

Performance based functional evaluation of non-operative and operative treatment after ACL injury

ABSTRACT

Highly active ACL injured patients are usually recommended surgical treatment as the primary intervention. The objective of this study was to compare the functional outcome in a cohort of individuals after non-operative treatment to individuals after surgical treatment at a one year follow-up. One-hundred-and-twenty-five subjects with a mean age of 27.2 years (± 8.6 years), and participating in level I or II activities were included. Baseline and one year follow-up examination included four single legged hop tests, IKDC 2000, KOS-ADLS, KT-1000 knee arthrometer measurement, VAS, episodes of giving way and activity level. Fifty-one percent went through non-operative treatment. Non-operated subjects performed significantly better on two out of the four single legged hop tests compared to the ACL reconstructed subjects at the one year follow-up. No other differences were observed. Both groups performed an average $>90\%$ compared to their uninjured leg on all single legged hop tests at the one year follow-up. The IKDC 2000 scores in the non-operated and ACL reconstructed group were on average 86 and 87. ACL injured subjects should be informed of the possibility of success after non-operative treatment, but future studies are needed to disclose significant predictive factors for success for non-operative and surgically treated individuals.

INTRODUCTION

The anterior cruciate ligament (ACL) is the most frequent injured ligament in the knee (Arendt et al. 1999b, Agel et al. 2005), and it seems apparent from the literature that ACL reconstruction is the preferred treatment especially for patients who participate in high level sports (Beynnon et al. 2005c). Despite the widely accepted treatment recommendation of ACL reconstruction for active individuals, no research which include validated performance based functional outcome measurements at baseline early after injury and at follow-up, have been reported comparing bone–patellar tendon–bone or multistrand hamstring autograft ACL reconstructions with non-operative treatment. The primary indication for ACL injured subjects to go through ACL reconstruction is to restore knee stability and enable the subjects return to desired activity level. A secondary argument is that the ACL reconstruction will reduce the danger of subluxation events which may lead to meniscus injury, cartilage injury, and an increased risk of development of knee osteoarthritis (OA) (Fink et al. 2001a, Beynnon et al. 2005b). Several authors have reported a high incidence of meniscus injury in subjects continuing high level pivoting sports after non-operative treatment (Scavenius et al. 1999a, Fink et al. 2001b, von Porat A. et al. 2004c, Nebelung & Wuschech 2005, Meunier et al. 2006). Conversely, research reports published in the recent years strongly suggest that undergoing an ACL reconstruction does not decrease the risk of development of knee osteoarthritis (OA) in the long term (von Porat A. et al. 2004b, Lohmander et al. 2004b, Fithian et al. 2005b). Meniscus injury and/or continuing to participate in pivoting sports seem to be important risk factors which highly influence the rate of knee OA development after ACL injury (Roos et al. 1995a, Gillquist & Messner 1999, Segawa et al. 2001b, Leitze et al. 2005, Fithian et al. 2005a, Kostogiannis et al. 2007d). The true ultimate outcome of ACL reconstructions is not known (Beynnon et al. 2005a). Reports concerning the success in returning to sport after ACL reconstruction varies from 65% to 88%, while the corresponding percentages for non-operative treatment varies from 19% to 82% (Smith et al. 2004b, Myklebust & Bahr 2005b). A high incidence of complications and re-injuries after ACL reconstruction is documented by several investigators, and should be taken into consideration before a decision on ACL reconstruction is made (Noyes & Barber-Westin 1996, Kartus et al. 1999, Salmon et al. 2005, Laxdal et al. 2005b).

The treatment algorithm for patients with ACL rupture in our institution differs to some degree from established clinical practice in the USA. Our institution advocate that all ACL injured patients should participate in rehabilitation programs to restore full range of motion and regain quadriceps strength before the question of ACL reconstruction is addressed. The decision on ACL reconstruction or further non-operative management is subsequently made by the patient in collaboration with an orthopedic surgeon or a qualified physical therapist. ACL reconstruction is in general not recommended unless the individual experiences dynamic knee instability. Approximately 50% of the ACL injured population in our country decide to undergo ACL reconstruction (Granán et al. 2004), while a proportion of subjects is well functioning with their ACL injury (copers), and some individuals decide to reduce their work or sports level to prevent their knee from giving way (adapters) (Button et al. 2006a).

