Published in final edited form as:
J Orthop Sports Phys Ther. 2008 October ; 38(10): 586–595.

Individuals With an Anterior Cruciate Ligament-Deficient Knee Classified as Noncopers May Be Candidates for Nonsurgical Rehabilitation

HÅVARD MOKSNES, PT[1], **LYNN SNYDER-MACKLER, PT, ScD**[2], and **MAY ARNA RISBERG, PT, PhD**[3]

[1] Researcher, NAR, Orthopedic Center, Ullevaal University Hospital, Oslo, Norway; Physical Therapist, Norwegian Sports Medicine Clinic (NIMI), Oslo, Norway

[2] Alumni Distinguished Professor, Department of Physical Therapy, University of Delaware, Newark, DE

[3] Associate Professor and Chair, NAR, Orthopedic Center, Ullevaal University Hospital, Oslo, Norway; Associate Professor, Norwegian Sports Medicine Clinic (NIMI), Oslo, Norway

Abstract

STUDY DESIGN—Prospective cohort study.

OBJECTIVES—First, to classify a group of individuals with an anterior cruciate ligament (ACL)-deficient knee as potential copers or potential noncopers, based on an established screening examination. Second, to prospectively follow a cohort of individuals with an ACL injury and characterize the nonoperatively treated subjects as true copers and true noncopers 1 year after injury, and evaluate the outcomes in operatively treated individuals 1 year after ACL reconstruction. Finally, to calculate the predictive value of the screening examination based on a 1-year follow-up of the group of subjects with ACL tears treated nonoperatively.

BACKGROUND—A screening examination has been developed for early classification of individuals with ACL injuries. Potential copers have successfully been identified as rehabilitation candidates and have shown that they are able to continue preinjury activities without ACL reconstruction (true copers). However, the potential of individuals identified as noncopers to become true copers has not been studied.

METHODS AND MEASURES—One hundred twenty-five subjects with ACL injury were evaluated using a screening examination consisting of 4 single-legged hop tests, the Knee Outcome Survey activities of daily living scale, the global rating of knee function, and the number of episodes of giving way. Knee laxity measurements, the international knee documentation committee subjective knee form (IKDC2000), and return to sport were included as outcome measurements.

RESULTS—Thirty-seven percent (n = 46) of the subjects with ACL Injury were classified as potential copers at the screening examination. Of the 102 subjects examined at follow-up, 51% (n = 52) had undergone nonoperative treatment. Sixty-five percent (n = 34) of the nonoperated subjects were classified as true copers at the 1-year follow-up. Among the potential copers, 60% were true copers, while 70% of the subjects initially classified as potential noncopers were true copers at the 1-year follow-up. The positive predictive value for correctly classifying true copers at the screening

Address correspondence to Håvard Moksnes, NIMI Ullevaal, Sognsveien 75 D, 0805 Oslo, Norway. havard.moksnes@nimi.no, h.m@hjelp24.no.

examination was 60% (95% confidence interval: 41%–78%), while the negative predictive value was 30% (95% confidence interval: 16%–49%).

CONCLUSION—A majority (70%) of subjects classified as potential noncopers were true copers after 1 year following nonoperative treatment. Individuals with nonoperative treatment and ACL reconstruction showed excellent knee function and were highly active at the 1-year follow-up. The prognostic accuracy of this screening examination for correctly classifying true copers was poor.

LEVEL OF EVIDENCE—Prognosis, level 1b.

Keywords

ACL; copers; screening; surgery

Anterior cruciate ligament (ACL) injuries are frequent, especially in young and active individuals.[6] An increasing amount of research has shown that knee function after ACL rupture varies considerably.[11,24,41] While the majority of individuals with ACL rupture lack dynamic knee stability, some seem to have the ability to dynamically stabilize their knee even during pivoting sports activities.[8,16,35] Surgical reconstruction is usually recommended to young active individuals,[6,32] but no studies have shown that ACL reconstruction restores dynamic knee stability or enables full return to preinjury activity level in all subjects.[4,15,34,43] Dynamic stability has operationally been defined as the ability of a joint to remain stable when subjected to rapidly shifting loads during motion.[26,46]

In 1983, Noyes et al[37] postulated the rule of thirds, which stated that one third of patients with ACL injury will compensate adequately and be able to pursue recreational activities without surgery. More recently, other authors have classified knee function early after ACL injury, based on a screening examination.[16,17] Individuals with an ACL injury passing the screening examination have been classified as potential copers.[13,17] Potential copers have been considered rehabilitation candidates, having the potential to return to preinjury activity level for a limited period without ACL reconstruction.[13,16,25] Individuals failing the screening examination have been termed noncopers.[13,17] Noncopers have traditionally been advised to undergo ACL reconstruction, based on the assumption that they are not good candidates for return to activities through non-operative treatment.[17,44,46] Moreover, early after injury noncopers have demonstrated lack of dynamic knee stability with significantly different lower extremity movement patterns as compared to potential copers.[1,5,7,10,11] Nevertheless, there is no evidence to date that clearly establishes that noncopers following an ACL injury should be excluded as rehabilitation candidates. Previous prospective studies have exclusively followed patients classified as potential copers[9] and, to our knowledge, no prospective study with 1-year follow-up exists on patients with ACL injury classified as noncopers. Consequently, it has not been determined if patients with an ACL-deficient knee classified as noncopers early after injury have the potential of turning into true copers. Additionally it is unknown if the dynamic knee joint stability observed early after the ACL injury in individuals considered potential copers continues over time (true copers).[16,45]

The treatment algorithm for patients with ACL rupture in our institution is different from the reported treatment algorithm by Fitzgerald et al,[16,17] who developed the screening examination. At our institution patients are encouraged to perform an exercise program for at least 3 months after the ACL injury, regardless of early classification as potential coper or noncoper. ACL reconstruction is, in general, not recommended unless the individual is pursuing professional sports or experiences lack of dynamic stability of the knee, which results in preference for nonoperative treatment for approximately 50% of all the patients with ACL injury.[18] This treatment algorithm is based on reports suggesting that preoperative resolution

of impairments (effusion, pain, restricted range of motion, and decreased muscle strength) seem to be helpful for successful outcome after ACL reconstruction.[21,29,38,39]

Because changes in knee function in individuals with an ACL tear, classified early after injury as noncopers, and because the predictive value of the screening examination has not previously been examined, the purpose of this cohort study was (1) to classify our population of subjects with ACL-deficient knees as potential copers or noncopers, based on an established screening examination,[16] (2) to prospectively follow a cohort of subjects with an ACL injury and characterize the nonoperatively treated subjects as true copers or true noncopers 1 year after injury, (3) to evaluate outcomes in operatively treated individuals 1 year after ACL reconstruction, and (4) to calculate the predictive value of the screening examination based on a 1-year follow-up of nonoperatively treated individuals with an ACL injury.

