

Proposed Practice Guidelines for Nonoperative Anterior Cruciate Ligament Rehabilitation of Physically Active Individuals

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Nonoperative management of anterior cruciate ligament (ACL) rupture has not been a successful option for those who participate in high-level physical activity. However, there are instances when patients may want to attempt to return to physically demanding activities with nonoperative rehabilitation for an ACL injury. The purpose of this commentary is to describe guidelines for nonoperative management of physically active individuals with ACL injuries who wish to return to preinjury levels of physical activity. The guidelines are based on the results of 2 clinical studies that improved the overall success of nonoperative management of physically active individuals with ACL ruptures. A decision-making process for selecting appropriate candidates for nonoperative management (rehabilitation candidates) is described. Individuals are classified as rehabilitation candidates if they have no concomitant ligament or meniscal damage associated with the ACL injury, have a unilateral ACL injury, and meet all 4 of the following criteria: (1) timed hop test score of 80% or more of the uninjured limb, (2) Knee Outcome Survey Activities of Daily Living Scale score of 80% or more, (3) global rating of knee function of 60% or more, and (4) no more than 1 episode of giving way since the incident injury to the time of testing. Individuals meeting the criteria of a rehabilitation candidate undergo an intensive rehabilitation program before returning to high-level activity. The rehabilitation program consisting of lower extremity muscle strength training, cardiovascular endurance training, agility and sport-specific skill training, and a training program using balance perturbations is described. *J Orthop Sports Phys Ther* 2000;30:194-203.

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Nonoperative management of anterior cruciate ligament (ACL) rupture has had limited success for those who participate in high-level physical activity.^{1,7,10,29} Many patients experience continued episodes of instability and reduce their activity levels as a result of their knee condition, even after undergoing rehabilitation.^{1,4,6,7,10,29} The evidence supports surgical management as the treatment of choice for those who want to return to high-level physical activity after ACL rupture.^{1,7,10} There are special circumstances, however, when individuals may want to attempt to return to physically demanding activities, at least temporarily, without undergoing surgery. Examples may include the athlete who has exhausted eligibility or who needs to compete to demonstrate worthiness for athletic scholarships or an all-star team or seasonal laborers who regularly subject the knees to climbing, lifting, and working on uneven surfaces and would like to postpone surgery until the busy work season is completed.

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We identified 2 areas and conducted studies that have allowed us to improve the odds of successful outcome of nonoperative management of ACL rupture for physically active individuals. The first area deals with selecting appropriate candidates for nonoperative treatment. In previous studies where the effectiveness of nonoperative management of ACL injuries was shown to be limited, subjects attempted to return to high-level activity with nonoperative management on a self-elected basis (without the use of evaluation criteria to select subjects for nonoperative management).^{1,10,29} We knew from previous work,^{9,27} as well as reports from other investigators,^{7,29} that some individuals can successfully return to high-level physical activity with nonoperative management. We hypothesized that nonoperative treatment outcome could be improved if individuals with good potential to succeed with nonoperative management could be identified early after injury.

We have developed and tested decision-making criteria based on scores from a composite of functional tests and self-report surveys to identify patients who have potential to succeed (rehabilitation candidates) with nonoperative treatment.¹¹ During a 2-year period, 93 patients with acute, unilateral ACL or graft ruptures without concomitant multiple ligament injury or repairable meniscal damage were tested. Thirty-nine (42%) of 93 patients tested were categorized as rehabilitation candidates and 54 (58%) of 93 were noncandidates based on test scores. Twenty-eight of the 39 patients categorized as rehabilitation candidates elected nonoperative management of the injury. Twenty-two (79%) of 28 patients were able to return to preinjury levels of activity and complete the season successfully. Success was defined as the ability to complete the season without an episode of giving way or buckling of the knee. None of the patients who elected nonoperative management in our study extended the injury to the knee as a result of participation in rehabilitation or athletic competition.

In previous studies where patients self-elected nonoperative management for ACL injury, success rates for returning patients to high-level physical activity were 23% (9/39),¹⁰ 30% (12/40),¹ and 39% (12/31).²⁹ Although direct comparison of our rate of success with previously reported studies is limited because of differences in methods, it appears that our decision-making criteria show promise as an alternative way of selecting appropriate candidates over a self-elected basis for nonoperative treatment. We currently are using these criteria as a decision-making tool to determine which patients will be allowed to delay surgical treatment and temporarily return to high-level physical activity.