The ultimate goal for rehabilitation after ACL injury, regardless of treatment modality, is to restore the patients' functional knee stability so that they are able to return to their desired activity level. Athletes returning to high level sports need to be mentally prepared and confident that their knee is successfully rehabilitated. Performance based single legged hop tests are commonly used to examine lower extremity function similar to the demands of high level sport activities and as objective criteria for return to sport. (Keays et al. 2003e, Augustsson et al. 2004, O'Donnell et al. 2006, Neeter et al. 2006, Myer et al. 2006c). Still, no consensus on objective criteria to decide when or if at all, an individual should return to high level sports after ACL reconstruction or non-operative treatment exists. The majority of literature on the topic lack specified functional criteria for safe and successful return to sport (Kvist 2004).

The primary purpose of this prospective cohort study was to compare the functional outcome for subjects who underwent non-operative treatment with subjects who underwent ACL reconstruction. Secondary, the purpose was to compare the functional outcome between subjects who succeed in returning to pre-injury activity level after non-operative or surgical treatment with subjects who did not return to pre-injury activity level. We hypothesized (1) that ACL reconstructed subjects will have higher functional outcomes compared to non-operated subjects at one year follow-up, and (2) that subjects who had returned to pre-injury activity level after non-operative or surgical

treatment will have higher functional outcome than subjects who did not return to pre-injury activity level.

MATERIAL AND METHODS

This prospective cohort study includes 125 subjects between the ages of 14 to 60 years who were referred to our institution in the period from August 2003 until October 2005. Inclusion criteria were participation in level I or II sports (Hefti et al. 1993) (Table 1), unilateral ACL rupture confirmed with magnetic resonance imaging (MRI) and sagittal tibiofemoral displacement of 3 mm or greater between the two knees, using maximum manual force (KT-1000, Med-Metric, San Diego, California, USA) (Daniel et al. 1985). The MRI scans were evaluated by the senior radiologist at the hospital or private clinic where the MRI was performed, and this evaluation was used for inclusion in the study. Subjects were included if they had an asymptomatic meniscus injury. A meniscus injury described from the post-injury MRI was regarded asymptomatic if the subject, at the time of baseline 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 (HM). Exclusion criteria were posterior cruciate ligament injury, intraarticular fractures, symptomatic meniscus injury, cartilage injury affecting the subchondral boneplate observed on MRI, or any injury to the other leg. Subjects with previous injury or surgery in the index- or contralateral knee were excluded. Subjects were not regarded eligible for inclusion when their responsible physician or orthopedic surgeon recommended early or subacute surgical intervention due to repairable meniscus or cartilage injury. 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.

Baseline functional examination was performed within the first six months after the index injury. According to the treatment algorithm for rehabilitation after ACL injury in our institution all subjects were encouraged to attend active rehabilitation programs for at least three months prior to deciding whether they should proceed non-operative management or undergo ACL reconstruction. The decision on whether a subject

continued non-operative treatment or underwent ACL reconstruction was made by the responsible orthopedic surgeon and physical therapist in collaboration with the patient. The orthopedic surgeon made the final decision on whether a subject was offered an ACL reconstruction or not. Orthopedic surgeons from five different hospitals were involved in treating the included subjects. Activity level, type of activities, number of giving way episodes, age, the subject's own wishes, and the results from the baseline examination was given weight in the decision-making regarding surgery or not. Subjects who were regularly active in level I activities and determined to have an ACL reconstruction could be offered a surgical intervention although he or she had not experienced giving way episodes and had performed excellent on functional examination (i.e. the well functioning knee was regarded positive for post-surgical outcome (Keays et al. 2003d)). Vice versa a subject could have surgical intervention denied or postponed if he or she did not comply with post-injury rehabilitation, had a swollen knee, knee extension deficit or other medical contraindications for surgery.

Baseline and follow-up examinations were observed by one single physical therapist (HM). Physical- and functional impairments such as joint effusion, gait abnormalities, and range of motion deficits were resolved before baseline examination. Subjects also had to be able to hop on one leg without pain. According to our institutions treatment protocol all subjects were encouraged to exercise on a stationary bicycle, to perform active quadriceps exercises and low load closed kinetic chain exercises to address the impairments prior to the functional examination. The subjects pre-injury activity level were classified according to the criteria described by Hefti et al. (1993), modified to European sports activities (Table 1), and based on the patients report of regular activities prior to the knee injury. There were no professional athletes participating in this study.

Baseline functional examination

Before the functional examination all subjects performed a standardized warm-up protocol consisting of 10 minutes cycling on a cycle ergometer. The baseline functional examination consisted of; (1) the single hop, (2) the triple hop, (3) the triple crossover hop, and (4) the six meter timed hop test (Noyes et al. 1991b, Fitzgerald et al. 2000a).

