

[Sports Physical Therapy]



Management of the Athlete With Acute Anterior Cruciate Ligament Deficiency

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Background: Identification of highly active individuals early after acute anterior cruciate ligament deficiency who are good candidates for nonoperative management is a clinical challenge. The University of Delaware has developed and validated a treatment algorithm and screening examination to distinguish between nonoperative and surgical candidates.

Study Design: Review.

Evidence Acquisition: A description of the decision-making rules and rehabilitation protocol for highly active individuals with anterior cruciate ligament deficiency is provided. Results from clinical trials, outcome studies, and biomechanical investigations conducted using the treatment algorithm and screening examination are also reviewed.

Results: Patients identified as nonoperative rehabilitation candidates using these clinical guidelines have a far greater success rate than what has been reported when patients self-select nonoperative management. Furthermore, nonoperative outcomes are improved when patients participate in a perturbation-enhanced rehabilitation protocol. Divergent lower extremity movement patterns are consistent with the different functional abilities of the dichotomous patient groups identified with the screening examination.

Conclusion: Given the differential patient response to anterior cruciate ligament injury, implementation of the decision-making guidelines discussed in this review offers clinicians the opportunity to provide individualized patient care rather than continuing with a blanket surgical treatment strategy.

Keywords: rehabilitation; knee; ligament; nonoperative; ACL; treatment algorithm

Nonoperative management after anterior cruciate ligament (ACL) rupture remains controversial. The highly active patient with ACL deficiency (ACL-D) who pursues nonoperative management is at risk for experiencing subsequent episodes of instability, meniscus and articular cartilage injury, premature knee joint degeneration, and an overall decline in function.⁹ These risks, combined with ready access to surgical facilities, widespread coverage provided by health insurance plans, and high return-to-sport rates after surgical reconstruction, have contributed to orthopaedists in the United States advocating early surgical intervention for individuals who wish to resume high-demand activities.^{20,25} This blanket surgical approach to patient management has come under recent scrutiny.²⁰ Recent reports of long-term results after ACL reconstruction (ACL-R) have illustrated that surgically restoring knee stability does not always permit a return to sports activities or

prevent future symptom complaints or degenerative knee arthritis.^{8,23,28,37} Furthermore, there is evidence that some individuals are able to regularly participate in high-level activities without symptom complaints or episodes of instability.^{5,6,13,15,17,27,35} Thus, it appears a nondiscriminating surgical approach for treatment of ACL-D may not be an appropriate strategy for providing the best possible outcomes for this patient population.

Identifying the best candidates for nonoperative care early after ACL injury is one of the keys to successful patient outcomes. Although there are descriptions in the literature of differential responses after ACL rupture, there is little evidence to assist in prospectively identifying individuals who may forego ACL-R and remain active in high-demand activities (ie, cutting, jumping, and pivoting maneuvers) without experiencing functional knee instability. The University of Delaware has devised a treatment algorithm and screening

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examination that distinguishes between highly active patients with different functional abilities early after injury, when treatment decisions are routinely made. Using these decision-making guidelines, patients may be prospectively classified as either good or poor candidates for nonoperative care. The dichotomous groups are also referred to as potential copers and noncopers. Potential copers are nonoperative candidates identified by the screening examination who have the potential to compensate well for their injury.¹⁰ Noncopers are surgical candidates, as these individuals cannot return to high-level athletic activities after ACL injury because of continued episodes of the knee giving way.^{5,6,20,35}

Classification cannot be predicted by a single clinical test or by demographic characteristics.^{6,16} And while it has been suggested the magnitude of knee laxity after ACL rupture may be predictive of a patient's ability to compensate for the diminished ligamentous knee stability, the amount of anterior tibia translation is not predictive of functional abilities.^{16,22,35} Instead, identification of individuals who are most likely to succeed with nonoperative care is predicated on a series of inclusion and exclusion criteria and the results of a battery of clinical tests. For more than 10 years the authors' rehabilitation research team has conducted clinical trials, long-term outcome studies, and laboratory investigations to evaluate the efficacy of the University of Delaware treatment algorithm and screening examination. After rigorous scrutiny, these decision-making guidelines have been established as perhaps the most effective nonoperative treatment approach for managing highly active patients with acute ACL-D. Therefore, the purpose of this review is to provide details of the treatment algorithm, screening examination, and rehabilitation protocol to facilitate implementation into the clinical practice of healthcare providers who regularly treat patients with ACL-D. Furthermore, the authors will review the results of their long-term outcome studies and biomechanical investigations that have been performed at their facility.

