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15-year Follow-up of Neuromuscular Function in Individuals with Unilateral Non-reconstructed ACL Injury Initially Treated with Rehabilitation and Activity Modification: A Longitudinal Prospective Study

***Running title*: 15-year Follow-up of Neuromuscular Function after ACL Injury**

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Abstract

Background: It has been suggested that neuromuscular function is of importance in the overall outcome after ACL injury.

Hypothesis: Good neuromuscular function can be achieved and maintained over time in subjects with ACL injury, treated with rehabilitation and activity modification, but without reconstructive surgery.

Study Design: Case series

Methods: One hundred consecutive patients (42 women and 58 men) with acute ACL injury at a non-professional, recreational or competitive, activity level were assessed 1, 3 and 15 years after injury. Their mean age at inclusion was 26 years (range 15 to 43). All patients initially underwent rehabilitation and were advised to modify their activity level, especially by avoiding contact sports. Patients with recurrent giving-way episodes and/or secondary meniscus injuries that required fixation, were subsequently excluded and underwent reconstruction of the ACL. Sixty-seven patients (71%) with unilateral non-reconstructed injury remained at the 15-year follow-up. Fifty-six of these 67 patients were examined with the one-leg hop test for distance and knee muscle strength. The Limb Symmetry Index (LSI), i.e., dividing the result for the injured leg by that of the uninjured leg and multiplying by 100, was used for comparisons over time (paired t-test).

Results: The LSI for the one-leg hop test was higher at the 3-year (mean 98.5%, SD 7.6%) than at the 15-year follow-up (mean 94.8%, SD 10.5%) (mean difference -3.7%, 95% CI -6.1% to -1.2%, P=0.004). The LSI for isometric extension was higher at the 15-year (mean 97.2%, SD 13.7%) than at the 1-year follow-up (mean 88.2%, SD 15.4%) (mean difference 9.0%, 95% CI 3.7% to 14.4%, P=0.001). At the 15-year follow-up, between 69% and 85% of the patients had an LSI ≥90%.

Conclusions: Good functional performance and knee muscle strength can be achieved and maintained over time in the majority of patients with ACL injury treated with rehabilitation and early activity modification, but without reconstructive surgery.

Key Terms: Anterior cruciate ligament, rehabilitation, neuromuscular function, follow-up studies

INTRODUCTION

ACL injuries are common with a yearly incidence of 0.81 per 1000 inhabitants aged 10 to 64 years [13]. Rehabilitation is normally included in the treatment after injury or reconstruction of the ACL [27]. Despite the fact that surgical treatment is widely used, there is still no evidence as to whether surgical or non-surgical treatment is best for these patients [20]. It is, however, well known that the risk of future joint problems, in the form of functional limitations, secondary lesions, and osteoarthritis (OA), is increased following such an injury [11, 29].

Neuromuscular function is the complex interaction between sensory and motor pathways. Defective neuromuscular function, leading to reduced strength and functional performance, alterations in movement and muscle activation patterns, proprioceptive deficiencies, and impaired postural control, is commonly seen after an ACL injury [1]. Improvements in neuromuscular function can be achieved by appropriate rehabilitation [19, 27]. It has been suggested that neuromuscular function is of importance for the overall outcome after ACL injury [10], and that long-term follow-up studies are needed in order to establish the role of neuromuscular function in future joint problems after knee injury [29]. However, to our knowledge, there are few prospective, longitudinal, long-term follow-up studies on patients with ACL injury, treated with or without reconstructive surgery, where measures of neuromuscular function are included [22, 32]. Only one of these studies reports comparisons over time [32].

The aim of the present study was to evaluate functional performance and knee muscle strength at 15 years compared with 1 and 3 years after the initial injury in subjects with unilateral non-reconstructed ACL injury. Forty-two women and 58 men (mean age 26 years, range 15 to 43) at a non-professional, recreational or competitive, activity level (i.e., patients on a professional athletic level were excluded) were included in the study 15 years ago. The patients were initially treated with rehabilitation and advice regarding activity modification. Those with recurrent giving-way and/or secondary meniscus injuries that required fixation, were subsequently excluded from the study and underwent reconstruction of the ACL [40]. At the 15-year follow-up, 67 subjects (71%) still had a unilateral non-reconstructed ACL injury, and the majority of these individuals had a good knee function and an acceptable activity level [18]. In the present study, we hypothesized that good functional performance and knee muscle strength could be achieved and maintained over time in the majority of the subjects with unilateral non-reconstructed ACL injury.