These tests has shown to be valid and reliable (Bolgla & Keskula 1997, Reid et al. 2007c), with intraclass correlation coefficients (ICC) for limb symmetry index values ranging from 0.82 to 0.93 for a population of ACL reconstructed subjects. Minimal detectable changes, at 90% confidence level, were 7.05% to 12.96% (Reid et al. 2007b). Subjects performed one practice trial followed by two measured trials of each hop test. The uninjured leg was tested first. The better of the two measured trials was reported as the hop test score. Subjects had to perform a solid landing without excessive balance movements or twisting of the foot to be considered a valid trial. No brace was used during the hop tests. The single hop, triple hop, and triple crossover hop test indexes were expressed as a percentage; (injured extremity result/uninjured extremity result) x 100. The six meter timed hop test index was expressed as; (uninjured extremity result/injured extremity result) x 100 (Fitzgerald et al. 2000a).

Furthermore, the Knee Outcome Survey Activities of Daily Living Scale (KOS-ADLS) (Irrgang et al. 1998c) and the International Knee Documentation Committee Subjective Knee Form (IKDC 2000) (Irrgang et al. 2001c), the global rating of knee function assessed by a visual analogue scale (VAS) (Fitzgerald et al. 2000a), the activity level (Hefti et al. 1993), and the number of episodes of giving-way since the ACL injury were also included as baseline measurements. An episode of giving way was defined as a subluxation event of the knee with pain and subsequent effusion (Fitzgerald et al. 2000a). The KOS-ADLS has shown to be a reliable, valid and responsive instrument for the assessment of functional limitations of the knee (Irrgang et al. 1998b). The KOS-ADLS has shown to have a test-retest reliability coefficient of 0.97, and high internal consistency (coefficient alpha, 0.92 to 0.93) (Irrgang et al. 1998a). Marx et al. (2001) reported an intraclass correlation coefficient (ICC) for KOS-ADLS to be 0.93 in a population of knee injured athletes. The IKDC 2000 has shown internal consistency and test-retest reliability of 0.92 and 0.95, and based on test-retest reliability the value for a true change in the score is 9.0 points (Irrgang et al. 2001b).

The score of KOS-ADLS was expressed as a percentage: $(X/70) \times 100$. X being the sum of points achieved by the patient, and 70 is the total possible number of points for the KOS-ADLS (Irrgang et al. 1998d). A VAS was used to investigate the patients' subjective global rating of knee function, measured on a ten centimeter horizontal line. The patients were instructed to draw a slash on the line indicating their own perception

of knee function with 100 being the patient's level of knee function prior to injury and 0 being the inability to perform any daily activities (Irrgang et al. 1998e). The IKDC 2000 include questions related to present activity level in relation to knee symptoms; pain, stiffness, swelling and instability related to the injured knee. The score of IKDC 2000 was presented as a percentage; $((X-18)/87) \times 100$, where X was the sum of points achieved by the patient (maximum 105) and 18 is the lowest possible sum of points (Irrgang et al. 2001a).

The baseline measurements were carried out in the following order: the single hop, the triple hop, the triple crossover hop, the six meter timed hop, the KT-1000 knee arthrometer measurement, the reported episodes of giving way, the KOS-ADLS, the VAS, and the IKDC2000.

Follow-up examination

Follow-up examination was performed one year after the baseline examination for non-operated individuals, and one year after surgery for individuals who underwent ACL reconstruction during the follow-up period. Outcome measurements at one year follow-up included (1) the four single legged hop tests, (2) the KOS-ADLS, (3) the VAS, (4) the number of episodes of giving way since the screening examination or ACL reconstruction, (5) the IKDC 2000, and (6) the registration of current activity level.

The follow-up measurements were carried out in the following order: the KOS-ADLS, the VAS, the IKDC2000, the single hop, the triple hop, the triple crossover hop, the six meter timed hop, the KT1000 knee arthrometer measurement, and the report of episodes of giving way and current activity level.

Data analysis

Statistical analyses were performed using NCSS97 software (Number Crunches Statistical System, version 2.0.0.406, NCSS, Kaysville, Utah, USA). Mean and SD were calculated for parametrical data and median and 95% confidence intervals were calculated for non-parametrical data. Two sample t-tests were used for comparisons between groups at baseline and to evaluate differences in improvement from baseline to one year follow-up (non-operated subjects versus ACL reconstructed subjects), when normality distribution were presumed for parametrical data. When normality

distribution was rejected and for unequal sample size (subjects who had returned to pre-injury activity level versus subjects who had not returned to pre-injury activity level) Mann-Whitney U tests were used for group comparisons. One-sample t-tests were used for comparisons between baseline data and the one year follow-up data, but for changes in activity level from baseline to the one year follow-up Wilcoxon Signed-Rank Test for differences was used. GLM ANOVA was used for comparison between non-operated and ACL reconstructed subjects at the one year follow-up by including baseline data as covariates to adjust for significant differences at baseline. Alpha level was set at 0.05.