TREATMENT ALGORITHM AND SCREENING EXAMINATION

Implementation of the Decision-Making Guidelines

Patient goals are an important factor when considering surgical versus nonsurgical management. Some individuals prefer to delay or avoid surgery. For instance, an athlete may want to finish the competitive season before having surgery, particularly if an upcoming game has significance. Furthermore, practice patterns outside of the United States are often quite different.^{21,26} In some countries, patients are counseled to undergo surgery only if nonoperative care has failed. For patients who are advised to have an ACL-R, resources may be limited, and the patient can be placed on a waiting list before he or she undergoes surgery.¹⁶ Counseling regarding appropriate activity participation in the interim would be useful in these instances. Hence, it is important for clinicians to consider each patient as an individual when making decisions regarding the ideal management strategy after ACL injury.

The authors implement the decision-making guidelines for all patients with ACL-D who are regularly involved in International Knee Documentation Committee (IKDC) level I or II activities (>50 hours/year of jumping, cutting, pivoting, or lateral movements).^{8,20} Participation in the University of Delaware algorithm and screening examination was originally developed to be a short-term, that is, 6 months or less, approach to nonoperative management, as surgical management has been the standard of care in the United States. Even if they were asymptomatic, patients were advised to return to their orthopaedic specialist for surgical management once they had completed their desired activities. However, some potential copers did not follow these recommendations. Hurd et al¹² followed up with potential copers who remained ACL-D for more than 2 years. This cohort (N = 25) was able to remain active in high-level sports activities and reported no compromise or symptom complaints with their daily function. These positive outcomes have prompted a shift in the authors' clinical practice: patients are instructed that, if they have no symptom complaints or compromise in activity participation, ACL-R is optional. Validation of long-term, nonoperative outcomes for potential copers is currently under way.

Concomitant Injuries

Before participating in the screening examination and determining whether the patient may be classified as either a potential copers or noncopers, multiple criteria must be met. Evaluation for concomitant injuries is the first step in the algorithm to discriminate between surgical and nonoperative candidates^{10,15} (Figure 1). The patient presenting with grade II or greater concomitant posterior cruciate ligament (PCL), medial collateral ligament (MCL), lateral collateral ligament laxity, bilateral knee involvement, or the presence of any severe lower extremity or low back injury (eg, nerve injury, fracture, dislocation, etc) is not considered a candidate for nonoperative care. When time is not an issue or the patient desires to exhaust all nonoperative options, clinicians may consider treating the concomitant injury to facilitate participation in the screening examination. One example is a grade II MCL injury. Once the MCL has healed and there is no longer an increase in valgus knee laxity, the MCL injury does not preclude the patient from continued nonoperative ACL management consideration.

Additional concomitant injuries that exclude patients from participating in the screening examination may be identified with magnetic resonance imaging (MRI). These injuries include full thickness articular cartilage lesions and potentially repairable meniscus tears.¹⁰ If a patient experiences subsequent giving way episodes in these instances, there is potential for the original injury to be extended. The following rationales for having strict exclusion criteria based on the presence of concomitant injuries are: these individuals are at high risk for experiencing subsequent knee injury if nonoperative care is pursued,^{1,5} the screening examination may not be safely completed, or a healthy contralateral knee is not available for comparison.¹⁵