METHODS

One hundred twenty-five consecutive subjects participating in level I and II sports,[20] between the ages of 14 to 60 years, and referred to our institution from August 2003 to October 2005 were included in this prospective cohort study. Subjects with ACL injury who regularly participated in level I or II sports, according to the criteria described by Hefti et al (TABLE 1),[20] for at least 50 hours a year, were considered eligible for inclusion in the study. Inclusion criteria were unilateral ACL rupture, confirmed with magnetic resonance imaging (MRI), and the results of an instrumented Lachman test with a knee arthrometer (KT-1000; Med-Metric, San Diego, CA).47 A side-to-side anterior tibiofemoral laxity difference of 3 mm or greater, using maximum manual force, was used to indicate unilateral injury to the ACL.12 Subjects were included if they had an asymptomatic meniscus injury within the previous 6 months. A meniscus injury was considered asymptomatic if the subject, at the time of screening examination, was able to run and perform a single-legged hop without knee pain or subsequent effusion. The decision on whether a subject was eligible for inclusion was made by the responsible physical therapist (H.M.). Subjects were excluded if they had posterior cruciate ligament injury, fractures, symptomatic meniscus injury, cartilage injury affecting the subchondral boneplate, or any previous injury to the involved or contralateral knee.

Forty-five percent (n = 56) of the subjects were females and 55% (n = 69) were males, with a mean ± SD age of 27.2 ± 8.6 years and time since injury of 82 ± 37 days at the time of screening examination. Preinjury activity level was level I for 68% (n = 85) and level II for 32% (n = 40) of the participants. The mean ± SD number of physical therapy sessions prior to the screening examination was 5.8 ± 3.6. One-hundred two subjects (82%) were included in the 1-year follow-up, of whom 51% (n = 52) had undergone nonoperative treatment and 49% (n = 50) ACL reconstruction. The remaining 23 subjects were excluded from the analysis due to the following reasons: 1 sustained an ACL injury to the contralateral knee, 4 had moved abroad, 8 did not respond to the invitation, and 10 subjects had gone through ACL reconstruction too close to the time of testing and were therefore not eligible for 1-year follow-up after surgery.

The screening examination was performed as soon as the prerequisites for the screening examination were met after the knee injury. Prerequisites for the screening examination included (1) resolution of physical and functional impairments, such as joint effusion, gait abnormalities, range-of-motion (ROM) deficits, and (2) the ability to hop on the involved lower extremity without pain. All subjects were assessed clinically by the same physical therapist (HM) to ensure that the prerequisites were met before the screening examination. Gait abnormalities were assessed by visual observation. Limping or ROM deficit during walking was considered a gait abnormality. Passive ROM was evaluated clinically by the physical therapist with the patient lying in supine position. Equal side-to-side passive knee extension and flexion was considered normal ROM. All patients were enrolled in the rehabilitation

program at our outpatient clinic and encouraged to consult a physical therapist once a week for progression of the program. Home exercises were provided, which participants were encouraged to perform daily. Rehabilitation and preoperative physical therapy are free for the first 6 months after ACL injury in Norway, and postoperative rehabilitation is similarly free for 6 months after ACL reconstruction. The physical therapist decides how many sessions are considered necessary within these time limits. Rehabilitation before the screening examination consisted of cycling on a stationary bicycle and weight-bearing exercises, with emphasis on neuromuscular control to enhance dynamic knee and hip stability. Low-load resistance strength-training exercises, such as leg press, seated knee extension, and leg curl, were also included in the program. The number of physical therapy visits prior to the screening examination was recorded, but rehabilitation attendance or compliance was not registered after the screening examination. After the screening examination, patients continued the rehabilitation program, with focus on regaining muscle strength, agility drills, and neuromuscular training until the orthopedic surgeon responsible decided on further treatment. Orthopedic surgeons from 5 different hospitals were involved in the treatment of the subjects. Activity level, type of activities, the number of giving-way episodes, age, the subject's own preferences, and the results from the screening examination were all considered when deciding whether to perform surgery or not.

The study was approved by the Data Inspectorate and the Regional Committee for Medical Research Ethics, and all subjects signed an informed consent form prior to participation.

Screening examination

The screening examination was performed within 6 months post injury, and consisted of (1) the timed 6-meter hop test,[16,36] (2) the Knee Outcome Survey activities of daily living scale (KOS-ADLS),[16,28] (3) the global rating of knee function assessed by a visual analogue scale (VAS),[16] and (4) determining the number of episodes of giving-way since the injury.16 An episode of giving way was defined as a perceived subluxation event of the knee with pain and subsequent effusion.16 To characterize the population of subjects with ACL injury we also included the 3 additional single-legged hop tests described by Fitzgerald et al and others.[13,16,36,45] Subjects who met all of the following criteria were classified as potential copers at the screening examination: (1) hop test index of 80% or more for the timed 6-meter hop test, (2) KOS-ADLS score of 80% or greater, (3) global rating of knee function of 60 or greater, and (4) no more than 1 episode of giving way since the injury.[13,17] Subjects who failed to meet all criteria were classified as potential noncopers.[16,45] The term *potential noncopers* was used to distinguish individuals considered potential noncopers at the time of the screening examination and the noncopers at the 1-year follow-up exam (true noncopers). To be able to compare our results to those reported by Fitzgerald et al,[16] we used identical criteria for the classification of potential copers and noncopers at the screening examination.