RESULTS

At baseline there were 45% (n=56) females, and 55% (n=69) males included. Mean age at time of injury was 27.2 years (± 8.6 years), and baseline examination was performed at a mean of 82 days (± 37 days) subsequent to ACL injury. Sixty-eight percent (n=85) of the subjects performed level I activities pre-injury, while 32% (n=40) performed level II activities. One-hundred-and-two subjects were included at follow-up. Among the 102 subjects, 51% (n=52) had undergone non-operative treatment, while 49% (n=50) were ACL reconstructed. A flowchart is provided in Figure 1 to visualize the distribution of subjects throughout the study.

Results from the baseline examination showed that the subjects who underwent non-operative treatment were significantly older and had significantly less episodes of giving way, compared to subjects who had undergone ACL reconstruction (Table 2). Subjects who continued through non-operative treatment performed significantly better at the triple crossover hop test and the 6 meter timed hop test, the VAS and the IKDC 2000 at baseline examination compared to subjects who subsequently underwent ACL reconstruction (Table 2). The post-injury MRI from the 125 included subjects showed that 16% (n=20) had medial meniscus injury, 15% (n=19) had lateral meniscus injury, and 9% (n=11) had minor pathological findings in the cartilage of the lateral femurcondyle. Included in these numbers are two subjects who had described both medial and lateral meniscus injury, of whom one continued through non-operative treatment and one through ACL reconstruction.

Among the 52 subjects who underwent non-operative treatment, the post-injury MRI showed that 12% (n=6) had medial meniscus injury, 6% (n=3) lateral meniscus injury, and 8% (n=4) minor pathological findings in the cartilage of the lateral femurcondyle. Among the 50 subjects who underwent ACL reconstruction the post-injury MRI showed that 20% (n=10) had medial meniscus injury, 14% (n=7) had lateral meniscus injury, and 6% (n=3) had minor pathological findings in the cartilage of the lateral femurcondyle. There were no statistical differences between subjects who continued non-operative treatment or ACL reconstruction with regard to the post-injury MRI findings for medial meniscus (p=0.26), lateral meniscus (p=0.17), medial cartilage (p=0.31) or lateral cartilage (p=0.42) injuries. With respect to the inclusion criteria all additional injuries described from the MRI were regarded as asymptomatic at the time of baseline examination.

Follow-up

The 52 non-operated subjects performed follow-up examination at a mean of 404 days (± 66 days) after baseline examination. No surgical procedures were performed in the non-operated group from baseline to follow-up. The 50 ACL reconstructed subjects had surgery at a mean of 184 days (± 91 days) after injury, and performed follow-up examination at a mean of 380 days (± 45 days) after ACL reconstruction. Among the ACL reconstructed subjects 80% (n=40) were reconstructed with multistrand hamstrings graft, and 20% (n=10) with bone-patellar tendon-bone graft. Surgical records from the ACL reconstructed subjects documented that 24% (n=12) had medial meniscus injury, of which surgical partial resection was performed on 75% (n=9), and 30% (n=15) had lateral meniscus injury of which surgical partial resection was performed on 53% (n=8). Three cases of minor medial femurcondyle and three cases of minor lateral femurcondyle cartilage injuries (grade I-II) were registered. No cartilage surgical procedures were performed.

When adjusted for the differences at the baseline examination the non-operated subjects had significantly better performance on the single and triple hop tests compared to the ACL reconstructed subjects at the one year follow-up examination (Table 3). ACL reconstructed compared to non-operated subjects had significantly higher improvement

from baseline to one year follow-up at the IKDC 2000 (21.6 versus 14.2, $p=0.01$) and the VAS (33.4 versus 20.1, $p<0.01$). There were no significant differences in improvement between the two groups for the other variables from baseline to one year follow-up.

Sixty-nine percent ($n=36$) of the non-operated subjects had returned to pre-injury activity level, while 70% ($n=35$) of the ACL reconstructed subjects had resumed their pre-injury activity level. Although a majority of subjects had resumed their pre-injury activity level at the one year follow-up, both groups had significantly lowered their activity level (non-operated $p=0.01$, and ACL reconstructed $p<0.01$). Forty percent (12/30) of the non-operated subjects with pre-injury activity level I had lowered their activity level, while 22% (4/22) with pre-injury activity level II had lowered their activity level. The corresponding percentages for ACL reconstructed subjects who had lowered their activity level were 32% (12/38) from level I and 25% (3/12) from level II. Non-operated subjects who had resumed pre-injury activity level had significantly better results on the IKDC 2000, the KOS-ADLS and less episodes of giving way compared to those that had not resumed pre-injury activity level at the one year follow-up. There were no differences in performance for any of the four single legged hop tests between the two groups (Table 4). ACL reconstructed subjects who had resumed pre-injury activity level had significantly better IKDC 2000 score than those that had not resumed pre-injury activity level at the one year follow-up. No other differences were observed (Table 5). For the non-operated group as well as the ACL reconstructed group, there were no statistical differences for any outcome measurements at the baseline examination between subjects who had resumed pre-injury activity level at the one year follow-up and those who had not resumed pre-injury activity level at the one year follow-up.

