

G. Kelley Fitzgerald
Michael J. Axe
Lynn Snyder-Mackler

A decision-making scheme for returning patients to high-level activity with nonoperative treatment after anterior cruciate ligament rupture

Received: 9 March 1999
Accepted: 25 October 1999

G. K. Fitzgerald (✉)
Department of Physical Therapy,
School of Health
and Rehabilitation Sciences,
University of Pittsburgh,
6035 Forbes Tower,
Pittsburgh, PA 15260, USA
e-mail: kfitzger+@pitt.edu
Tel.: +1-412-647-1232
Fax: +1-412-647-1222

M. J. Axe
First State Orthopaedics,
Medical Arts Pavilion, Suite 225,
Newark, DE 19713, USA

L. Snyder-Mackler
Department of Physical Therapy,
University of Delaware,
309 McKinly Laboratory,
Newark, Delaware, USA

Abstract This report describes the development and current use of decision-making criteria for returning patients to high-level physical activity with nonoperative management of anterior cruciate ligament ruptures, and presents the results of treatment for patients who met our criteria as candidates for nonoperative rehabilitation and attempted to return to high-level physical activity with nonoperative management. The screening examination consists of four one-legged hop tests, the incidence of knee giving-way, a self-report functional survey, and a self-report global knee function rating. We screened 93 consecutive patients with acute unilateral anterior cruciate ligament rupture, classifying them as either candidates ($n = 39$, 42%) or noncandidates ($n = 54$, 58%) for nonoperative management. Of the 39 rehabilitation

candidates 28 chose nonoperative management and returned to preinjury activity levels, 22 of whom (79%) returned to preinjury activity levels without further episodes of instability or a reduction in functional status. No patient sustained additional articular or meniscal damage as a result of rehabilitation or return to activity. The decision-making scheme described in this study shows promise in determining who can safely postpone surgical reconstruction and temporarily return to physically demanding activities. Continued study to refine and further validate the decision-making scheme is recommended.

Key words Anterior cruciate ligament · Screening examination · Rehabilitation · Knee injuries

Introduction

Rupture of the anterior cruciate ligament (ACL) predictably leads to knee instability and loss of function in the majority of those who regularly participate in strenuous physical activity. Evidence suggests that nonoperative management of ACL ruptures yields limited success in returning individuals to physically active life-styles [1, 4–6, 9, 16]. 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, 9, 16]. Decision making appears to be straightforward: physically active individuals who wish to return

to the same activity level should have reconstructive surgery.

Specific circumstances, however, make decisions regarding the timing of surgery difficult. This is especially true in the case of preseason or early season ACL injury. The athlete who has exhausted eligibility, who needs to compete in order to demonstrate worthiness for athletic scholarships or an all-star team, or an individual facing a major competition or event (e.g., regional tennis club championships) may wish to try to “play through the season.” Construction workers and seasonal laborers who subject the knees to climbing, lifting, and working on uneven surfaces and often wish to postpone surgery until the busy season is over also fall into this category. Tradition-

ally many of these patients have self-selected nonoperative management, and their rate of success with this approach has been unacceptable [1, 9, 16]. The need has been recognized in the literature for establishing useful evaluation criteria to identify patients who could rehabilitate and continue to work, or compete, at least temporarily, with minimal risk of reinjuring the knee [1, 9]. Establishment of these criteria would be helpful to patients and their physicians in determining the risk/benefit relationship of nonoperative management.

Passive anterior knee joint laxity (excessive anterior tibial translation) is not well correlated with functional outcome after ACL injury [9, 11, 13, 16, 17] and does not appear to be useful for predicting potential for successful outcome. Andersson [1], however, reported that patients with multidirectional instability resulting from multiple knee ligament injury fare poorly with nonoperative management of their injuries. Therefore the presence of multiple ligament rupture would seem to be an exclusion criterion for nonoperative management.

Several other measurable factors may be useful in estimating a patient's potential for success with nonoperative management of an ACL rupture. Quadriceps femoris muscle strength has been reported to be related to functional ability in ACL-deficient patients [8, 13]. Eastlack et al. [8] found the composite score of a global rating of knee function, the single leg cross-over hop test, and the Knee Outcome Survey-Sports Activity Scale to be correlated with the level of functional recovery in patients with ACL rupture. Being able to take these types of measurements relatively early after an injury may make possible to establish criteria for identifying patients who have a reasonable chance to succeed in returning to high-level physical activity following nonoperative ACL rehabilitation.