Before the screening examination, all subjects performed a standardized warm-up program consisting of 10 minutes on a stationary cycle. All tests were supervised by the same physical therapist (H.M.). A tape measure was taped to the floor for the measurement of hop distance. A stopwatch was used to manually time the timed 6-meter hop test. The 4 single-legged hop tests were (1) the single-hop for distance, (2) the straight triple-hop for distance, (3) the triple-crossover hop for distance, and (4) the timed 6-meter hop test. Subjects performed 1 practice trial, followed by 2 recorded trials of each hop test The uninjured side was tested first. The test was considered valid only if the subject managed a firm landing without twisting the foot or excessive balance movements. No brace was used during the hop tests. The hop test score for each side was reported as the better of the 2 recorded trials. The single-hop, triple-hop, and crossover hop test index were expressed as a percentage by dividing the performance of the injured extremity by the performance of the uninjured extremity. The timed 6-meter hop index

was expressed as a percentage by dividing the time for the uninjured extremity by the time for the injured extremity result.[13,16]

The score on the KOS-ADLS was calculated by adding the values for each question on all 14 items, divided by 70 (the total possible number of points for the questionnaire), and multiplied by 100, with the final score expressed as a percentage.[28]

The global rating of function was measured on a scale ranging from 0 to 100 points, with 100 being the patient's level of knee function prior to injury and 0 being the inability to perform any daily activities. The patients were instructed to draw a vertical mark on a 10-cm-long horizontal line, with 0 and 100 at either end of the line.[28]

The International Knee Documentation Committee Subjective Knee Form (IKDC2000) was included as an outcome measure to characterize the population and comparison with other reports on individuals with ACL injury.[27] The score on the IKDC2000 is calculated by adding the values for each question (maximum 105), minus the lowest possible total score (18), divided by the range of possible scores (87), multiplied by 100.27

The test protocol was performed in the following order: the single-hop, the triple-hop, the crossover hop, and the timed 6-meter hops. Then, the individuals answered questions regarding the number of giving-way episodes, followed by the KOS-ADLS, the global knee rating, and the IKDC2000 questionnaires.

One-Year Follow-up Examination

The follow-up examination was performed 1 year after the initial screening examination for the nonoperatively treated individuals. If a subject underwent ACL reconstruction during the follow-up period, the follow-up examination was performed 1 year after surgery. Based on the report from Fitzgerald et al,[16] we classified nonoperated subjects as true copers at the 1-year follow-up exam if they had resumed their previous activity level without episodes of giving way. Subjects who had not returned to their previous activity level or had experienced giving-way episodes were classified as true noncopers at the 1-year follow-up exam.

The 1-year follow-up test protocol was carried out in the following order subsequent to the KT-1000 measurement: the KOS-ADLS, the global knee rating, and the IKDC2000. Then, the single-legged hop tests were performed as follows: the single-hop, the triple-hop, the crossover hop, and the timed 6-meter hops. Finally, the subjects reported on the number of giving-way episodes and answered the questionnaire on current activity level.

Data Analysis

Statistical analyses were performed using the NCSS97 (Number Crunches Statistical System, Version 2.0.0.406; NCSS, Kaysville, UT). Mean and SD were calculated for numerical data; median and range were calculated for ordinal data. Two sample *t* tests were used for comparisons between groups (potential copers versus noncopers, and true copers versus true noncopers) when normality distribution was confirmed. Where normality distribution was rejected, the Mann-Whitney *U* test was used for group comparisons and reported with median and 95% confidence intervals (CIs). Alpha level was set at .05.

The positive predictive value of the classification as potential coper at the screening examination was calculated as follows: true positives ÷ (true positives + false positives).[40] Subjects classified as potential copers at the screening examination and true coper at the 1-year follow-up were true positives, while subjects classified as potential coper at the screening examination and true noncoper at the 1-year follow-up were false positives. The negative predictive value of the classification as potential coper (correct classification as true noncoper)

at the screening examination was calculated as follows: true negatives ÷ (true negatives + false negatives).40 Subjects classified as potential noncoper at the screening examination and true noncoper at the 1-year follow-up were true negatives, while subjects classified as potential noncoper at the screening examination and true coper at the 1-year follow-up were false negatives. The sensitivity, specificity, and positive and negative likelihood ratios with 95% CI were also calculated.42

RESULT

Following the screening examination, 63% (n = 79) of the subjects were classified as potential noncopers and 37% (n = 46) as potential copers. There were no differences in subject characteristics, time since injury, knee joint laxity, prescreening physical therapy sessions, or preinjury activity level between potential copers and noncopers (TABLE 2). There were highly significant differences ($P<.001$) between potential copers and noncopers for all parameters included in the screening examination and for the IKDC2000 (TABLE 3).

The postinjury MRI scans demonstrated that 15% (n = 18) of the subjects had asymptomatic medial meniscus injury, 9% (n = 11) had asymptomatic lateral meniscus injury, and 6% (n = 7) had minor pathological findings in the cartilage of the lateral femoral condyle.

For the 51% (n = 52) nonoperated subjects, the average ± SD time from screening examination to 1-year follow up was 404 ± 66 days. For the 49% (n = 50) of the subjects with ACL reconstructed knees the average ± SD time from injury to ACL reconstruction was 184 ± 91 days, and the time from screening examination to ACL reconstruction was 104 ± 88 days. The average ± SD time from ACL reconstruction to the 1-year follow up was 380 ± 45 days. The number of potential copers and potential noncopers, subjects with ACL reconstruction, and true copers and true noncopers among those who did not have surgery are illustrated in the FIGURE.

One-Year Follow-up: Nonoperated Subjects

Fifty-one percent (n = 52) of the subjects went through nonoperative treatment, of which 44% (n = 23) were females and 56% (n = 29) were males. Sixty-five percent (n = 34) of all the nonoperated subjects were classified as true copers, and 35% (n = 18) as true noncopers at the 1-year follow-up. According to the criteria for true copers of having returned to preinjury activity level without episodes of giving way, 15 out of 25 subjects initially classified as potential copers were true copers at the 1-year follow-up exam, giving a positive predictive value of 60% for correctly classifying true copers at the screening examination. Only 8 of 27 subjects classified as potential noncopers at the screening examination were true noncopers at the 1-year follow-up exam, giving a negative predictive value of 30% for correctly classifying true noncopers at the screening examination (TABLE 4). The sensitivity, specificity, and positive and negative likelihood ratios of the screening examination classification are presented in TABLE 5.