The second area of study was directed at improving the quality of nonoperative rehabilitation strategies. Traditionally, nonoperative ACL rehabilitation programs have been primarily impairment based,

TABLE 1. Number of patients who had successful and failed rehabilitation for perturbation and standard groups.

Group	Successful*	Failed†	Total
Perturbation	11 (2.08)‡	1 (-2.08)‡	12
Standard	7 (0.0)	7 (0.0)	14
Total	18	8	26

* Successful rehabilitation is defined as having no episodes of giving way and maintaining functional status as a rehabilitation candidate. Candidates must meet all the following criteria: (1) timed hop test score of 80% or more of the uninjured limb, (2) Activities of Daily Living Scale score of 80% or more, (3) global rating of 60% or more during a 6-month postinjury follow-up period.

† Failed rehabilitation is defined as having at least 1 episode of giving way or a reduction in functional status to a noncandidate. Candidates must be unable to meet all the following criteria: (1) timed hop test score of 80% or more of the uninjured limb, (2) Activities of Daily Living Scale score of 80% or more, (3) global rating of 60% or more during a 6-month postinjury follow-up period.

‡ The residual values for the perturbation group cells indicate that the significant value of χ^2 is due to the high proportion of subjects who succeeded and the low proportion of subjects who failed rehabilitation in this group compared with the standard group.

emphasizing lower extremity muscular strength and endurance, restoring knee joint mobility, agility training, activity modification, and bracing.^{6,7,12,17,36} However, recent studies have indicated that successful return to high-level activities after ACL rupture was correlated with alterations in lower extremity muscle activity patterns.^{5,19,20,27,30,31,33} There is evidence that treatment techniques, involving perturbations of support surfaces, can be used to induce compensatory alterations in muscle activity patterns in patients who are ACL deficient.^{2,8,16} We hypothesized that augmenting standard nonoperative ACL rehabilitation, which includes lower extremity muscular strength and endurance exercises, knee joint mobility exercises, and agility and sport-specific training,^{6,7,12,17,36} with perturbation training techniques would improve the probability of successful return to high-level activity.

We conducted a randomized clinical trial that compared the effectiveness of a standard nonoperative ACL rehabilitation program with one that was augmented with a perturbation training program.¹¹ The perturbation training program consisted of applying destabilizing forces to the patient's involved limb while the patient stood on tilt boards and roller boards. All subjects met the criteria for a rehabilitation candidate. Twenty-six subjects completed the study. The frequency of successful and failed rehabilitation between groups is illustrated in Table 1. Failed rehabilitation was defined as having at least 1 episode of giving way at the knee or a reduction in functional status to a noncandidate during a 6-month postinjury follow-up period. A χ^2 analysis²⁶ ($\chi^2_1 = 5.27$, critical value = 3.84, $P < .05$) indicated that a significantly greater number of subjects in the standard group failed rehabilitation (7/14) compared with subjects in the perturbation group (1/12). The