DISCUSSION

The primary purpose of this investigation was to compare the functional outcome in ACL injured subjects who had undergone non-operative treatment to subjects who had undergone ACL reconstruction. Our first hypothesis was not supported since non-operated subjects performed significantly better on two out of four single legged hop

tests (single- and triple hop) compared to the ACL reconstructed subjects. No other differences were found between the two groups at the one year follow-up. Significant differences between groups at baseline were adjusted by including the baseline values as covariates in the GLM ANOVA analysis of the results from the one year follow-up. Due to the significant differences at baseline the results also showed that ACL reconstructed subjects had a significant higher improvement for IKDC 2000 and VAS from baseline to one year follow-up. No differences in improvement between groups were found on the performance based single legged hop tests.

The high incidence of ACL injuries in the physical active population impose high monetary costs on the society (Arendt et al. 1999a, Shea et al. 2004), in addition to the short term impairments and possible long term disability for individuals suffering an ACL injury. Recent publications provide evidence that the incidence of knee OA is similar in ACL reconstructed individuals and individuals treated non-operatively (Lohmander et al. 2004a, von Porat A. et al. 2004a, Kostogiannis et al. 2007c). Despite the vast amount of published scientific papers on treatment after ACL injury, to our knowledge no randomized study exist comparing non-operative treatment to ACL reconstruction subjects treated with current surgical techniques. One randomized study with long-term follow-up (Meunier et al. 2006) has reported no differences in functional outcome or risk of knee OA between patients treated with primary ACL repair or ACL reconstruction, and non-operative treatment. However, one third of the non-operated subjects included had to undergo ACL reconstruction due to instability, and they had an increased risk of secondary meniscus injury.

The present study describes the functional outcome at one year follow-up for ACL injured patients who have undergone the treatment algorithm followed by our institution. Both the non-operated and the ACL reconstructed group were well functioning at the one year follow-up with IKDC 2000 scores above 86%, KOS-ADLS above 92%, and global knee function above 85 (Table 3). According to IKDC normative scores from Anderson et al. (2006) the subjects in the present study show near normal knee function. We have found only one study with comparable performance based functional outcomes and a follow-up time of a minimum of one year (Laxdal et al. 2005a), in which 948 ACL reconstructed patients had a single hop test result of median 95%. Gustavsson et al (2006) reported that only 10% of non-operated

(11 months post injury) and ACL reconstructed subjects (6 months post surgery) displayed hop test performance >90% of their uninjured leg. The research group from the University of Delaware reported that a small population of 11 subjects who had undergone perturbation training performed symmetrically on single legged hop tests six months after injury (Fitzgerald et al. 2000b). Keays et al. (2003c) reported single hop and triple hop for distance of 88.0% and 89.6% compared to the uninjured side six months after ACL reconstruction. Results from the present study indicated that a majority of subjects who undergo non-operative treatment after ACL injury may be able to regain their functional stability and continue to be physical active without ACL reconstruction following our treatment algorithm.

In the present study there were no statistical differences in the incidence of meniscus injuries from the post-injury MRI between subjects who continued through non-operative treatment or ACL reconstruction. The total incidence of meniscus injuries from the post-injury MRI scans were 31%, which is in the lower part of the variations from 16% to 82% reported in the literature (Jones et al. 2003). However, those subjects who had symptomatic meniscus injuries or other indications for subacute surgical intervention were excluded from this study in accordance with the exclusion criteria described in the material and methods section. Considering the design of this study, without arthroscopic evaluation of the non-operated subjects, we do not have data to compare the incidence of meniscus injuries between the non-operated and ACL reconstructed subjects at the one year follow-up. Among the 50 subjects who underwent ACL reconstruction partial medial meniscus resection was performed on 18% (n=9), while lateral partial resection was performed on 16% (n=8). MRI has shown significantly decreased sensitivity for detecting meniscus tears in the presence of an ACL tear (Stevens & Dragoo 2006), probably because the forces involved in the ACL injury produces meniscus injuries that are difficult to detect on MRI and have a healing potential (Jones et al. 2003). The surgical records from the present study show that only 53% of the lateral meniscus injuries described from MRI needed surgical intervention in the 50 ACL reconstructed subjects, and no meniscus surgeries have been performed in the 52 non-operated subjects during the 12 months following the baseline examination. Kartus et al. (1999) reported that the incidence of re-operations after ACL