True copers had significantly less knee joint laxity, fewer giving-way episodes, significantly higher activity levels, and greater improvement in KOS-ADLS and IKDC2000 scores compared to true noncopers at the 1-year follow-up (TABLE 6). No statistical significant differences between true copers and true noncopers were observed for any of the single-legged hop tests at the 1-year follow-up (TABLE 6).

One-Year Follow-up: Subjects Post-ACL Reconstruction

Forty-nine percent (n = 50) of the subjects went through ACL reconstruction during the 1-year follow-up period, of which 52% (n = 26) were females and 48% (n = 24) were males. Eighty percent underwent surgery using a hamstrings graft, and 20% underwent surgery using bone-

patella tendon-bone graft. Surgical records documented that 24% (n = 12) had medial meniscus injury, of which partial meniscectomy was performed on 75% (n = 9), while 25% (n = 3) were left untreated. Thirty percent (n = 15) had lateral meniscus injury, of which partial meniscectomy was performed on 53% (n = 8), while 47% (n = 7) were left untreated. Three cases of minor cartilage injuries (grade I–II) on the medial femoral condyle and 3 cases on the lateral femoral condyle were recorded in the medical records, but no cartilage surgical procedures were performed. Among subjects with ACL reconstruction, 70% (n = 35) had returned to preinjury activity level at the 1-year follow-up. The outcomes of the subjects with ACL reconstruction at the 1-year follow-up are presented in TABLE 7.

DISCUSSION

Of the 125 subjects with ACL injury enrolled in this study, 37% were classified as potential copers and 63% as potential noncopers at the initial screening examination. The percentage of potential copers was previously reported by Fitzgerald et al[16] and Hurd et al[25] as 42% in similar populations of subjects with ACL-deficiency. We thereby presume that the populations are comparable, and that the small differences may be related to the fact that Fitzgerald et al[16] and Hurd et al[25,26] excluded subjects if they had quadriceps muscle strength deficits of less than 70% compared to the uninjured side. Muscle strength deficits were not part of our exclusion criteria. Fitzgerald et al[16] and Hurd et al[25] used a numeric scale for the global rating of knee function, while we used a linear visual analogue scale.

With regard to the second aim of the study, 65% of the nonoperated subjects were classified as true copers at the 1-year follow-up. There are no directly comparable studies reporting the percentage of true copers (defined as returning to preinjury activity level and no episodes of giving way) after 1 year following nonoperative treatment for a torn ACL. However, authors have reported a return-to-sport rate of subjects with a torn ACL treated nonsurgically to be between 19% and 82%.[3,14,34] Sixty-nine percent of our subjects with ACL tear treated nonoperatively had returned to preinjury activity level 1 year after screening examination. Fitzgerald et al16 reported that 79% of the subjects initially classified as potential copers who underwent nonoperative treatment were classified as true copers after returning to preinjury activity level for a limited period. Nonoperatively treated true copers from Fitzgerald et al[16] were selected exclusively from a population of potential copers, leaving only 24% (22 of 93) of the entire population investigated as true copers because potential noncopers were excluded from nonoperative treatment.[16] Fitzgerald et al16 excluded potential noncopers from the nonoperative treatment because they assumed that noncopers would not be capable of safe return to sport due to the lack of dynamic knee joint stability. The single most important reason for our decision to investigate the screening examinations predictive value for correctly classifying true copers was our experience with the treatment algorithm, in which all subjects are considered rehabilitation candidates early after ACL injury. We have observed that the development of knee function in nonoperatively treated subjects takes time, and we were concerned that excluding potential noncopers from nonoperative treatment, in fact, would lead to unnecessary surgery for a number of patients or exclude the potential noncopers from significant preoperative rehabilitation. The present study provides a scientific rationale for not excluding potential noncopers from nonoperative treatment; however, further research is necessary to further examine significant predictive factors for nonoperative treatment.

In this study, the overall results for knee function and return to sport are good for subjects who underwent ACL reconstruction, as well as for those treated nonoperatively (TABLES 6 and **7**). The 50 subjects with ACL reconstruction averaged greater than 90% on all single-legged hop tests and the KOS-ADLS questionnaire, while the IKDC2000 and global rating scores were greater than 84. Anderson et al[2] reported the normative IKDC2000 score for subjects in the age group 25 to 34 years, with a previous knee injury, to be on average 88.9 points (95%

CI: 87.6–90.3) for men, and on average 86.0 points (95% CI: 84.5–87.0) for women. Related to the normative IKDC2000 data, nonoperated and ACL reconstructed subjects in this study showed near-normal knee function at the 1-year follow-up exam. Interestingly, among the nonoperatively treated subjects, true copers had a median IKDC value of 92, while true noncopers had a score of 84, which placed them, respectively, above and below the normative values reported by Anderson et al.[2] Keays et al30 reported that 31 subjects post-ACL reconstruction performed 88.0% on the single-hop test and 89.6% on the triple-hop for distance test, compared to the uninjured side 6 months after ACL reconstruction; while Gustavsson et al[19] reported that only 30% of their subjects with ACL injury performed better than 90% on the single-legged hop tests 6 months after ACL reconstruction. Myer et al[33] have developed criteria-based clinical guidelines with functional test for late-phase rehabilitation and return to sport. The rationale for this bilateral comparison is the assumption that subjects who resume high-level activities with asymmetric lower limb function are at risk of reinjury.23 Myer et al[33] used a variety of functional tests and used a cut-off of 85%, compared to the uninjured side for return-to-sport criteria. In the present study we found that true copers scored significantly higher than true noncopers on all the questionnaires (KOS-ADLS and IKDC2000), but not on any of the performance based single-legged hop tests. True noncopers as well as true copers performed better than 90% on all 4 single-legged hop tests, which does not support the use of the single-legged hop tests as criteria for safe return to sport. There is little scientific evidence regarding return to sport criteria in the literature,[31] and there is also a debate if return-to-sport criteria should be used as a criterion for success.31,[34] There are difficulties related to the use of return to preinjury activity level as a success criterion. Individuals with an ACL-deficient or reconstructed knee may have other substantial reasons for not returning to sports after injury. Some individuals prefer not returning to high-risk activities due to the strenuous rehabilitation after an ACL reconstruction. These so-called adapters[7] will not be considered successfully treated individuals, even though they may be satisfied and have excellent knee function related to their adjusted activity level. In the present study there may be several adapters who have been classified as true noncopers, which may in part explain the small differences in performance on functional tests between true copers and true noncopers. Return to preinjury activity level as a main outcome may give a false impression of lower success rates at follow-up and does not give an objective measurement of knee function.