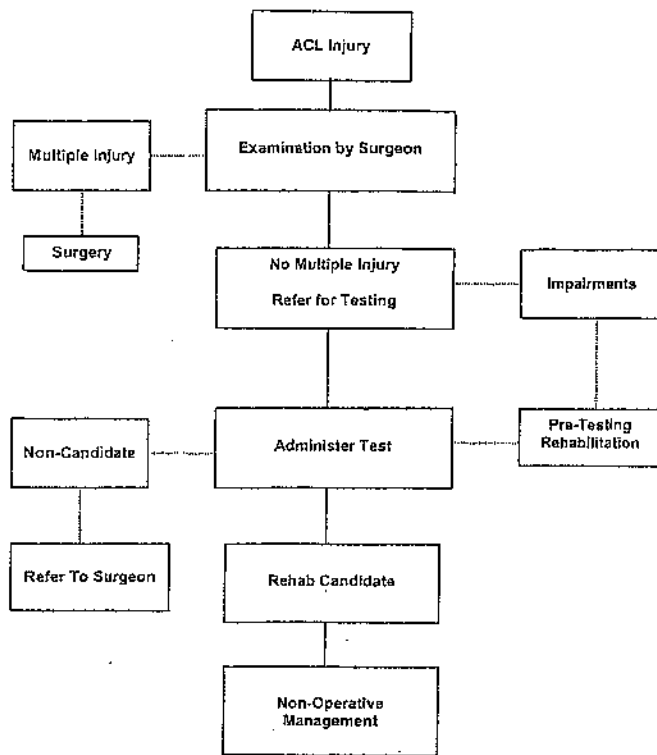


FIGURE 1. Patient selection algorithm for nonoperative treatment.

perturbation training resulted in greater long-term success in returning patients to high-level activity.

The results of both the study in which we developed and tested patient selection criteria¹¹ and the randomized trial concerning the perturbation training program¹¹ have prompted us to establish treatment guidelines for returning patients, at least temporarily, to high-level physical activity after ACL rupture. High-level activity is defined as regular participation in sport or recreational activities that require jumping, cutting, and pivoting or occupations that require physically demanding labor.⁷ The purpose of this commentary is to describe the guidelines for patient selection and rehabilitation. These guidelines are applicable to individuals with unilateral ACL rupture who do not have concomitant ligament or repairable meniscal damage associated with their injury. The guidelines do not necessarily apply to individuals who are ACL deficient and wish to partake in long-term participation in high-level activity (± 6 months) or those who do not meet the criteria of a rehabilitation candidate.

SELECTING PATIENTS FOR NONOPERATIVE MANAGEMENT

The patient selection algorithm is summarized in Figure 1. The first order of decision making is to determine the extent of damage to the knee. It has been shown that patients who sustained damage to other ligaments, repairable meniscal damage, or

TABLE 2. Outline of pretesting rehabilitation program.

Pain and inflammation	Medication, ice, other modalities as needed
Effusion	Ace wrap, limb elevation, isometric muscle pumping, retrograde massage of lower extremity
Joint mobility	Supine wall slides (patient places feet on wall and slides feet down the wall to increase knee flexion), flexion and extension active range of motion, patellar mobilizations, stationary cycling (low resistance), low-load prolonged stretching, emphasis of normal knee flexion and extension excursions during gait
Muscle performance	Isometric quadriceps and hamstring contractions, straight leg raising, electrical stimulation quadriceps strength training protocol (if indicated by presence of diminished isometric quadriceps contraction, knee extensor lag on straight leg raising, or inability to perform a straight leg raise), resisted leg extensions (90–45°) and leg curls with theraband
Weight-bearing	Partial squats (0–45°), heel raises, lateral step-ups, trampoline jogging and hopping, encourage walking program and stair climbing, progress to skipping and short single leg hops on floor when tolerated without pain in preparation for hop tests

chondral defects with the ACL rupture have not been successful with nonoperative management^{1,7} and are therefore candidates for surgical treatment. This decision making is performed by the surgeon. If these pathological conditions have been ruled out, the patient is referred to physical therapy for testing.

Preparing the Patient for Testing

Testing procedures include a series of single-leg hop tests. Testing is usually performed within 1–4 weeks after the initial injury; therefore, joint effusion and pain, limitations in knee joint motion, and quadriceps femoris weakness must be resolved before testing. Patients may participate in a pretesting rehabilitation program until these impairments are resolved. Table 2 outlines the pretesting rehabilitation program. The criteria used to determine readiness for testing include the following: (1) no evidence of joint effusion, (2) full passive knee joint range of motion, (3) full knee extension during a straight leg raise on the involved limb, (4) a quadriceps femoris maximum voluntary contraction force on the involved limb equivalent to 75% of that on the unin-

volved limb, and (5) tolerance for single-leg hopping on the involved limb without pain.