reconstruction were 26.7%. The follow-up time in the present study is not sufficient to draw any conclusions on the risk factors for re-operations after ACL reconstruction or the incidence of meniscus or cartilage injuries in the investigated population. Tandogan et al. (2004) reported that the risk of sustaining a medial meniscus injury was 2.2 times higher in years 2 to 5 after injury and 5.5 times higher >5 years after injury compared to the first year after the ACL injury in ACL deficient subjects, which indicate that the present population should be re-examined at least five years after the initial injury.

A limitation in this study is the lack of treatment randomization and controlled rehabilitation. Randomization to non-operative or operative treatment for ACL injured subjects is hard. We assumed that it would be difficult to recruit young and highly active patients in the study if randomization of treatment had been part of the methodology in the investigation. Due to the design there were some differences between the groups who continued through non-operative and surgical treatment. The baseline results showed that subjects who continued through non-operative treatment were significantly younger, had borderline significant lower pre-injury activity level, and performed significantly better on the triple crossover hop for distance test and the six meter timed hop test compared to subjects who subsequently had their ACL reconstructed. They also reported less episodes of giving way, better global rating of knee function and had a significantly higher IKDC 2000 score. Although this limits the conclusions that may be drawn from this study, it nevertheless reflects the clinical challenges met by orthopaedic surgeons, physical therapists and patients after ACL injury with regard to predicting who will succeed following non-operative treatment or ACL reconstruction. Another limitation is the lack of MRI or arthroscopy at follow-up to evaluate the intraarticular cartilage and meniscus injuries. Furthermore, quadriceps muscle strength has shown to be important as an outcome measurement in prospective studies on ACL injured subjects (Snyder-Mackler et al. 1995, Beynon et al. 2002, Keays et al. 2003b, Tadokoro et al. 2004, Trees et al. 2005, Williams et al. 2005). We did not have muscle strength testing equipment available at the start of this study. Future studies should include muscle strength testing both at baseline and as an outcome measurement at follow-up.

The second aim of this study was to compare the functional outcome between subjects who succeed in returning to pre-injury activity level after non-operative or surgical treatment to those subjects who did not return to pre-injury activity level. The second hypothesis was supported as the results showed that subjects who had returned to their pre-injury activity level scored significantly higher on some variables compared to subjects who had not returned to their pre-injury activity level at the one year follow-up (table 4 and 5).

Non-operated subjects who had returned to their pre-injury activity level had significantly higher scores on the IKDC 2000 and the KOS-ADLS, and significantly less episodes of giving way compared to non-operated subjects who had not returned to their pre-injury activity level at the one year follow-up. But, there were no statistical differences for any of the performance based functional single legged hop tests between those who returned to their pre-injury activity level and those who did not. Comparing the ACL reconstructed subjects who returned to their pre-injury activity level to those who did not, the IKDC 2000 showed a significant higher score for those who had returned ($p=0.04$). There were no other differences for any of the performance based functional hop tests between ACL reconstructed subjects who had resumed pre-injury activity level compared to those that had not at the one-year follow-up.

Among the non-operated subjects 69% had returned to their pre-injury activity level at the one year follow-up, which is high compared to previous reports (Andersson et al. 1991, Engstrom et al. 1993, Bak et al. 1997, Scavenius et al. 1999b). There were higher percentages of subjects who had lowered their activity level from level I to level II, than from level II to level III at the one year follow-up in both the non-operated and the ACL reconstructed group. Although this study does not provide information on the specific reasons why subjects had not returned to their pre-injury activity level, one may assume that there are several adapters among non-operated and ACL reconstructed subjects. It is intriguing to theorize when we use the short term return to sport as a success criterion, there probably is a number of adapters among those who fail to return to pre-injury activity level. The literature on knee OA after ACL injury suggest that continuing high level sports after ACL injury increases the risk of long term OA, which makes it possible that the population of adapters reduce their risk of knee OA development – regardless of treatment method (Roos et al. 1995b, Segawa et al. 2001a, von Porat A. et

al. 2004d, Kostogiannis et al. 2007b). The results of the present study support previous reports which state that single legged hop tests alone are not valid as discriminating tests for return to sport activities after ACL reconstruction (Noyes et al. 1991a, Reid et al. 2007a).