The final aim of this study was to calculate the predictive value of the screening examination. The positive predictive value of classification as potential coper at the screening examination was 60% (95% CI: 41%-78%), while the negative predictive value of the classification at the screening examination was 30% (95% CI: 16%-49%). Among the potential copers, 60% were true copers, while 70% of the potential noncopers were true copers at the 1-year follow-up exam. TABLE 5 shows that for all elements of the prognostic accuracy profile, the results are not statistically significant, as the 95% CIs include the null values for the statistics. The null values for sensitivity, specificity, and positive and negative predictive values are all 50%, showing that the level of prognostic accuracy is no different than random chance. The null value for the likelihood ratios was 1.0, which indicates no shift from pretest to posttest probability. Considering that upper bounds of the 95% CIs are all below 80% for sensitivity, specificity, and predictive values, prognostic usefulness of the screening examination is unlikely. The only result with 95% CI close to being clinically acceptable is the positive predictive value with an upper bound of 78%. The intention behind the development of the screening examination was to create a tool to identify individuals with an ACL-deficient knee early after injury who had a potential of returning to preinjury activity level for a limited period.[16,17] Subjects classified as potential noncopers at the screening examination have traditionally been considered noncandidates for nonoperative treatment; but the low negative predictive value from this study suggests that subjects classified as potential noncopers should also be considered rehabilitation candidates. Additionally, the results from the present study indicate

that to exclude subjects from nonoperative treatment based on the classification of potential noncopers at the screening examination is to underestimate the true proportion of subjects who are able to continue to be active at their preinjury activity level after nonoperative treatment.

The findings in this study illustrate the challenges clinicians meet in daily practice. We still do not have the optimal clinical tests to correctly assign individuals with an ACL tear to the correct treatment (conservative or surgery) early after injury. However, the screening examination should be further developed to be a significant clinical tool to correctly identify lack of dynamic knee stability in individuals with an ACL tear after optimal exercise programs have been performed. Time is sometimes an essential aspect of the decision-making process following and ACL injury. Regaining dynamic knee stability in some individuals with an ACL tear can take time.

Although some athletes may regain dynamic knee stability through non-operative treatment, most athletes will not be willing to invest sufficient time in postinjury rehabilitation to fully explore the potential of nonoperative treatment before deciding on surgical treatment.

The design of this study does not allow us to examine the significant factors contributing to the low predictive value at the 1-year follow-up of nonoperative treatment. However, dynamic knee joint stability seems to change in both potential copers and potential noncopers, probably due to both time and treatment. There is a possibility that the classification criteria put forward by Fitzgerald et al[16] might not be strict enough to separate the dynamically stable ACL-deficient subjects from the unstable ACL-deficient subjects, or that the screening examination was only valid for assigning individuals with ACL injury as short-term rehabilitation candidates. Other studies have suggested that evaluating dynamic knee joint stability with several single-legged hop tests is a more valid measure of knee function.[22,36] Future studies should examine if all 4 single-legged hop tests should be included in the classification of dynamic knee stability early after ACL injury. Our results suggest that the timing of the screening examination might be too early to classify individuals as rehabilitation candidates or not, because potential noncopers as well as potential copers seem to improve their knee function significantly from the screening examination until the 1-year follow-up. This investigation establishes support for an assumption that a significant proportion of potential noncopers have the possibility of regaining dynamic knee stability similar to potential copers. Furthermore, future studies need to examine changes in movement patterns and neuromuscular function, using motion analysis and electromyography in both true copers and true noncopers.

The foremost limitations of this study are its lack of assessment of compliance to rehabilitation after the screening examination and of the subjects' knees by MRI or arthroscopy at follow-up. We wanted to include muscle strength testing both at time of the screening examination and as an outcome measurement at follow-up but did not have appropriate muscle strength-testing equipment available at that time. Future studies should evaluate whether muscle strength is a significant factor for the classification of true copers and true noncopers.

Further research should continue to develop criteria for performance-based clinical tests to investigate the predictive value of an early functional screening examination and significant factors to correctly identify lack of dynamic knee stability in subjects with ACL injury.

CONCLUSION

In this study, 37% of those with ACL injury were classified as potential copers and 63% as potential noncopers. Subjects who underwent ACL reconstruction as well as those who followed a conservative rehabilitation program showed excellent results on single-legged hop tests and good results on functional questionnaires at the 1-year follow-up exam. One year after the screening examination 60% of the potential copers were true copers, and at the 1-year

follow-up exam 70% of the subjects initially classified as potential noncopers were true copers. The positive predictive value for correctly classifying true copers at the screening examination was 60% (95% CI: 41%–78%), while the negative predictive value was 30% (95% CI: l6%–49%). None of the prognostic accuracy statistics showed clinically useful results in the investigated population.

The screening examination had poor predictive value for correctly classifying true copers and true noncopers at the 1-year follow-up, bringing into question the use of this screening examination to determine who should have surgery post ACL injury.

KEY POINTS

FINDINGS

The majority (70%) of subjects with ACL injury classified as potential noncopers were true copers after 1 year following nonoperative treatment. The prognostic accuracy of the screening examination was poor.

IMPLICATION

Subjects classified as potential noncopers and potential copers from the screening examination should be equally regarded as rehabilitation candidates. Orthopaedic surgeons and physical therapists should be cautious when advising treatment options to subjects with an ACL injury, based on the screening examination.

CAUTION

The results presented in this paper were obtained from subjects regularly performing level I and II sports; no professional athletes were included in the study.

Acknowledgments

We acknowledge our research coordinator Linn Gjersing for her involvement in database maintenance and logistic skills, which made this study possible. Finally, we acknowledge our funding institutions, the Eastern Norway Regional Health and the National Institutes of Health.

This study was financed by grants from the Eastern Norway Regional Health Authorities and NIH R01HD 037985-05. The protocol of this study was approved by the Regional Ethical Committee, Health Region East, Norway (Institutional Review Board).