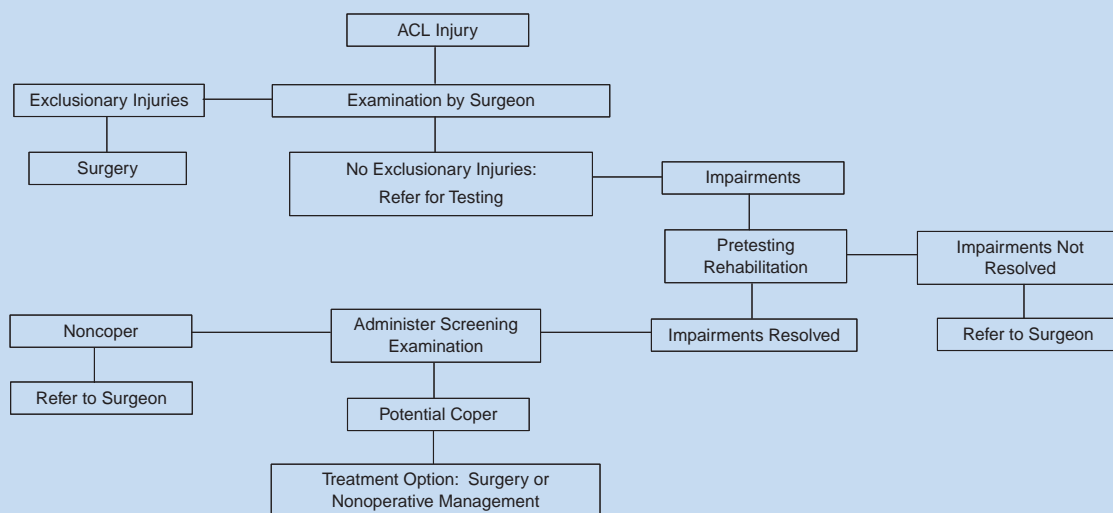


Figure 1. University of Delaware patient selection algorithm for nonoperative versus operative treatment after ACL injury. (Figure from Fitzgerald GK, Axe MJ, Snyder-Mackler L. Proposed practice guidelines for nonoperative anterior cruciate ligament rehabilitation of physically active individuals. *J Orthop Sports Phys Ther.* 2008;30(4):194-203, reproduced with permission of the Orthopaedic and Sports Physical Therapy Sections of the American Physical Therapy Association.)

Physical Impairments

Patients must meet the following rehabilitation criteria before they may participate in the screening examination: have no or minimal knee joint effusion, full, symmetrical knee active range of motion, $\geq 70\%$ quadriceps strength on bilateral comparison, and the ability to hop on the injured knee without pain while wearing a functional derotation knee brace.^{10,15} Individuals who have any of the listed impairments should undertake supervised rehabilitation with the goal of completing the screening examination as soon as the impairments are resolved. Patients are referred to their orthopaedic specialist if the rehabilitation criteria are not met within 4 weeks.¹⁵

It is currently unknown how an extended trial of rehabilitation (>4 weeks) for impairment resolution may impact patient outcomes. The authors' rationale for a finite rehabilitation period was that many individuals in the United States who pursue nonoperative management are attempting to make a rapid return to high-level activities. An extended period of rehabilitation to resolve impairments may result in a missed opportunity to return to the desired activities. Consequently, nonoperative care is no longer advantageous. When timing is not an issue, clinicians may consider whether continued treatment to address impairments may be advantageous. It is possible, however, an extended inflammatory response and inability to regain quadriceps strength may be a consequence of knee instability, suggesting these individuals are not good candidates for nonoperative care.¹⁵

Application of the treatment algorithm excludes a large percentage of patients from participation in the screening

examination (Figure 2). A systematic review of an entire population of highly active individuals with acute ACL-D revealed 54% of patients were excluded from screening consideration secondary to either the presence of concomitant injury (42%) or unresolved impairments (12%).¹⁵ These results support the belief that ACL ruptures frequently occur in conjunction with other injuries. Furthermore, the large number of individuals not considered for nonoperative management demonstrates the treatment algorithm is by nature conservative; any factor that may contribute to future knee instability or extend the index injury must be considered as rationale for surgery as the treatment of choice.¹⁵

Screening Examination

The screening examination consists of a battery of sequential clinical tests: unilateral hop testing, self-assessment questionnaires, and recording the number of giving way episodes since the index injury.¹⁰

Unilateral hop testing is conducted according to the protocol described by Noyes et al²⁹ and consists of the single-legged hop for distance, triple crossover hop for distance, straight triple hop for distance, and a 6-meter timed hop. Patients perform 2 practice trials on each limb followed by 2 test trials. The 2 test trials for each limb are averaged, and a hop index is calculated for each test with performance of the injured limb calculated as a percentage of the uninjured limb. Patients wear a functional derotation knee brace on the injured limb throughout practice and testing.^{10,15}