Quadriceps femoris weakness has been shown to be correlated with poor outcomes and is of great concern following ACL injury.^{22,32} Quadriceps femoris weakness should be resolved promptly. If the inability to perform a voluntary quadriceps isometric contraction or the presence of an extensor lag on straight leg raising persists for more than 1 week of voluntary exercise, then the use of high-intensity electrical stimulation of the quadriceps femoris muscle group is recommended as an adjunct to the pre-screening rehabilitation program. The high-intensity electrical stimulation quadriceps femoris strength training protocol has been described by Snyder-Mackler et al.³² Use of this protocol as an adjunct to voluntary strength training exercises has been shown to be more effective in improving quadriceps femoris strength than voluntary exercise alone.³² The high-intensity stimulation treatment is discontinued when the quadriceps force output of the involved limb is equivalent to 80% of that from the uninvolved limb.

Test Procedures and Criteria for Patient Selection

The patient selection process includes 4 tests administered in the following order: (1) single, cross-over, triple, and timed hop tests²⁴; (2) reported number of giving way episodes from the time of injury to the time of testing; (3) the Knee Outcome Survey Activities of Daily Living Scale¹⁸; and (4) a global rating of knee function. The hop tests used in this study have been described by Noyes et al.²⁴ as performance-based measures of knee function. The tests are all single-leg hops and include (1) a single hop for distance, (2) a triple cross-over hop for distance in which the subject crosses over a 6-in-wide tape with each consecutive hop, (3) a straight triple hop for distance, and (4) a timed hop in which the subject hops a distance of 6 m as fast as possible. In our clinic, all patients wear a functional knee brace during the hop tests. Patients perform 2 practice trials followed by 2 measured trials of each hop test on both limbs. The hop test score for each limb is reported as the average of the 2 measured trials. The single hop, cross-over hop, and triple hop scores are expressed as a percentage of the injured extremity score divided by the uninjured extremity score. The timed hop score is expressed as a percentage of the uninjured extremity score divided by the injured extremity score.

The report of episodes of giving way is the number of times the patient experiences buckling or subluxation of the tibiofemoral joint that results in pain and joint effusion from the time of injury to the time of testing. This report does not include the giving way episode that occurred at the time of the initial injury. The frequency of episodes of giving way

TABLE 3. Knee Outcome Survey Activities of Daily Living Scale.¹⁸

To what degree does each of the following symptoms affect your level of daily activity? (check one answer on each line)

	Never have	Have, but does not affect activity	Affects activity slightly	Affects activity moderately	Affects activity severely	Prevents me from all daily activity
Pain						
Grinding or Grating						
Stiffness						
Swelling						
Slipping or Partial Giving Way of the Knee						
Buckling or Full Giving Way of Knee						
Weakness						
Limping						

How does your knee effect your ability to ... (check one answer on each line)

	Not Difficult at all	Minimally Difficult	Somewhat Difficult	Fairly Difficult	Very Difficult	Unable To Do
Walk						
Go up stairs						
Go down stairs						
Stand						
Kneel on the front of your knee						
Squat						
Sit with your knee bent						
Rise from a chair						

has been shown to be associated with the risk of further damage to the knee.^{25,29}

The Knee Outcome Survey is a self-report survey that is used to determine the functional level of patients with knee injuries.¹⁸ The Activities of Daily Living Scale portion of the Knee Outcome Survey (Table 3) assesses how the patient's knee condition affects daily activities, such as ambulation, stair climbing, kneeling, sitting, and squatting.¹⁸ There are 16 items in this survey in which patients will rate their knee function. There are 6 possible ratings for each item, which range from 0-5, with 5 representing the best functional score for the item (eg, for the pain item, a score of 5 is applied if the patient marks the box under "never have," and a 0 is applied if the patient marks the box under "prevents me from all daily activity"). The ratings for each item are then summed, which would result in a highest possible rating of 80 (5 × 16 items). The final score for the Activities of Daily Living Scale is as follows: (the sum of the patient's ratings/80) × 100. For example, if the sum of the patient ratings equaled 75, the calculated Activities of Daily Living Scale score would be (75/80) × 100 = 94.

A global rating of knee function is used to assess the patient's overall perception of his or her knee

TABLE 4. Guidelines for progression of nonoperative rehabilitation program.