References

1. Alkjaerl Simonsen, EB.; Jorgensen, U.; Dyhre-Poulsen, R. Evaluation of the walking pattern in two types of patients with anterior cruciate ligament deficiency; copers and non-copers; Eur J Appl Physiol. 2003. p. 301-308.http://dx.doi.org/10.1007/s00421-002-0787-x
2. Anderson, AF.; irrgang, JJ.; Kocher, MS.; Mann, BJ.; Harrast, JJ. The International Knee Documentation Committee Subjective Knee Evaluation Form; normative data; Am J Sports Med. 2006. p. 128-135.http://dx.doi.org/10.1177/0363546505280214
3. Andersson C, Odensten M, Gillquist J. Knee function after surgical or nonsurgical treatment of acute rupture of the anterior cruciate ligament a randomized study with a long-term follow-up period. Clin Orthop Relat Res 1991:255–263. [PubMed: 1997243]
4. Augustsson, J.; Thomee, R.; Karlsson, J. Ability of a new hop test to determine functional deficits after anterior cruciate ligament reconstruction. Knee Surg Sports; Traumatol Arthrosc. 2004. p. 350-356.http://dx.doi.org/10.1007/S00167-004-0518-4
5. Barrance, PJ.; Williams, GN.; Snyder-Mackler, L.; Buchanan, TS. Altered knee kinematics in ACL-deficient non-copers: a comparison using dynamic MRI; J Orthop Res. 2006. p. 132-140.http://dx.doi.org/10.1002/jor.20016

6. Beynnon, BD.; Johnson, RJ.; Abate, JA.; Fleming, BC.; Nichols, CE. Treatment of anterior cruciate ligament injuries, part I; Am J Sports Med. 2005. p. 1579-1602.http://dx.doi.org/10.1177/0363546505279913
7. Button, K.; van Deursen, R.; Price, P. Classification of functional recovery of anterior cruciate ligament copers, non-copers, and adapters; Br J Sports Med. 2006. p. 853-859.discussion 859. http://dx.doi.org/10.1136/bjsm2006.028258
8. Caborn DN, Johnson BM. The natural history of the anterior cruciate ligament-deficient knee. A review. Clin Sports Med 1993;12:625–636. [PubMed: 8261517]
9. Chmielewski TL, Hurd WJ, Rudolph KS, Axe MJ, Snyder-Mackler L. Perturbation training improves knee kinematics and reduces muscle co-contraction after complete unilateral an terior cruciate ligament rupture. Phys Ther 2005;85:740–749. discussion 750–744. [PubMed: 16048422]
10. Chmielewski, TL.; Hurd, WJ.; Snyder-Mackler, L. Elucidation of a potentially destabilizing control strategy in ACL deficient non-copers; J Electromyogr Kinesiol. 2005. p. 83-92.http://dx.doi.org/10.1016/j.jelekin2004.07.003
11. Chmielewski TL, Rudolph KS, Fitzgerald GK, Axe MJ, Snyder-Mackler L. Biomechanical evidence supporting a differential response to acute ACL injury. Clin Biomech (Bristol, Avon) 2001;16:586–591.
12. Daniel DM, Stone ML, Sachs R, Malcom L. Instrumented measurement of anterior knee laxity in patients with acute anterior cruciate ligament disruption. Am J Sports Med 1985;13:401–407. [PubMed: 4073348]
13. Eastlack ME, Axe MJ, Snyder-Mackler L. Laxity, instability, and functional outcome after ACL injury: copers versus noncopers. Med Sci Sports Exerc 1999;31:210–215. [PubMed: 10063808]
14. Engstrom B, Gornitzka J, Johansson C, Wredmark T. Knee function after anterior cruciate ligament ruptures treated conservatively. Int Orthop 1993;17:208–213. [PubMed: 8407034]
15. Fithian DC, Paxton EW, Stone ML, et al. Prospective trial of a treatment algorithm for the management of the anterior cruciate ligament-injured knee. Am J Sports Med 2005;33:335–346. [PubMed: 15716249]
16. Fitzgerald GK, Axe MJ, Snyder-Mackler L. A decision-making scheme for returning patients to high-level activity with nonoperative treatment after anterior cruciate ligament rupture. Knee Surg Sports Traumatol Arthrosc 2000;8:76–82. [PubMed: 10795668]
17. 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 2000;30:194–203. [PubMed: 10778796]
18. Granan LP, Engebretsen L, Bahr R. Surgery for anterior cruciate ligament injuries in Norway. Tidsskr Nor Laegeforen 2004;124:928–930. [PubMed: 15060639]
19. Gustavsson, A.; Neeter, C.; Thomee, P., et al. A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction; Knee Surg Sports Traumatol Arthrosc. 2006. p. 778-788.http://dx.doi.org/10.1007/s00167-006-0045-6
20. Hefti F, Muller W, Jakob RP, Staubli HU. Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc 1993;1:226–234. [PubMed: 8536037]
21. Heijne, A.; Axelsson, Kt; Werner, S.; Biguet, G. Rehabilitation and recovery after anterior cruciate ligament reconstruction: patients' experiences; Scand J Med Sci Sports. 2008. p. 325-335.http://dx.doi.org/10.1111/j.1600-08382007.00700.x
22. Herrington, L.; Fowler, E. A systematic literature review to investigate if we identify those patients who can cope with anterior cruciate ligament deficiency; Knee. 2006. p. 260-265.http://dx.doi.org/10.1016/j.knee.2006.02.010
23. Hewett, TE.; Myer, GD.; Ford, KR., et al. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study; Am J Sports Med. 2005. p. 492-501.http://dx.doi.org/10.1177/0363546504269591
24. Houck JR, Duncan A, De Haven KE. Knee and hip angle and moment adaptations during cutting tasks in subjects with anterior cruciate ligament deficiency classified as noncopers. J Orthop Sports Phys Ther 2005;35:531–540. http://dx.doi.org/10.2519/jospt2005.1763. [PubMed: 16187513]