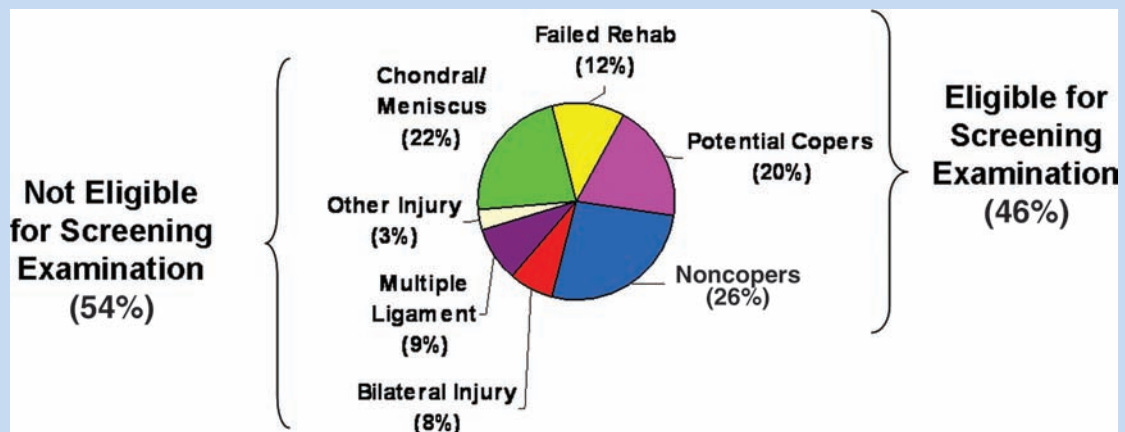


Figure 2. Ten-year outcomes of the University of Delaware algorithm and screening examination.

Although all unilateral hop tests are performed as part of the screening examination, only the timed hop test is used for patient classification. Potential copers must have a timed hop index of $\geq 80\%$.¹⁰ Out of the 4 hopping tasks, the timed hop is influenced the least by quadriceps strength¹⁶ and has been described as one of the less demanding hop tests.³⁰ It is, however, unique in requiring patients to hop repeatedly over a fixed distance (unlike the other hop tasks that require the patient to hop for a maximum distance). Hurd et al¹⁶ suggested that the task demands—selecting and repeatedly performing a dynamic movement strategy—effectively challenges the neuromuscular control of patients with ACL injury. This is consistent with the theory that dynamic knee stability is more a consequence of coordinated muscle contractions than forceful muscle contractions.¹⁶

Patient Self-Assessment

The 2 self-assessment questionnaires that are completed immediately after unilateral hop testing are the Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS)¹⁹ and the global rating of knee function.¹⁰ Fitzgerald et al¹⁰ reported in preliminary work that patients tended to either underestimate or overestimate self-report scores if the hop tests were performed after the self-assessment surveys. Consequently, the authors of this article advocate that patients perform the hop tests first to give them an opportunity to self-evaluate their knee status after performing a physically challenging task, resulting in more accurate reporting of knee function.^{10,15}

The KOS-ADLS consists of 14 questions with 6 possible answers (each answer weighted from 0 to 5 points for a maximum of 70 points) and assesses knee function and symptoms during a variety of daily activities, such as ambulation, stair climbing, squatting, kneeling, and sitting.³⁴ A higher score represents a higher level of function. The global rating of knee function is a single number between 0 and 100 and represents the patient's current knee function, including

sports, with a score of 100% representing preinjury function. Classification criteria for potential copers include a score of $\geq 80\%$ on the KOS-ADLS, and a $\geq 60\%$ global rating score.¹⁰

Knee Giving Way

Giving way is defined as buckling, or subluxation, of the tibiofemoral joint.¹⁰ Only those episodes that occur during activities of daily living (ADL) are considered for patient classification. The rationale is that if recurrent episodes of giving way occur during daily tasks, the patient is at high risk for extended knee damage if they return to high-level activities without reconstructive surgery. For patients to be classified as a potential coper they must have experienced ≤ 1 giving way episodes since the index injury.¹⁰

Classification

For patients to be classified as a potential coper and considered good candidates for a nonoperative return to pre-injury activities, they must meet all criteria (timed hop score of $\geq 80\%$; a KOS-ADLS score of $\geq 80\%$; a global rating score of $\geq 60\%$; and ≤ 1 giving way episodes).¹⁰ Failure to meet a single criterion results in patient classification as a noncoper or poor candidate for nonoperative management. These patients are advised to return to their orthopaedic specialist and be considered surgical candidates.¹⁵

The screening examination is performed only once. There is currently no evidence to support repeated performance of the screening examination to provide noncopers the opportunity to improve their test scores and change their classification status. Likewise, individuals whose scores are "close" to but do not meet potential coper classification criteria should not be considered nonoperative candidates. In these circumstances it can be challenging for the healthcare professional to instruct an athlete that his or her competitive season is over. However, consistent implementation and execution of the treatment