Type of training	Milestones	Activities
Muscle performance	Quadriceps strength <80% of uninjured leg	Electrical stimulation protocol, leg curls, leg press
	Quadriceps strength ≥80% of uninjured leg	Discontinue electrical stimulation, continue with leg extensions, leg curls, leg press
Endurance training	Tolerate <10-15 minutes without pain, swelling	Treadmill running, stationary cycling, or sliding board training
	Tolerate >10-15 minutes without pain, swelling	Progress to road running or cycling or ice skating
Agility training	Initial treatment session	Half-speed agility skill training
	Tolerate half-speed training without pain or apprehension	Progress to full-speed skill training
Sport-specific training	Initiate when tolerating full-speed agility training without pain or apprehension	Unopposed practice of sport-specific skills*
	Tolerate unopposed practice without pain or apprehension	Progress to one-on-one opposed practice of sport-specific skills†
	Tolerate opposed practice without pain or apprehension	Begin full practice activity with team

* Unopposed practice refers to practice of skill without a training partner attempting to defend against or inhibit the performance of the skill.

† Opposed practice refers to practice of skill with a training partner attempting to defend against or inhibit the performance of the skill.

function. Patients rate knee function based on the following question: "How would you rate your current level of knee function on a scale from 0%–100%, with 100% being your level of knee function before your injury?"

Rehabilitation candidates are those patients who meet all 4 of the following criteria: (1) timed hop test score of 80% or more of the uninjured limb, (2) Activities of Daily Living Scale score of 80% or more, (3) global rating of 60% or more, and (4) no more than 1 episode of giving way since the incident injury to the time of screening. Patients who fail to meet any of these criteria are classified as noncandidates. Rehabilitation candidates are allowed the option of pursuing a nonoperative treatment approach for their injury. Noncandidates are referred back to their surgeons for consultation. We have no evidence for the effectiveness of our rehabilitation program for patients classified as noncandidates.

TABLE 5. Guidelines for progression of perturbation training.

Perturbation technique	Milestones	Activities
Roller board translations	Initial treatment session	Double limb support perturbations
	Controlled balance with double limb support	Progress to single limb perturbation in parallel bars
	Controlled balance with single limb support in parallel bars	Progress to single limb support in parallel bars
Tilt board perturbations	Initial treatment session	Double limb support perturbations
	Controlled balance with double limb support	Progress to single limb perturbation
	Controlled balance with single limb support	Add functional training performance during perturbations
Roller board and stationary platform perturbations	Initial treatment session	Perform perturbation in straddle stance position
	Match therapist's forces without excessive movement of the roller board	Progress to diagonal stance perturbation
	Match therapist's forces in diagonal stance without excessive movement of the roller board	Add functional training performance during perturbations

NONOPERATIVE REHABILITATION

The goal of the rehabilitation program is to return patients to full participation in high-level physical activities. The focus of rehabilitation is to restore muscle performance, cardiovascular endurance, agility and coordination skills, and sport-specific skills.

Guidelines for the progression of treatment are outlined in Tables 4 and 5. Patients receive 10 training sessions at a frequency of 2–3 sessions per week, depending on individual scheduling constraints. Return to part-time competitive sports or work activity is allowed the last week of training (sessions 8–10). Patients return to full activity at the completion of the training program.

Muscle Performance Training

The muscle performance training program emphasizes increased capacity for muscle force output of the quadriceps femoris and hamstring muscle groups. If the involved limb quadriceps femoris maximum voluntary isometric force output is less than 80% of that from the uninvolved limb, the high-intensity electrical stimulation protocol described by Snyder-Mackler et al³² is continued until this criterion is met. Non-weight-bearing resisted leg extension

exercises are performed in a limited range of 90–45° of flexion. The evidence suggests that resisted leg extensions can be performed in this range without inducing significant anterior shear forces on the tibiofemoral joint.^{3,14} Resisted leg curls are used for hamstring strengthening. Leg press and squat lifts are also used for general lower extremity musculature strength training. These exercises are performed in a limited range of 0–45° of flexion to minimize excessive stress on the patellofemoral joint and to minimize excessive anterior shear that may occur with greater flexion ranges in these exercises.^{15,34,37} We use high-load, low-repetition application of the exercises (eg, 10 repetition maximum), which has been shown to be optimal for inducing improvements in muscle force output.^{19,26} Patients perform 3 sets of each exercise, including 1 set of 10 repetitions at 75%, 1 set of 7–8 repetitions at 85%, and 1 set of 5–6 repetitions at 95% of the 10 repetition maximum load. Patients are encouraged to perform strength training exercises at least 3 times per week. Training loads are increased as their 10 repetition maximum load increases.