The number of giving-way episodes at the knee during functional activity may also be useful in predicting success with nonoperative treatment in patients with acute ACL rupture. Giving-way is defined as buckling, or subluxation, of the tibiofemoral joint that results in pain and joint effusion. Recurrent episodes of giving-way have been associated with the severity of arthritic changes [15] and with an increased incidence of additional meniscal damage over time [16]. If patients report recurring episodes of giving-way with activities of daily living early after ACL rupture, they are likely to be at risk for extending damage to the knee if they return to high-level activity without reconstructive surgery. The frequency of giving-way episodes therefore appears to be an important factor for predicting who would be able to succeed, and who would be at high risk for experiencing further knee damage in returning to high-level activity with nonoperative management after acute ACL rupture.

We have recently developed and are currently using decision-making criteria for selecting patients whom we believe can attempt a return to high-level physical activity

following nonoperative rehabilitation with minimal risk of reinjury. The criteria are based on the results of an inexpensive and easily administered screening examination that includes a series of functional hop tests, a self-report knee function survey, a global rating of knee function, and the frequency of giving-way episodes at the knee during activities of daily living. The purposes of this report are to: (a) describe the development and current use our decision-making criteria, and (b) present the results of treatment for patients who met our criteria as candidates for nonoperative rehabilitation and attempted to return to high-level physical activity with nonoperative management.