Table 1. Perturbation exercises and progression guidelines.^a

	Rockerboard	Rollerboard/Platform	Rollerboard
Sets/duration	2-3 sets/1 min each	2-3 sets/1 min each; performed bilaterally	2-3 sets/30 seconds-1 min each
Direction of board movement	A/P, M/L	Initial: A/P, M/L Progression: diagonal, rotation	Initial: A/P, M/L Progression: diagonal, rotation
Application	Begin in bilateral stance for first session. Perform in single leg stance for remaining sessions.	Subject force is counter-resistance opposite of rollerboard, matching intensity and speed of application so rollerboard movement is minimal. Leg muscles should not be contracted in anticipation of perturbation, nor should response be rigid co-contraction.	Begin in bilateral stance for first session. Perform in single-leg stance for remaining sessions. Perturbation distances are 1-2 inches.
<p>Cognitive (Early) Phase (Sessions 1-4) <i>Treatment Goals:</i></p> <ul style="list-style-type: none"> • Expose athlete to perturbations in all directions • Elicit an appropriate muscular response to applied perturbations (no rigid co-contraction) • Minimize verbal cues <p>Associative (Middle) Phase (Sessions 5-7) <i>Treatment Goals:</i></p> <ul style="list-style-type: none"> • Add light sport-specific activity during perturbation techniques • Improve athlete accuracy in matching muscle responses to perturbation intensity, direction, and speed <p>Autonomous (Late) Phase (Sessions 8-10) <i>Treatment Goals:</i></p> <ul style="list-style-type: none"> • Increase difficulty of perturbations by using sport-specific stances • Obtain accurate, selective muscular responses to perturbations in any direction and of any intensity, magnitude, or speed 			

^aA/P, anterior/posterior; M/L, medial/lateral.

algorithm, screening examination, and patient classification system is paramount to successful patient outcomes.

REHABILITATION

Potential copers who elect nonoperative management are advised to participate in a 10-session perturbation-enhanced rehabilitation protocol (Table 1) before returning to high-demand activities.¹⁵ Perturbation training is one type of neuromuscular exercise designed to improved knee stability after ACL rupture and involves the manipulation of an unstable support surface while the patient maintains his or her balance.¹¹ Additionally, the rehabilitation program includes cardiovascular exercise, muscle strengthening, agility and coordination training, and sport-specific skills.²⁵ Treatment frequency can range from twice a week to daily sessions, with the frequency dependent on symptom exacerbation and the patient's time constraints. Similar to the patient who has undergone ACL reconstruction, it is recommended that the patient with ACL-D pass all functional testing criteria before discharge and clearance for a full return to preinjury activities.

Perturbation exercise includes 3 conditions: rollerboard, rockerboard, and rollerboard with block (Figure 3).¹¹ Verbal cues such as “keep your knees soft,” “keep your trunk still,” and “relax between perturbations” are provided during training

early in the program to provide patients with a framework for successful task completion. Each exercise condition promotes the recruitment of muscle groups to oppose the perturbation. The focus of training is not on developing specific muscle activation patterns. Rather, patients are allowed to develop individualized patterns as long as the task is successfully completed, for example, maintain balance without rigid muscle co-contraction.

The perturbation-enhanced rehabilitation protocol consists of 3 phases. The first phase of the protocol, sessions 1 through 4, is the cognitive, or early, phase (Table 1). During this period the patient is exploring and developing knee stabilization strategies. Clinicians can expect to see rapid improvements as the patient develops successful responses to the perturbations. Sessions 5 through 7 are part of the associative, or middle, phase and the second segment of the training protocol (Table 1). Knee stabilization strategies are refined during this rehabilitation stage. Additionally, sport-specific activities are incorporated into the perturbation exercise (ie, kicking a soccer ball or passing a basketball) and patients are allowed to return to practice on a limited basis, that is, noncontact or part-time. The final phase of the training protocol, sessions 8 through 10, is the autonomous, or late, phase (Table 1). Knee stabilization strategies are now automatic as the patient prepares for a full return to sports activities. Intensity, speed, and force of perturbations are advanced throughout the program.¹¹

