of the graft as well as the loads that the graft can withstand at specific points in the range of motion are not clearly understood, ACL rehabilitation has recently been accelerated.<sup>30</sup> The stresses applied to the ACL during various activities are also unknown.

The clinician must use his or her knowledge of basic science to choose the appropriate ACL rehabilitation for each patient. The ACL rehabilitation protocol supplied to the clinician is only a guideline, and the clinician must be able to accelerate or slow the rehabilitation process as he or she sees appropriate for the patient. Accurate and recent knowledge of ACL rehabilitation research will allow the clinician to provide the best and most beneficial treatment to the patient.



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