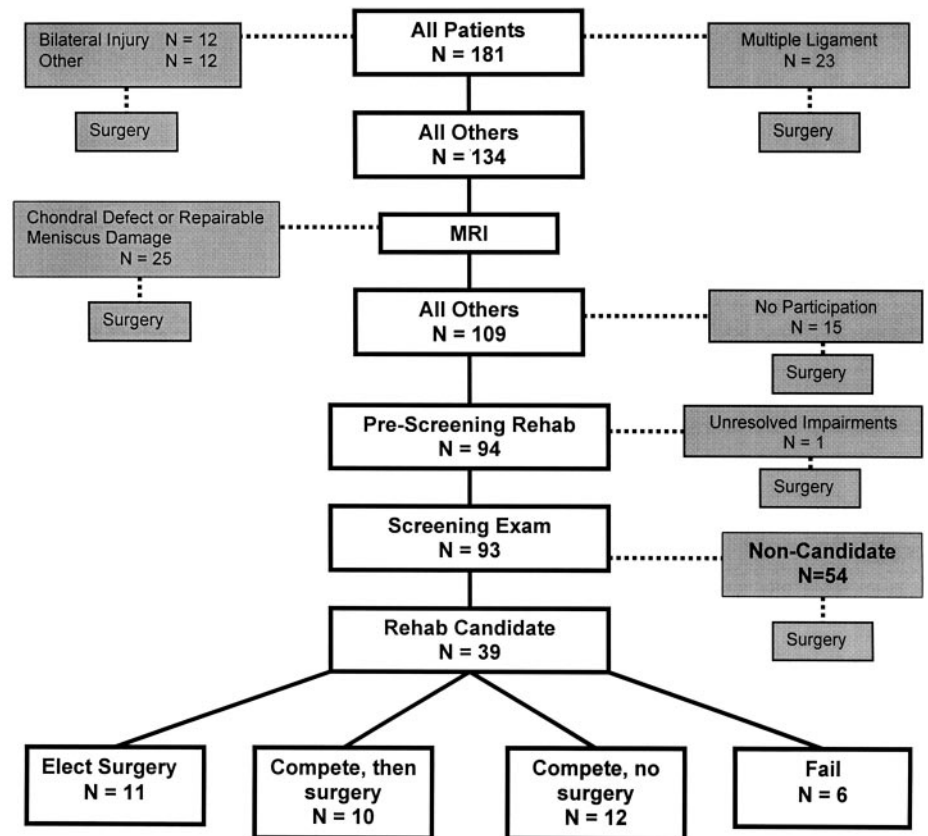
Patients and methods

Patients

The potential subjects for this study included all 181 patients with first-time ACL ruptures ($n = 164$) or acute ruptures of ACL grafts ($n = 17$) seen by a single orthopedic surgeon (M.J.A.) from 1 May 1996 to 30 April 1998 who were regular participants (> 100 h/year) in level I (i.e., football, basketball, soccer) [6] or level II (i.e., racquet sports, skiing, manual labor occupations) [6] activities. The first level of excluding patients from attempting nonoperative management was the presence of concomitant injuries associated with the ACL rupture. We believed, based on evidence in the literature [1, 6], that there would be a high probability of risking further damage to the knee if these patients participated in nonoperative management of their injuries. We excluded 23 patients because of concomitant grade II or greater injury to one or more additional knee ligaments (medial collateral ligament, $n = 16$; lateral collateral ligament, $n = 1$; posterior cruciate ligament, $n = 3$; posterior cruciate ligament plus medial collateral ligament, $n = 2$; posterior cruciate ligament plus lateral collateral ligament, $n = 1$). Twelve patients were excluded because they had other trauma such as fracture or dislocation associated with the ACL injury, and another 12 were excluded because they had bilateral ACL injury and did not have a healthy contralateral extremity for comparison (see Fig. 1). All others underwent magnetic resonance imaging to screen for repairable meniscal lesions or full thickness cartilage defects, and 25 were excluded on the basis of the imaging results. The remaining 109 patients were included in the screening examination. Fifteen of these were not tested for the following reasons: (a) scheduling problems ($n = 3$), (b) missed referrals ($n = 4$), or (c) refusal to participate ($n = 8$). Thus 94 subjects were enrolled in the study and underwent prescreening rehabilitation. One patient had an unresolved knee flexion contracture after prescreening rehabilitation and was not tested. Chart review at the conclusion of the study period confirmed that all patients in the original 181 patient cohort who were not screened underwent surgical stabilization.

The 93 patients in the study included 31 women and 62 men, with an age of 15–57 years (mean = 28.7 ± 10.7), height of 152–190 cm (175.5 ± 8.9), and weight of 50.5–125 kg (79.6 ± 15.3). All patients participating in the screening examination had side-to-side differences in anterior tibiofemoral laxity of 3 mm or greater (mean = 6.0 ± 2.3) as measured with an arthrometer (KT-1000, Med-Metric, San Diego, Calif., USA) by a single examiner (G.K.F.) using maximum manual force. A side-to-side anterior tibiofemoral laxity difference of 3 mm or greater indicates unilateral injury to the ACL [7]. All patients gave informed written consent on a form approved by the institutional Human Subjects Review Board prior to testing.

Fig. 1 Algorithm for clinical decision-making used in this study



Screening examination

The screening examination included the following tests: (a) single, triple, cross-over, and timed hop tests [14], (b) quadriceps femoris maximum voluntary isometric strength test [18], (c) global rating of knee function, (d) the Knee Outcome Survey Activities of Daily Living Scale [12], and (e) report of the number of knee giving-way episodes from the time of injury to the time of testing. These tests were selected as a basis for the functional screening examination based on results from a previous study that indicated that these tests may be related to functional outcome after ACL rupture [8].

The hop tests used in this study have been described by Noyes et al. [14] as performance-based measures of knee function. Measurements from these tests have been shown to be reliable [2, 3, 10]. The tests are all single leg hops and include (a) a single hop for distance, (b) a triple cross-over hop for distance in which the subject must cross over a 15-cm-wide tape with each consecutive hop, (c), a straight triple hop for distance, and (d) a timed hop in which the subject hops a distance of 6 m as rapidly as possible. Subjects performed two practice trials followed by two measured trials of each hop test on both legs. The hop test score for each leg was reported as the average of the two measured trials. The single-hop, cross-over hop, and triple-hop scores were expressed as a percentage of the injured extremity score divided by the uninjured extremity score. The timed hop score was expressed as a percentage of the uninjured extremity score divided by the injured extremity score.