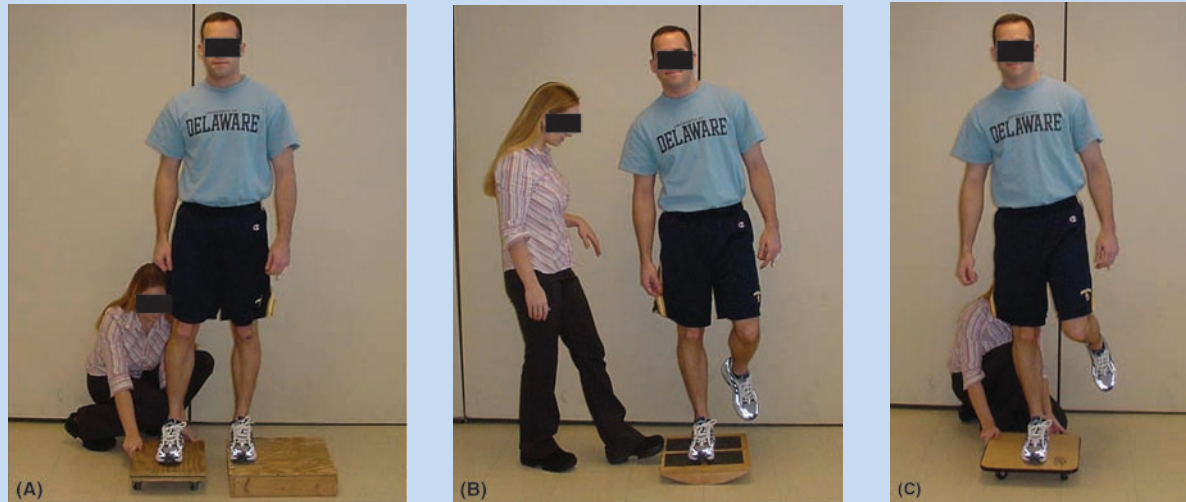


Figure 3. Perturbation exercises. Rollerboard and block (A), rockerboard (B), and rollerboard (C).

Muscle strengthening should be undertaken for all lower extremity impairments identified during initial evaluation. Muscle weakness of the quadriceps femoris complex is common after ACL rupture.¹¹ If the strength of the involved limb is <80% of the contralateral limb, a high-intensity electrical stimulation protocol may be used to advance quadriceps muscle strength until this criteria is met.^{11,34} A combination of open and closed chain exercises may also be implemented with the goal of restoring full strength, with care taken to avoid exacerbation of any knee pain or effusion.¹¹

Cardiovascular training is incorporated to restore the patient's endurance.¹¹ Because endurance capacity is specific to the type of training that is performed, it is advised the type of endurance training be related to the patient's sport or work activity.^{11,24,36} The majority of patients are involved in sports activities that include running. Consequently, a progressive treadmill program is the most common mode of cardiovascular exercise. When patients can run 15 to 20 minutes without pain or swelling, they may progress to level road or track running and finally to road or field hill running.¹¹

Agility and sport-specific training are implemented to allow the patient to adapt to quick changes in direction and prepare for return to sport demands.¹¹ During agility exercises the patient wears a functional knee brace. Agility exercises are begun with single-direction movements, such as a lateral slide and shuttle run. They are progressed to cutting and spinning techniques with intensity advancing from half to full speed. Sport-specific drills are performed in the context of playing situations. For example, if the patient's goal is to return to basketball, they would perform plyometric jumping drills and practice dribbling skills, jump shots, and lay-ups.¹¹ These activities are initiated without being opposed by a training

partner and then progressed to practice with one-on-one opposition (usually during session 7).

OUTCOMES

Hurd et al¹⁵ prospectively characterized and classified the entire population of highly active individuals with ACL-D from a single orthopaedic surgeon over a 10-year period. Of the 345 individuals who completed the screening examination, 42% (n = 146) were classified as potential copers and 58% (n = 199) as noncopers (Figure 2). Although there were overall significantly more noncopers than potential copers within this cohort, these results indicate there are a large number of individuals who sustain an ACL injury who have the potential to succeed with nonoperative care. Seventy-two percent (63 of 88) of potential copers who pursued nonoperative management were able to return to their preinjury activities without symptom exacerbation and/or experiencing additional giving way episodes (5 individuals experienced a giving-way episode during rehabilitation and were referred for surgery; 13 experienced a giving-way episode when attempting a return to sports; 5 individuals self-elected to mitigate their activity level; 2 were lost to follow-up).¹⁵ Eventually, 36 of 63 potential copers who had been successful with their nonoperative course returned to their orthopaedist for ACL-R.¹⁵ There were 25 potential copers who had not undergone surgical reconstruction at the time of follow-up but were still active in high-level activities. Telephone interviews revealed these individuals were asymptomatic and had not compromised their activity level (KOS-ADLS X = 97%; global rating X = 92%). These results suggest there is potential for the algorithm and screening examination to identify candidates who may have long-term success with nonoperative care.¹⁵