The average scores at the one year follow-up for both non-operated and ACL reconstructed subjects in this study were above 90% for all the four performance based single legged hop tests, which in the literature is considered normal knee function (Kvist 2004, Myer et al. 2006b). Ten to fifteen percent difference between injured and non-injured leg for single legged hop tests have been considered return to sport criteria in recent reports (Keays et al. 2003a, Kvist 2004, Myer et al. 2006a). The results of the present study challenge the use of functional performance based hop tests as criteria for a safe return to sport, as the subjects who did not return to sport performed equal for all four single legged hop tests compared to those who did return to sport in ACL reconstructed subjects as well as non-operated subjects. Other significant subjective factors should also be considered; the long and strenuous rehabilitation, social and family situation, professional advice from physicians or physical therapists, adaptation to a lower activity level or fear of re-injury or the surgical process (Nyland et al. 2002, Kvist et al. 2005, Thomee et al. 2006, Button et al. 2006b, Heijne et al. 2007). Among the ACL reconstructed subjects in this study 70% returned to their pre-injury activity level, which is in the higher region of what has been reported in comparable studies on ACL reconstructed subjects (Feller & Webster 2003, Myklebust et al. 2003, Smith et al. 2004a, Myklebust & Bahr 2005a, Kostogiannis et al. 2007a).

Subjects who were treated with ACL reconstruction were significantly younger and, although borderline statistically significant, had a higher pre-injury activity level compared to those who continued through non-operative treatment (Table 2). The results may indicate that active young individuals are more susceptible to succeed after ACL reconstruction than older subjects (Table 5), when the criterion for success is return to pre-injury activity level. The relatively small population of ACL reconstructed subjects who did not return to pre-injury activity level makes it appropriate to point out the possibility of a type II statistical error with regard to the borderline significant result for this outcome.

The results from this study showed that our treatment algorithm resulted in successful outcome for a majority of the non-operated and the ACL reconstructed subjects at one year follow-up. We will continue to advocate that ACL injured patients should be informed and given the possibility of non-operative treatment as an alternative to ACL reconstruction, provided that they perform well on single legged hop tests, IKDC 2000 and has avoided giving way episodes. Future prospective studies should include outcome variables related to why individuals do not return to their pre-injury activity level – whether it is knee related or not. Additionally, long-term prospective studies including performance based functional outcomes are needed to predict the outcome of treatment decisions, and to establish functional criteria in the guidance of treatment of ACL injured subjects.

PERSPECTIVES

This study provides new knowledge on knee function for ACL injured subjects after non-operative treatment. The majority of ACL injured subjects treated non-operatively resumed good knee function and returned to pre-injury activity level one year after ACL injury. Performance based outcome measurements and the number of subjects who returned to pre-injury activity level was similar for non-operative and operative treated ACL injured subjects. Subjects with the highest pre-injury activity level had a higher percentage of not returning to pre-injury activity level. We suggest that patients suffering from an ACL injury should be informed of the possibility of success from non-operative treatment and rehabilitation with regard to knee function. Young subjects performing at the highest activity level (level I) seem to be more susceptible to undergo and succeed from ACL reconstruction. Further research on valid and predictive functional criteria for successful treatment strategies after ACL injury should be continued.

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Table 1 Activity level classification (Hefti et al. 1993). Modified to European sport activities

Level	Sports Activity	Occupation activity
I	Jumping, Cutting, pivoting (Soccer, Team Handball, Basketball, Floorball)	Activity comparable to Level 1 sports
II	Lateral movements, less pivoting than Level 1 (Racket sports, Alpine skiing, Snowboarding, Gymnastics, Aerobics)	Heavy manual labour, 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 Baseline results for subjects who underwent non-operative treatment versus subjects who underwent ACL reconstruction (ACLR), mean (\pm SD)

	Baseline Non-operated (n=52)	Baseline ACLR (n=50)	p-value
Age (years)	30.0 (\pm 9.1)	25.9 (\pm 8.2)	0.04
Pre-injury activity level	1(1-2)*	1(1-1)*	0.051
KT-1000 (mm difference)	6.9 (\pm 3.8)	6.9 (\pm 3.3)	0.41
Time from injury (days)	82.6 (\pm 39.9)	80.4 (\pm 39.8)	0.77
Single hop (% of uninjured)	88.0 (\pm 11.7)	82.7 (\pm 14.9)	0.07
Triple hop (% of uninjured)	87.9 (\pm 10.8)	84.9 (\pm 12.1)	0.30
Triple crossover hop (% of uninjured)	89.7 (\pm 11.4)	83.6 (\pm 13.2)	0.02
Six meter timed hop test (% of uninjured)	93.0 (\pm 10.8)	86.6 (\pm 12.1)	0.01
KOS-ADLS	89.1 (\pm 9.6)	83.8 (\pm 14.4)	0.13
Global rating of knee function (VAS 0-100)	66.0 (\pm 19.8)	51.8 (\pm 22.5)	<0.01
IKDC 2000	73.4 (\pm 10.4)	63.7 (\pm 15.2)	<0.001
Episodes of giving way	0 (0-1)*	1 (1-2)*	<0.01