A burst-superimposition maximum voluntary isometric quadriceps femoris strength test was used to compare the torque produced during a maximum voluntary isometric contraction of each subject's involved and uninjured quadriceps femoris muscle. Torque measurements obtained from this technique have been

shown to be reliable [18]. Patients were seated on an isokinetic dynamometer (Kin-Com, Chattecx, Chattanooga, Tenn., USA), and the dynamometer force arm was secured to the ankle. The knee was held in 90° of flexion. Self-adhesive electrodes were applied to the quadriceps so that an electrical stimulus could be applied during strength testing. Subjects were asked to exert as much force as possible while extending the knee against the force arm of the dynamometer. An electrical stimulus (amplitude 130 V, pulse duration 600 μ s, pulse interval 10 ms, train duration 100 ms) was applied during the contraction to ensure that the muscle was maximally activated during the test. If the voluntary effort from the subject produced a torque that was greater than 95% of the electrically stimulated torque, the test was accepted, and the highest value of torque was recorded. If the voluntary effort produced a torque that was less than 95% of the electrically stimulated torque, the test was not accepted, and additional trials were performed until a voluntary effort of 95% or greater was achieved. The strength test score was expressed as an index representing the injured limb torque divided by the noninjured limb torque.

The Knee Outcome Survey is a self-report survey that is used to determine the functional level of patients with knee injuries [12]. This survey has been shown to be a responsive and reliable measure of knee function [12]. The Activities of Daily Living Scale portion of the Knee Outcome Survey assesses how the patient's knee condition affects daily activities, such as ambulation, stair climbing, kneeling, sitting, and squatting [12]. A global rating of knee function was also used to assess the patient's overall knee function. Patients rated knee function on a scale of 0–100%, with 100% representing preinjury function.

All patients were treated prior to testing using a rehabilitation program designed to address impairments associated with the initial injury (i.e., pain, joint effusion, limitations in joint motion, and

high muscle weakness). When the patient met the criteria to be tested (lack of pain and joint effusion, full joint motion, ability to hop on involved leg), the screening examination was performed. Testing was performed within an average of 4 weeks from the incident injury (median 4 weeks, range 1 week–4 months). The screening tests were performed in the following order: single hop, cross hop, triple hop, timed hop, quadriceps strength test, report of giving-way, Activities of Daily Living Scale, and the global knee rating. Subjects wore a functional knee brace on the involved limb for the hop tests as requested by the referring physician (Legend, Smith and Nephew-DonJoy, Carlsbad, Calif., USA). Earlier observations in development of the screening examination suggested that performing the hop tests first had an impact on the self-report functional survey scores. Patients tended to either underestimate or overestimate self-report scores if the hop tests were performed after the self-report surveys. We believed that allowing patients to perform the hop tests first gave them an opportunity to self-evaluate the status of their knees during a physically challenging task, resulting in more accurate ratings of knee function on the self-report surveys.

Grouping variables and criteria

Data from the first 18 patients participating in this study were used to establish grouping criteria. Six of these patients were preliminarily categorized as rehabilitation candidates because they had had no incidents of knee instability with activities of daily living. The remaining 12 were preliminarily categorized as noncandidates because they either experienced additional episodes of giving-way or reported that their knees were unstable during activities of daily living. A multiple regression analysis using the preliminary grouping category as the dependent variable was performed to determine which variables from the screening examination are best correlated with group assignment. Four variables accounted for 72% of the variance ($R^2 = 0.72$): global rating of knee function, incidents of giving-way, Activities of Daily Living Scale, and timed hop test. Grouping cutoff point criteria were then established for each of these variables.

Cutoff levels were based on values two standard deviations below the group mean for those we preliminarily categorized as rehabilitation candidates. We selected a value of 2 SD below this group's mean as the level because we believed patients scoring below this level would most likely be at high risk of sustaining further knee damage if returned to preinjury activity levels with nonoperative management of the injury. Subjects were classified as rehabilitation candidates if they met all four of the following criteria: (a) global rating of 60% or higher, (b) no more than one episode of giving-way at the knee since the incident injury (not including the episode of giving-way at the time of injury) to the time of the screening examination, (c) Activities of Daily Living Scale score of 80% or higher, (d) timed hop test of 80% or higher. Subjects who failed to meet any of these criteria were classified as noncandidates.