25. Hurd, WJ.; Axe, MJ.; Snyder-Mackler, L. A 10-year prospective trial of a patient management algorithm and screening examination for highly active individuals with anterior cruciate ligament injury: part 1, outcomes; Am J Sports Med. 2008. p. 40-47.http://dx.doi.org/10.1177/0363546507308190
26. Hurd, WJ.; Axe, MJ.; Snyder-Mackler, L. A 10-year prospective trial of a patient management algorithm and screening examination for highly active individuals with anterior cruciate ligament injury: part 2, determinants of dynamic knee stability; Am J Sports Med. 2008. p. 48-56.http://dx.doi.org/10.1177/0363546507308191
27. Irrgang JJ, Anderson AF, Boland AL, et al. Development and validation of the international knee documentation committee subjective knee form. Am J Sports Med 2001;29:600–613. [PubMed: 11573919]
28. Irrgang JJ, Snyder-Mackler L, Wainner RS, Fu FH, Harner CD. Development of a patient-reported measure of function of the knee. J Bone Joint Surg Am 1998;80:1132–1145. [PubMed: 9730122]
29. Keays SL, Bullock-Saxton JE, Newcombe P, Bullock MI. The effectiveness of a pre-operative home-based physiotherapy programme for chronic anterior cruciate ligament deficiency. Physiother Res Int 2006;11:204–218. [PubMed: 17236528]
30. Keays, SL.; Bullock-Saxton, JE.; Newcombe, P.; Keays, AC. The relationship between knee strength and functional stability before and after anterior cruciate ligament reconstruction; J Orthop Res. 2003. p. 231-237.http://dx.doi.org/10.1016/S0736-0266(02)00160-2
31. Kvist J. Rehabilitation following anterior cruciate ligament injury: current recommendations for sports participation. Sports Med 2004;34:269–280. [PubMed: 15049718]
32. Marx RG, Jones EC, Angel M, Wickiewicz TL, Warren RF. Beliefs and attitudes of members of the American Academy of Orthopaedic Surgeons regarding the treatment of anterior cruciate ligament injury. Arthroscopy 2003;19:762–770. [PubMed: 12966385]
33. Myer, GD.; Paterno, MV.; Ford, KR.; Quatman, CE.; Hewett, TE. Rehabilitation after anterior cruciate ligament reconstruction: criteria-based progression through the return-to-sport phase; J Orthop Sports Phys Ther. 2006. p. 385-402.http;//dx.doi.org/10.2519/jospt.2006.2222
34. Myklebust, G.; Bahr, R. Return to play guidelines after anterior cruciate ligament surgery; Br J Sports Med. 2005. p. 127-131.http://dx.doi.org/10.1136/bjsm.2004.010900
35. Myklebust G, Holm I, Maehlum S, Engebretsen L, Bahr R. Clinical, functional, and radiologic outcome in team handball players 6 to 11 years after anterior cruciate ligament injury: a follow-up study. Am J Sports Med 2003;31:981–989. [PubMed: 14623667]
36. Noyes FR, Barber SD, Mangine RE. Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. Am J Sports Med 1991;19:513–518. [PubMed: 1962720]
37. Noyes FR, Matthews DS, Mooar PA, Grood ES. The symptomatic anterior cruciate-deficient knee. Part II: the results of rehabilitation, activity modification, and counseling on functional disability. J Bone Joint Surg Am 1983;65:163–174. [PubMed: 6822580]
38. Risberg MA, Engebretsen L, Holm I. Which factors may predict success after ACL reconstruction? [abstract]. Norsk Idrettsmedisn 2005;20:25.
39. Risberg MA, Holm I, Tjomstand O, Ljunggren E, Eketand A. Prospective study of changes in impairments and disabilities after anterior eructate ligament reconstruction. J Orthop Sports Phys Ther 1999;29:400–412. [PubMed: 10416180]
40. Rothstein, J.; Echternach, J. Reliability and Validity. Primer on Measurement An Introductory Guide to Measurement Issues. Alexandria, VA: American Physical Therapy Association; 1993.
41. Rudolph KS, Axe MJ, Buchanan TS, Scholz JP, Snyder-Mackler L. Dynamic stability in the anterior cruciate ligament deficient knee. Knee Surg Sports Traumatol Arthrosc 2001;9:62–71. [PubMed: 11354855]
42. Sim J, Reid N. Statistical inference by confidence intervals: issues of interpretation and utilization. Phys Ther 1999;79:186–195. [PubMed: 10029058]
43. Smith FW, Rosenlund EA, Aune AK, MacLean JA, Hillis SW. Subjective functional assessments and the return to competitive sport after anterior cruciate ligament reconstruction. Br J Sports Med 2004;38:279–284. [PubMed: 15155426]

44. Snyder-Mackler L. Fate of the ACL-injured patient: a prospective outcome study. Am J Sports Med 1995;23:372–373. [PubMed: 7661272]

45. Snyder-Mackler L, Fitzgerald GK, Bartolozzi AR 3rd, Ciccotti MG. The relationship between passive joint laxity and functional outcome after anterior cruciate ligament injury. Am J Sports Med 1997;25:191–195. [PubMed: 9079172]

46. Williams GN, Chmielewski T, Rudolph K, Buchanan TS, Snyder-Mackler L. Dynamic knee stability: current theory and implications for clinicians and scientists. J Qrthop Sports Phys Ther 2001;31:546–566.

47. Wroble RR, Van Ginkel LA, Grood ES, Noyes FR, Shaffer BL. Repeatability of the KT-1000 arthrometer in a normal population. Am J Sports Med 1990;18:396–399. [PubMed: 2403189]

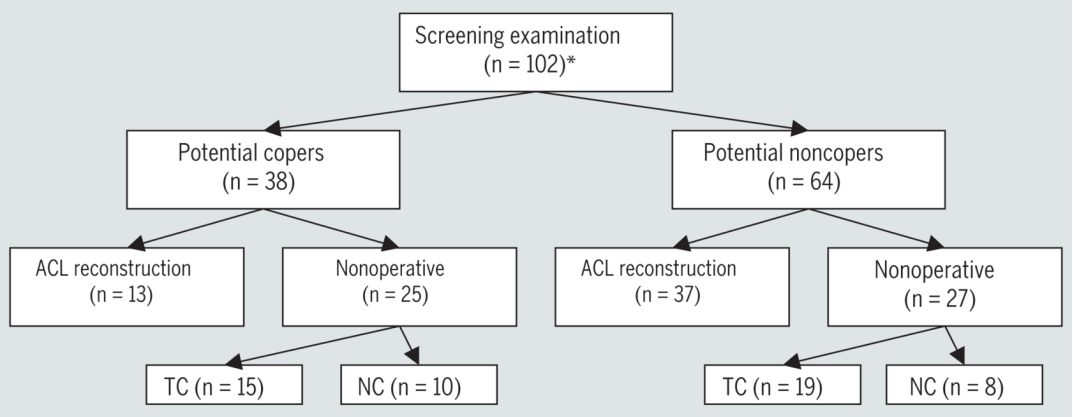

Figure.
Flow chart of the subjects throughout the study. *23 dropouts (8 potential copers, 15 potential noncopers). Abbreviations: ACL, anterior cruciate ligament; NC, true noncopers; TC, true copers.