None of the potential copers who pursued nonoperative management and ultimately returned for surgery extended their original knee injury. One reason highly active individuals are counseled against nonoperative management after ACL injury is the increased risk for sustaining a meniscus tear or articular cartilage lesion from recurrent giving-way episodes, and subsequently developing premature knee osteoarthritis. The authors consider potential copers to have failed nonoperative management if they experience a single additional giving-way episode. Therefore, the authors do not believe these patients are at greater risk for experiencing premature degenerative knee damage than individuals who undergo ACL-R. The long-term, successful patient outcome is predicated greatly on early patient counseling and education. Because knee status may change over time, patients should be instructed to return to their physician or rehabilitation specialist if they experience any knee instability, effusion, or symptom exacerbation subsequent to discharge. The emphasis on “patient ownership” of the injury may reduce the likelihood that any changes in knee status that may contribute to early knee degeneration will be ignored.

Evidence supports participation in the perturbation-enhanced rehabilitation protocol before potential copers return to their preinjury activities. In a prospective randomized clinical trial, Fitzgerald et al¹² assessed outcomes for ACL deficient potential copers who participated in 10 sessions of either standard (ie, cardiovascular, agility, and plyometric exercises) or combined standard and perturbation exercise. Six months after completing rehabilitation, more potential copers from the standard group (7 out of 14) had failed in their attempt to return to preinjury activities than the perturbation group (1 out of 12), with failure defined as giving way of the knee, symptom exacerbation, or the inability to resume all activities.¹² Results reported by Hurd et al¹⁵ detailing outcomes of a 10-year prospective trial of the treatment algorithm and screening examination were consistent with Fitzgerald et al's¹⁰ earlier work. Out of the 13 potential copers who failed in their attempt to resume preinjury activities without surgical intervention, 6 had not participated in the perturbation-enhanced rehabilitation protocol. Based on the collective results of Fitzgerald et al¹⁰ and Hurd et al,¹⁵ the authors of this article strongly encourage all patients identified as potential copers who elect nonoperative management do so only after participating in perturbation-enhanced rehabilitation.¹⁵

There is biomechanical evidence that corroborates differences in function after ACL rupture and supports the implementation of perturbation-enhanced rehabilitation for potential copers. Noncopers implement a stiffening strategy in a crude attempt to maintain knee stability after ACL rupture. These altered movement patterns include lower sagittal plane knee motion, knee moments, and higher muscle co-contraction on the injured limb in comparison to their uninjured limb and uninjured subjects.^{18,31,32} In contrast, potential copers exhibit movement patterns intermediate to noncopers and uninjured subjects.^{2,3} Although these findings support the theory that potential copers have more advanced

dynamic knee stabilization strategies than noncopers early after injury, it also supports implementation of additional rehabilitation. Chmielewski et al² evaluated the gait patterns of ACL-D potential copers before and after participation in the perturbation-enhanced rehabilitation protocol. The investigators reported potential coper movement patterns after training that were more like uninjured subjects, including an increase in sagittal plane knee excursion and reduced quadriceps-gastrocnemius muscle co-contraction.² Chmielewski et al² suggested findings from this study were evidence for a biomechanical mechanism by which perturbation training acts as an effective intervention for promoting dynamic knee stability in this select population with ACL rupture. The authors are now investigating the effect rehabilitation has on movement patterns and functional abilities of noncopers.

CONCLUSION

The success rate (72%) of the University of Delaware screening examination in returning highly active individuals to preinjury activities is far greater than those described in previous studies in which nonoperative care was based on patient self-selection (23%-39%).^{1,7,33} This disparity in patient outcomes suggests use of the treatment algorithm and screening examination described in this article is an effective clinical tool to discriminate between operative and nonoperative candidates, improving the probability of a safe, successful return to preinjury activities.¹⁶ Given the differential patient response to ACL injury, implementation of these effective decision-making guidelines offers clinicians the opportunity to provide individualized patient care rather than a blanket surgical treatment strategy.¹⁵

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