A total of 93 patients were tested, with 39 (29 men, 10 women) meeting the criteria for rehabilitation candidacy and being given the option of nonoperative treatment for the injury, while 54 (33 men, 21 women) were classified as noncandidates and referred back to the surgeon. Of the 39 candidates 28 attempted to rehabilitate their knees without surgery, and 11 chose to have surgery. Six rehabilitation candidates choosing surgery were physically active adults who did not want to risk extending their knee injuries by returning to activity without reconstructive surgery, and five were competitive athletes who were in the off season and had time to recover from surgery before their next athletic season.

Nonoperative management consisted of lower extremity muscular strengthening, agility skill training (quick start and stops, cariocas, cutting and spinning drills), and sport-specific skill training. The frequency and duration of rehabilitation sessions was two or three times per week for 3–5 weeks. Table 1 describes the type of physical activities in which the 28 rehabilitation candidates choosing nonoperative management participated. Subjects were returned to full activity an average of 4 weeks after the screening examination (median 3 weeks, range 2–10 weeks). We defined successful treatment outcome as the ability to return to preinjury levels of activity without experiencing an episode of giving-way at the knee. Failure was defined as either having at least one episode of giving-way at the knee or a reduction in functional status below that of a

Table 1 Number of participants in various physical activities from sample of rehabilitation candidates electing nonoperative management

Activity	Completed season, no surgery	Completed season, postseason surgery	Unable to complete season	Returned to full activity, injured contralateral knee, surgery
Collegiate football	1	2	1	
Collegiate lacrosse			1	
Collegiate field hockey		1		
Collegiate track/soccer	1			
High School basketball		1	1	
High School softball		1		
High School field hockey		1		
Semiprofessional soccer				1
Semiprofessional baseball		1		
Senior Olympic volleyball	1			
Basketball	3 ^a		2 ^a	
Hockey	2			
Tennis		1	1	
Softball	3 ^b			
Volleyball		1		
Skiing	1			

^a One patient also worked as construction worker (level II occupation)

^b One patient was also a candidate for local police academy (level II occupation)

rehabilitation candidate based on our screening criteria at the time of follow-up examination.

Results

Of the 28 rehabilitation candidates choosing nonoperative management 22 (79%) were able to return to preinjury levels of activity without experiencing an episode of giving-way at the knee, and 6 were considered to have failed rehabilitation (21%). Nine of these 22 successfully returning to high-level activity resumed full sport activity for the remainder of their athletic seasons and then underwent reconstructive surgery. One patient returned to full sport activity but sustained an injury to the contralateral ACL and then decided to undergo surgical reconstruction of both knees. Twelve patients continued to perform at preinjury levels of activity and chose not to undergo reconstructive surgery at the time of follow-up examination. Five of six patients failing rehabilitation had experienced a giving-way episode on return to high-level activity. One patient did not experience a giving-way episode, however, regressed in functional status below our criteria for a rehabilitation candidate at the time of follow-up examination. These six patients subsequently underwent reconstructive surgery. A comparison of preoperative magnetic resonance imaging to operative reports provided evidence that none of the patients who eventually had surgery had extended the knee injury as a result of participation in rehabilitation or returning to athletic competition.

Table 2 provides means and standard deviations for follow-up examination Knee Outcome Survey-Sports Activity Scale scores and global ratings of knee function between those who succeeded and those who failed rehabilitation. These scores represent the degree to which patients returned to preinjury levels of function. The scores demonstrate that patients who successfully returned to high-level activity reported to be performing at an average of over 90% of their preinjury functional status.