TABLE 1

Activity Level Classification[20] Modified to European Sport Activities

Level	Sports Activity	Occupation Activity
I	Jumping, cutting, pivoting (soccer, team handball, basketball, floorball)	Activity comparable to level I sports
II	Lateral movements, less pivoting than level I (racket sports, alpine skiing, snowboarding, gymnastics, aerobics)	Heavy manual labor, working on uneven surface
III	Straight-ahead activities, no jumping or pivoting (running, cross-country skiing, weightlifting)	Light manual work
IV	Sedentary	Activities of daily living

Table 2

Subject Characteristics at Screening Examination*

Measures	Potential Copers (n = 46)	Potential Noncopers (n = 79)	*P* Value
Age (y)	27.9 ± 10.3	26.8 ± 7.6	.52
Time from injury (d)	80.2 ± 33.4	82.9 ± 40.1	.91
Physical therapy sessions	5.9 ± 3.4	5.7 ± 3.8	.84
KT-1000 (mm difference)	6.5 ± 3.5	7.5 ± 3.3	.31
Activity level (level I and II)	35 and 11†	50 and 29†	

*Data are mean ± SD.

†Number of subjects at each level

Table 3

Performance and Outcome Measures at Screening Examination*

Measures	Potential Copers (n = 46)	Potential Noncopers (n = 79)	*P* Value
Single-hop for distance (% of uninjured)	90.3 ± 9.0	82.5 ± 14.8	<.01
Triple-hop for distance (% of uninjured)	92.3 ± 7.8	83.6 ± 12.5	<.001
Crossover hop for distance (% of uninjured)	91.7 ± 9.4	84.5 ± 13.3	<.001
Timed 6-meter hop test (% of injured)	95.6 ± 6.5	87.4 ± 12.5	<.001
KOS-ADLS	94.3 ± 3.7	81.5 ± 13.3	<.001
Global rating of knee function (VAS, 0–100)	77.7 ± 9.3	47.6 ± 20.1	<.001
Episodes of giving way	0 (0–1)	1 (0–6)	<.001
IKDC2000	78.5 ± 8.2	61.9 ± 14.0	<.001

Abbreviations: IKDC2000, International Knee Documentation Committee Subjective Knee Form; KOS-ADLS, Knee Outcome Survey activities of daily living scale; VAS, visual analogue scale.

*Data are mean ± SD, except for episodes of giving way, which were median (minimum-maximum).

Table 4

Classification of Subjects at Screening and 1-Year Follow-up After Nonoperative Treatment

	True Coper at 1-Year Follow Up		
Potential Coper at Screening Examination	**Yes**	**No**	**Total**
Yes	15	10	25
No	19	8	27
Total	34	18	52

Table 5

Prognostic Accuracy Profile of the Screening Examination

Measures	Accuracy	95% Confidence Interval
Sensitivity	44.1%	28.9%–60.6%
Specificity	44.4%	24.6%–66.3%
Positive predictive value	60.0%	40.7%–77.6%
Negative predictive value	29.6%	15.9%–48.5%
Positive likelihood ratio	0.79	0.45–1.39
Negative likelihood ratio	1.26	0.69–2.28

TABLE 6

Nonoperated Subjects at 1-Year Follow-up*

Instruments/Tests	True copers (n = 34)	True Noncopers (n = 18)	*P* Value
KT-1000 (mm difference)	5 (4–7)	8 (6–11)	.02
Single-hop for distance (% of uninjured)	97 (94–99)	96 (93–99)	.30
Triple-hop for distance (% of uninjured)	96 (94–98)	96 (95–99)	.99
Crossover hop for distance (% of uninjured)	96 (94–97)	97.5 (94–100)	.41
Timed 6-m hop test (% of injured)	96 (95–100)	100 (94–100)	.72
KOS ADLS	97 (96–100)	93.5 (87–97)	<.01
Global rating of knee function (VAS, 0–100)	92 (87–94)	84.5 (76–95)	.05
Episodes of giving-way	0 (0–0)	1.5 (0–2)	<.01
Preinjury activity level (level I or II)	1.5 (1–2)	1 (1–2)	.13
Activity level at follow-up (level I, II, or III)	1 (1–2)	2 (2–2)	<.01
IKDC2000	92 (89–95)	84 (75–87)	<.01

Abbreviations: IKDC2000, International Knee Documentation Committee Subjective Knee Form; KOS ADLS, Knee Outcome Survey activities of daily living scale; VAS, visual analogue scale.

* Data are median (95% confidence intervals).

Table 7

Subjects With ACL Reconstruction at 1-Year Follow-up*

Instruments/Tests	Scores (n = 50)
KT-1000 (mm difference)	3.2 ± 2.2
Single-hop for distance (% of uninjured)	91.0 ± 14.4
Triple-hop for distance (% of uninjured)	91.0 ± 11.2
Crossover hop for distance (% of uninjured)	92.0 ± 12.4
Timed 6 meter hop test (% of injured)	92.5 ± 9.9
KOS ADLS	91.7 ± 8.4
Global rating of knee function (VAS, 0–100)	85.2 ± 11.5
Activity level at follow-up (level I, II, or III)	1 (1–2)
IKDC2000	84.6 ± 13.3

Abbreviations: IKDC2000, International Knee Documentation Committee Subjective Knee Form; KOS ADLS, Knee Outcome Survey activities of daily living scale; VAS, visual analogue scale.

* Data are mean ± SD, except for activity level at follow-up, which is median (95% confidence interval).