Cardiovascular Endurance Training

There is evidence that endurance capacity is specific to the type of training that is performed.^{23,35} Therefore, the type of endurance training selected should be related to the patient's sport or work activity. Many of our patients are involved in sport activities that require running. A graded running program is used for these patients for cardiovascular endurance training. The program begins with treadmill running. When patients can run 15–20 minutes without pain or swelling, they progress to level road or track running and finally to road or field hill running. If patients are involved in cycling activities, we initiate the endurance training program with stationary cycling. When they can ride 15–20 minutes of stationary cycling without pain or swelling, they progress to road or track cycling workouts. For patients whose sport activity requires skating, we begin the endurance training on a sliding board to simulate skating motions. They progress to actual skating workouts when they perform 5–10 minutes of the sliding board workout without pain or swelling.

Agility and Sport-Specific Skill Training

The agility training program is designed to allow the patient to adapt to quick changes in direction, quick starting and stopping, and cutting activities. It is recommended that patients wear their functional knee brace during these activities. Side slides and carioca drills are used to promote quick changes in direction in lateral movement. Shuttle runs are used to expose the lower extremities to quick starting and

stopping forces. Patients also practice 45° cutting and cutting and spinning techniques. Agility training is initiated at half speed and progresses to full-speed activity.

Sport-specific skills are incorporated into the program when the patient can perform full-speed agility training without pain, swelling, or hesitation. Sport-specific tasks (eg, ball catching, passing, kicking) are added during the agility training techniques. Sport-specific skill practice is also performed in the context of playing situations. For example, basketball players begin practicing dribbling skills, jump shots, and lay-ups. Hockey players perform stick handling, passing, and shooting drills during their skating workouts. These activities are initiated without being opposed by a training partner and then progressed to practice with one-on-one opposition. Patients are allowed to begin full practice activities when they tolerate the opposed sport-specific skill training without difficulty.

Perturbation Training Program

Three types of perturbation techniques are used in the training program. The first is the application of translational perturbations to the involved limb through a roller board (Figure 2). Patients begin this technique standing in double limb support on a roller board within parallel bars. The therapist applies translational perturbations of the roller board in anterior and posterior, medial and lateral, and rotary directions. Patients are instructed to maintain their balance during the perturbations. The direction and magnitude of the perturbations are applied by the therapist in a random fashion. Only small perturbations are needed to disrupt the patient's balance. When patients have adapted to the perturbations in double limb support, the treatment is progressed to single limb support on the involved limb. This progression usually occurs within 1–2 treatment sessions. As skill improves, patients are instructed to perform this activity without the use of arm support on the parallel bars.

Second, a tilt board technique is used to apply rotational perturbations in anterior and posterior and medial and lateral directions (Figure 3). Treatment is initiated with the patient standing on the tilt board in double limb support. When the patient has gained a balanced position on the board, the therapist applies anterior and posterior tilting perturbations at random to disturb the patient's balanced position. The therapist provides standby assistance in the event that the patient steps off the board. The timing and speed of the perturbations are randomly varied by the therapist. The same process is repeated for medial and lateral tilting perturbations. When the patient can maintain balance without difficulty during the perturbations, treatment is progressed to single limb