The screening examination scores between those who successfully returned to preinjury levels of activity and those who failed were compared to determine whether there were differences in any of the test variables between these groups. Means and standard deviations for screening variables for each group are provided in Table 3. A standard *t* test was performed to determine differences in group means ($\alpha = 0.05$). There were no differences be-

Table 2 Means and standard deviations of follow-up Sports Activity Scale scores and global ratings of knee function in patients who successfully returned to high-level activity (*success*) and patients who failed rehabilitation (*fail*)

Self-report survey	Success	Fail
Sports Activity Scale	95.9 ± 4.4	58.0 ± 29.4
Global ratings of knee function	92.9 ± 6.2	60.8 ± 18.5

Table 3 Mean and standard deviations for screening examination scores between patients who successfully returned to high-level activity (*success*) and patients who failed rehabilitation (*fail*)

Test	Success	Fail
Activities of Daily Living Scale	91.4 ± 6.2	90.9 ± 4.6
Global rating of knee function	78.0 ± 8.0	75.8 ± 11.1
Single hop for distance	91.9 ± 8.9	82.5 ± 9.4
Triple hop for distance	94.5 ± 7.4	89.6 ± 8.6
Cross-over hop for distance	93.8 ± 8.4	83.0 ± 12.4
Timed hop	95.1 ± 6.6*	85.4 ± 4.1*
Quadriceps femoris maximum voluntary isometric torque index	88.7 ± 16.9	85.0 ± 11.9
Side-to-side difference in passive anterior knee laxity	5.8 ± 2.3	5.3 ± 2.8

* $P < 0.01$

tween groups at the time of screening for self-report measures of function, quadriceps femoris strength, or passive anterior knee laxity. The failed group scored significantly lower on the timed hop test than patients who successfully returned to preinjury levels of function. Single-hop and cross-over hop scores also appeared lower in the failed group, but these differences were not significant (single-hop $P = 0.06$; cross-over hop $P = 0.08$).

Discussion

We screened 93 patients with unilateral ACL rupture or rupture of ACL grafts to select candidates for return to high-level activity with nonoperative rehabilitation. Only 42% ($n = 39$) met our criteria as a candidate for nonoperative rehabilitation, and only 30% ($n = 28$) actually attempted a return to high-level physical activity with nonoperative rehabilitation. These findings suggest that the majority of patients who sustain a unilateral ACL rupture and wish to return to high-level physical activity may either not be safe or may not be willing to do so without surgical reconstruction.

Of the 28 patients classified as rehabilitation candidates, and who attempted return to activity after nonoperative rehabilitation 22 (79%) were able to return to preinjury levels of activity without recurring episodes of giving-way or extending the knee injury. In previous studies, patients attempted to return to high-level activity with nonoperative management on a self-selected basis without the use of evaluation criteria for determining appropriate patients for nonoperative management [1, 9, 16]. Anderson [1] reported that only 30% of those choosing nonoperative management were able to return to preinjury activity levels within 1 year of injury. Engström et al. [9] reported that only 23% were able to return to preinjury activity levels with nonoperative management. The highest reported success rate returning patients to high-level physical activity is that of Shelton et al. [16], in which pa-

tients were self-selected for nonoperative treatment and were excluded only if multiple ligament or repairable meniscal damage was associated with the ACL injury. Of the 43 patients in this study 31 returned to athletic competition; only 12 of the 31 (39%) were able to resume athletic competition without experiencing an episode of giving-way at the knee. It appears that use of our decision-making scheme allowed improvement in the probability of successful return to preinjury levels of function over simple self-selection for nonoperative management.

Only patients who met all four criteria for nonoperative treatment, based on screening examination scores, attempted nonoperative management. Although failure on any one criterion measure excluded the patients from classification as a rehabilitation candidate, most noncandidates (42/54) failed by more than one of these criteria. Of the 54 noncandidates, however, 12 failed only one criterion measure (Activities of Daily Living Scale score, $n = 5$; global rating of knee function, $n = 1$; episodes of giving-way, $n = 2$; timed hop test score, $n = 4$). No one criterion was disproportionately represented, which suggests that clustering on the four criteria is more effective in classifying patients for nonoperative management than the use of any single criterion. The validity of our decision-making scheme can be fully determined only by observing the outcome of patients classified as noncandidates who chose nonoperative treatment. While our decision-making scheme does not guarantee success, it does have promise as a mechanism for improving the probability of successful return, at least temporarily, to preinjury levels of function with nonoperative ACL rehabilitation.