* median (95% confidence interval)

Table 3 Non-operated subjects versus ACL reconstructed (ACLR) subjects at follow-up, mean (\pm SE)

	Follow-up Non-operated (n=52)	Follow-up ACLR (n=50)	p-value
Activity level at follow-up	2 (1-2)*	1 (1-2)*	0.15
KT-1000 (mm difference)	7.6 (\pm 0.5)	4.1 (\pm 0.7)	<0.001
Single hop (% of uninjured)	95.9 (\pm 1.4)	91.8 (\pm 1.4)	0.048
Triple hop (% of uninjured)	95.5 (\pm 1.1)	91.4 (\pm 1.2)	0.01
Triple crossover hop (% of uninjured)	95.4 (\pm 1.1)	93.5 (\pm 1.2)	0.24
Six meter timed hop test (% of uninjured)	96.2 (\pm 0.9)	94.2 (\pm 1.0)	0.14
KOS-ADLS	94.4 (\pm 0.9)	92.5 (\pm 0.9)	0.14
Global rating of knee function (VAS 0-100)	85.3 (\pm 1.8)	86.0 (\pm 1.8)	0.78
IKDC 2000	86.1 (\pm 1.6)	87.0 (\pm 1.7)	0.73

* median (95% confidence interval)

Table 4 Non-operated subjects who returned to pre-injury activity level versus subjects who did not return to pre-injury activity level, median (95% confidence interval)

	Return to pre-injury activity level (n=36)	Did not return to pre-injury activity level (n=16)	p-value
Age (years)	30.5 (28-34)	29.0 (22-31)	0.10
Pre-injury activity level	1.5 (1-2)	1 (1-1)	0.10
Activity level at follow-up	1 (1-2)	2 (2-2)	<0.001
KT-1000 (mm difference)	6 (4-8)	7 (5-9)	0.16
Single hop (% of uninjured)	97.1 (94.0-99.3)	96.0 (88.9-98.7)	0.19
Triple hop (% of uninjured)	96.2 (94.3-98.6)	95.7 (92.2-97.7)	0.52
Triple crossover hop (% of uninjured)	95.9 (94.0-96.9)	98.2 (93.3-100.3)	0.18
Six meter timed hop test (% of uninjured)	96.0 (94.7-100.0)	100.0 (94.4-100.0)	0.93
KOS-ADLS	97 (96-100)	92 (87-97)	<0.01
Global rating of knee function (VAS 0-100)	92 (87-94)	85 (68-95)	0.07
IKDC 2000	91 (89-94)	83 (71-86)	<0.001
Episodes of giving way	0 (0-0)	1 (0-2)	<0.001

Table 5 ACL reconstructed subjects who returned to pre-injury activity level versus subjects who did not return to pre-injury activity level, median (95% confidence interval)

	Return to pre-injury activity level (n=35)	Did not return to pre-injury activity level (n=15)	p-value
Age (years)	23.0 (19-26)	27 (25-35)	0.06
Pre-injury activity level	1.1 (1-1)	1 (1-1)	0.67
Activity level at follow-up	1 (1-1)	2 (2-2)	<0.001
KT-1000 (mm difference)	3 (2-4)	2 (1.5-5)	0.50
Single hop (% of uninjured)	95.9 (88.7-100.0)	91.2 (80.3-95.8)	0.12
Triple hop (% of uninjured)	94.1 (91.8-97.0)	89.7 (84.3-94.8)	0.08
Triple crossover hop (% of uninjured)	96.1 (91.6-100.0)	89.8 (83.2-98.3)	0.07
Six meter timed hop test (% of uninjured)	95.0 (94.1-100.0)	93.8 (88.9-94.7)	0.28
KOS ADLS	94 (91-97)	94 (86-99)	0.81
Global rating of knee function (VAS 0-100)	88 (80-93)	83 (76-95)	0.79
IKDC 2000	90.8 (86.2-93.1)	83.9 (70.1-92.0)	0.04
Episodes of giving way	0 (0-0, min 0, max 0)	0 (0-0, min 0, max 2)	0.13

Figure 1 Flowchart visualizing subjects throughout the study