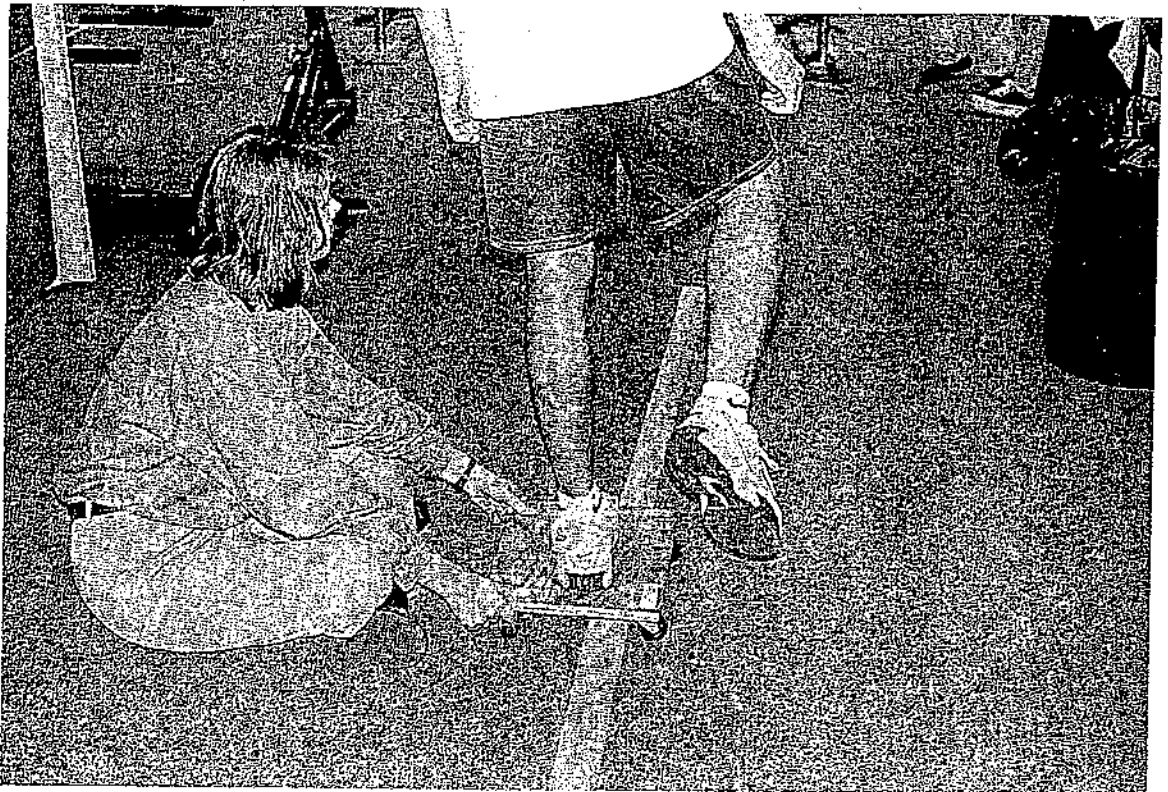


FIGURE 2. Roller board translational perturbation technique.

support on the involved limb. Once the patient is able to maintain balance during single limb support perturbations, treatment is progressed by having the patient perform a sport-specific task, such as ball

catching and throwing, during the perturbation treatment.

The third type of treatment technique used in the program is a roller board and stationary platform