The self-report measures of function at follow-up examination for patients who successfully returned to preinjury levels of activity indicated that these patients were performing at greater than 90% of preinjury levels of function. Subjects were satisfied that they were able to perform without modifying the intensity of physical activity. We studied only those situations in which patients wished temporarily to delay surgical treatment to complete an athletic season or temporarily to return to a physically demanding occupation until a time when having reconstructive surgery was more convenient. Our data cannot therefore be generalized to support long-term participation in high-level activity with nonoperative management. The evidence is strong that patients with ACL-deficient knees are at high risk of extending damage to their knees with long-term participation in high-level physical activity [6, 9].

Patients who failed rehabilitation had lower timed hop test scores at the time of the screening examination than those who successfully returned to high-level activity. This may indicate that the timed hop test cutoff score in the clinical decision-making scheme is not high enough and needs revision. The present timed hop test cutoff is 80% (uninvolved limb score/involved limb score). Subjects successfully returning to preinjury levels of activity

had a screening examination mean hop test score of 95%, compared with the failed rehabilitation mean of 85%. Raising the hop test cutoff score in the decision-making scheme may result in higher probabilities of success. The disparity in numbers of patients who succeeded ($n = 22$) versus those who failed ($n = 6$) prevents us from accurately determining an appropriate cutoff score for the hop tests from our present data. Continued observation of larger numbers of patients is needed to accurately revise the timed hop test criteria for our decision-making scheme.

Another issue concerning the hop test examinations is the time at which these tests were administered in our study, an average of 4 weeks after the injury. It may be argued that extending this period would have allowed some patients to perform better on the hop tests and therefore be better able to meet the criteria of a rehabilitation candidate. In some situations, when there is ample available time to make a decision, delaying the screening examination may improve the likelihood that an individual would meet the criteria for nonoperative rehabilitation. However, in many instances the decision as to whether it is safe for an individual to try nonoperative rehabilitation and complete the remainder of the athletic season must be made in a relatively short time period. Thus patients in our study performed the hop tests as soon as they met the criteria for testing (lack of pain and joint effusion, full joint motion, and ability to hop on the involved leg). We would argue that if patients are unable to perform the hop tests to within at least 80% of the uninvolved limb at this time, it is doubtful whether they could successfully rehabilitate their knee in time to complete the remainder of the athletic season.

This study was limited to patients with an isolated rupture of the ACL who wished to return to regular participation in activities at level I (i.e., football, basketball, soccer) [6] or level II (i.e., racquet sports, skiing, manual labor occupations) [6]. Patients with multiple ligament damage or repairable meniscal tears associated with ACL rupture were not tested. Existing evidence indicates that patients with multiple structural damage associated with an ACL rupture are at high risk of further knee damage with continued participation in high-level activity [1, 6, 9]. It is unlikely that our criteria would improve the probability of successful return to high-level activity with nonoperative management for these patients. Patients willing to modify physical activity to avoid surgery were also not tested in our study. Other studies in which patients were willing to modify physical activity levels as part of the nonoperative management have found that some patients continue to be dissatisfied with treatment outcome and experience episodes of giving-way even after rehabilitation [4, 5]. It would be interesting to determine whether our criteria, or a modification of them, could be used to improve successful treatment outcome in this patient population.

The criteria used in our decision-making scheme require no expensive equipment; only a stopwatch, tape measure, and questionnaire are required. The tests take less than 1 h to administer. These qualities allow easy application of the screening examination in the clinic environment. It should be emphasized that all of our rehabilitation candidates who successfully returned to full activity without surgery did so only after an intensive rehabilitation program. The role of the screening examination in the clinical decision-making process is to determine who may have a chance to succeed after undergoing rehabilitation. Patients should not return to high-level activity solely on the basis of the screening examination. It should also be emphasized that the purpose of the screening examination is to identify potential candidates for *short-term* (i.e., to finish the remainder of the season) return to high-level activity. The consequences of long-term participation in high-level physical activity with nonoperative ACL rehabilitation cannot be determined from our data.

The decision-making scheme presented in this report allowed an improvement in the probability of successful return to high-level activity with nonoperative manage-

ment of ACL ruptures over what has been previously reported for patients who selected themselves for nonoperative management. Further study is needed to refine the decision-making criteria and to further validate its value in distinguishing between candidates and noncandidates for nonoperative management. The effects of long-term participation in high-level activity without reconstructive surgery also needs to be more clearly defined in patients who are classified as candidates for nonoperative management. We believe that our decision-making scheme shows promise in offering a better mechanism for selecting patients for return to high-level activity with nonoperative management than simply attempting this treatment approach on a self-selected basis.