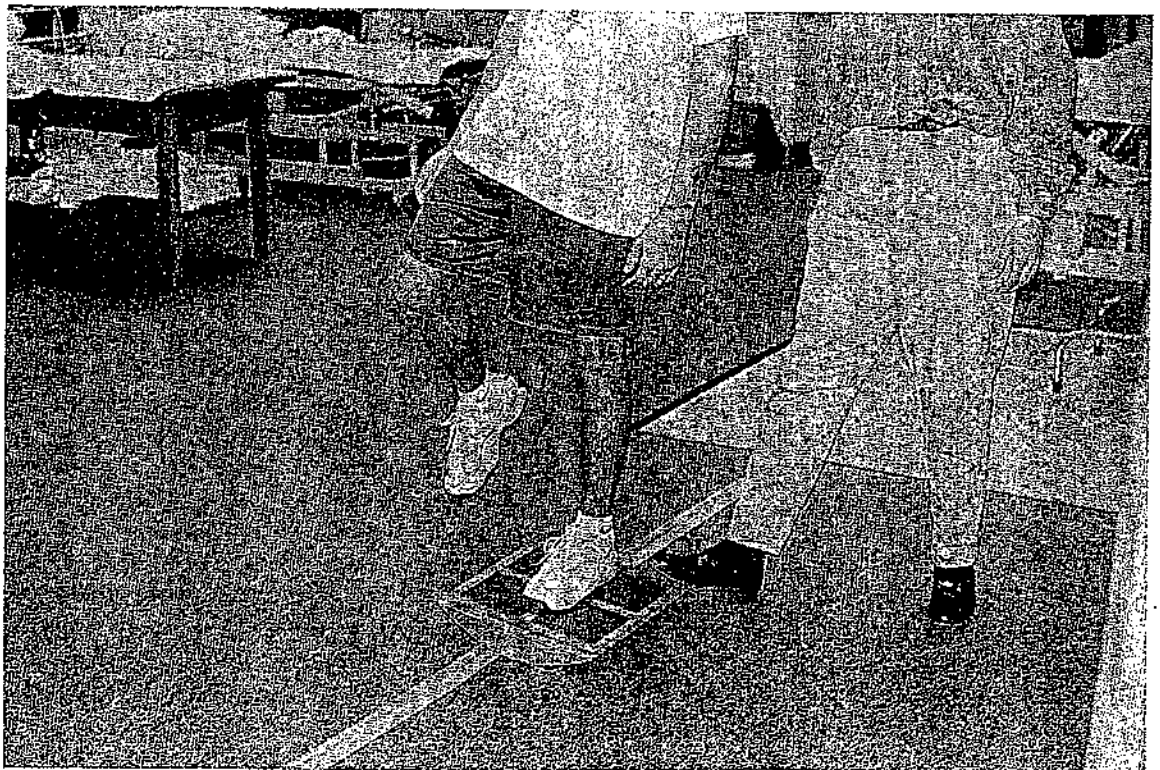


FIGURE 3. Tilt board perturbation technique.



FIGURE 4. Roller board and stationary platform perturbation technique.

technique (Figure 4). This treatment technique is similar to a rhythmic stabilization proprioceptive neuromuscular facilitation technique.²¹ The patient stands with one limb on the roller board and another limb on a box (stationary platform) that is approximately the same height as the roller board. The patient is instructed to maintain a steady position of the roller board when the therapist attempts to move the board. The patient attempts to resist the therapist's force on the board by pushing the lower extremity on the board in the opposite direction while matching the speed and intensity of the therapist's perturbation force. Patients are instructed to match, rather than overcome, the therapist's perturbation force. This is done to encourage a selective muscle activation response from the patient instead of a strong co-contraction response of the lower extremity musculature. The therapist perturbs the board in anterior and posterior, abduction and adduction, and left and right rotational directions. The direction, intensity, and speed of the perturbations are randomly applied. A training exercise bout consists of approximately 1-1.5 minutes of perturbations. The patient will perform a training bout with the involved limb on the roller board and a second bout with the involved limb on the stationary box. Training is initiated with the patient assuming a straddle stance then progressed to forward and backward diagonal stances when the patient becomes competent in matching the therapist's perturbation forces. Sport-specific

tasks are also added during the perturbation treatment when the patient exhibits the ability to match the therapist's perturbation forces during the diagonal stance techniques.

CONCLUSION

Patient selection and treatment guidelines for returning physically active individuals to high activity levels with nonoperative ACL rehabilitation have been proposed in this commentary. The guidelines include decision-making criteria for selecting appropriate candidates for nonoperative ACL rehabilitation and treatment guidelines that include the addition of perturbation training techniques to the rehabilitation program. The effectiveness of these treatment guidelines on long-term participation in high-level physical activity with nonoperative ACL rehabilitation is not known at this time.

Further study is needed for continued validation of the proposed treatment guidelines. We have not encouraged patients who did not meet the criteria for a rehabilitation candidate to participate in nonoperative rehabilitation. The validity of our selection criteria could be more clearly defined if noncandidates were allowed to attempt nonoperative rehabilitation in future studies. It is not known at this time if the perturbation training program would improve the likelihood of successful return to high-level activity for patients classified as noncandidates based on

the test criteria described in this commentary. Future studies in which treatment application variables for the perturbation training program (ie, magnitude of the perturbations, frequency and duration of treatment sessions, etc) are varied between groups may help to determine optimal treatment prescriptions. We hope that the information presented in this commentary will assist clinicians in improving their success and foster continued research in nonoperative management of individuals with ACL ruptures.

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