Acknowledgements This research was supported in part by the National Athletic Trainers Association (United States) and the Foundation for Physical Therapy Research (United States). The authors acknowledge Leslie Lear, MPT, and Laura Schmitt, BS, for their assistance with data collection during the project. The research was performed at the Department of Physical Therapy, University of Delaware, 303 McKinly Laboratory, Newark, Del., USA.

References

- Andersson AC (1993) Knee laxity and function after conservative treatment of anterior cruciate ligament injuries: a prospective study. *Int J Sports Med* 14: 150–153
- Bolgia LA, Keskula DR (1997) Reliability of lower extremity functional performance tests. *J Orthop Sports Phys Ther* 26: 138–142
- Booher LD, Hench KM, Worrell TW, Stikeleather J (1994) Reliability of three single-leg hop tests. *J Sport Rehabil* 165–170
- Buss DD, Min R, Skyhar M, Galinat B, Warren RF, Wickiewicz TL (1995) Nonoperative treatment of acute anterior cruciate ligament injuries in a selected group of patients. *Am J Sports Med* 23: 160–165
- Ciccotti MG, Lombardo SJ, Nonweiler B, Pink M (1994) Non-operative treatment of ruptures of the anterior cruciate ligament in middle-aged patients. *J Bone Joint Surg Am* 76: 1315–1321
- Daniel DM, Stone ML, Dobson BE, Fithian DC, Rossman DJ, Lephart SM (1994) Fate of the ACL-injured patient: a prospective outcome study. *Am J Sports Med* 22: 632–644
- Daniel DM, Stone ML, Sachs R, Malcolm L (1985) Instrumented measurement of anterior laxity in patients with acute ligament disruption. *Am J Sports Med* 13: 401–407
- Eastlack ME, Axe MJ, Snyder-Mackler L (1999) Laxity, instability, and functional outcome after anterior cruciate ligament injury: copers vs non-copers. *Med Sci Sports Exerc* 31: 210–215
- Engström B, Gornitzka J, Johansson C, Wredmark T (1993) Knee function after anterior cruciate ligament ruptures treated conservatively. *Int Orthop* 17: 208–213
- Greenberger HB, Paterno MV (1995) Relationship of knee extensor strength and hopping test performance in the assessment of lower extremity function. *J Orthop Sports Phys Ther* 22: 202–206
- Harilainen A, Alaranta H, Sandelin J, Vanhanen I (1995) Good muscle performance does not compensate instability symptoms in chronic anterior cruciate ligament deficiency. *Knee Surg Sports Traumatol Arthrosc* 3: 135–137
- Irrgang JJ, Snyder-Mackler L, Wainner RS, Fu FH, Harner CD (1998) Development of a patient-reported measure of function of the knee. *J Bone Joint Surg Am* 80: 1132–1145
- Lephart SM, Perrin DH, Fu FH (1992) Relationship between selected physical characteristics and functional capacity in the anterior cruciate ligament-insufficient athlete. *J Orthop Sports Phys Ther* 16: 174–181
- Noyes FR, Barber SD, Mangine RE (1991) Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *Am J Sports Med* 19: 513–518
- Noyes FR, Moar PA, Matthews DS (1983) The symptomatic anterior cruciate-deficient knee. I. The long-term functional disability in athletically active individuals. *J Bone Joint Surg Am* 65: 154–162
- Shelton WR, Barrett GR, Dukes A (1997) Early season anterior cruciate ligament tears. *Am J Sports Med* 25: 656–658
- Snyder-Mackler L, Fitzgerald GK, Bartolozzi AR, Ciccotti MG (1997) Relationship between passive joint laxity and functional outcome after anterior cruciate ligament injury. *Am J Sports Med* 25: 191–195
- Snyder-Mackler L, Binder-MacLeod SA, Williams PR (1993) Fatigability of human quadriceps femoris muscle following anterior cruciate ligament reconstruction. *Med Sci Sports Exerc* 25: 783–789