SUBJECTS AND METHODS

Patients

Between the years 1985 and 1989, 200 patients presenting with an acute knee sprain combined with hemarthrosis and/or instability at manual testing were referred, within 5 days, by the emergency unit at the [redacted] University Hospital for further evaluation by the same orthopedic surgeon ([redacted]) specializing in knee injuries. Patients presenting at times when this physician was off-duty (n=100) were not included in the study. Inclusion criteria when the patients entered the study 15 years ago were: 1) age between 15 and 45 years, 2) acute knee trauma to a previously normal knee, with complete ACL rupture, with or without associated lesions of other structures of the knee, and 3) an uninjured contralateral extremity. Patients on a professional athletic level (i.e., a Tegner score of 10) and not willing to accept a decrease in activity level (n<5), those who specifically requested a primary ligament reconstruction (n=2–3), those with fracture seen on radiographs, or those with psycho-social disorders were excluded. The patients' mean age at inclusion was 26 years (range 15 to 43). The cause of injury was ball sports (n=59), alpine skiing (n=30), and other activities (n=11) [43]. The diagnosis was verified in all patients by stability testing and arthroscopy, by the same orthopedic surgeon ([redacted]), within ten days of injury. Meniscal tears were not sutured at the time of this study. Resections were made on menisci with large, unstable lesions whereas smaller or partial tears were left untreated. Collateral ligament lesions were not operated on, and the ACL was not reinserted or reconstructed. A detailed description of the patients' knee injuries (e.g. number of patients with isolated ACL injury, and associated lesions) has been provided in other reports [18, 40, 43].

The patient cohort comprising 100 consecutive patients was followed prospectively at regular intervals for three years [2, 12, 40, 42, 43]. These 100 patients were contacted for a long-term follow-up assessment at a mean of 15 years after the initial injury (SD 1.4 years). Six of these patients were lost to follow-up (four had moved abroad and two did not reply). Sixty-seven subjects (71%) still had a unilateral non-reconstructed ACL injury, 22 (23%) subjects had undergone ACL reconstruction, and 6 (6%) had sustained an ACL injury to the contralateral knee (one of these patients had also undergone reconstructive surgery). The number of patients from initial injury to the 15-year follow-up has been described in detail elsewhere [18]. Fifty-six (20 women and 36 men) of the 67 subjects with unilateral non-reconstructed ACL injury at the 15-year follow-up attended the assessment of neuromuscular function (Figure 1). Five of these 56 subjects (1 woman and 4 men) had radiographic tibiofemoral OA, and 19 (5 women and 14 men) had suffered a major meniscal tear (which had been sutured or resected). The subjects' age, height, weight, and Knee injury and Osteoarthritis Outcome Score (KOOS) [30, 31] at the 15-year follow-up are given in Table 1. Their Tegner activity level [36] and Lysholm knee score [36] at the time of injury (Tegner activity level), and at 1, 3, and 15 years after the injury are given in Table 2. Details on activity level and subjective function have been given elsewhere [18]. The reported decrease in activity level in the long-term perspective (from 6 to 4) may reflect a normal adaptation to older age and changed phase of life [18]. This decrease is comparable to that of a control group of uninjured subjects [4].

Eleven subjects (7 women, 4 men) did not attend the assessment of neuromuscular function due to the following reasons: six subjects had moved from the region, three declined to participate, and two subjects were not able to perform the test due to pregnancy (n=1) or a recently sustained hamstring rupture (n=1). These subjects did not differ from those who attended the assessment of neuromuscular function with regard to age (P=0.17), activity level (P=0.16), Lysholm score (P=0.29) or KOOS (P=0.32 – 0.98).

The Research Ethics Committee of [redacted] University approved the study. All subjects gave their written informed consent to participate in the study.

Treatment algorithm

The aim of the initial treatment was to achieve good knee function without discomfort or lack of confidence in the knee, on a satisfactory activity level from the patient's perspective. The aim was also to reduce the risk of new injuries and degenerative changes in the longer perspective. The treatment algorithm included: 1) non-operative treatment, 2) rehabilitation, 3) advice regarding activity modification, and 4) ACL reconstruction in selected cases; because of giving way, unacceptable activity level, or re-injury resulting in a symptomatic reparable meniscal tear.

Non-operative treatment

The intention was to treat the patients without primary reconstructive surgery. Patients in doubt were actively encouraged not to undergo primary ACL reconstruction.

Rehabilitation

All patients underwent training; randomized to either neuromuscular training supervised by physical therapists specializing in knee injury training, or self-monitored training [43]. The overall aim of both training methods was to regain joint mobility and restore muscle function. The patients were allowed to use crutches as long as necessary because of pain and dysfunction. They were told not to force movements if they caused pain so that the injured knee structures would have time to heal. They were also asked to do exercises daily at home to improve joint mobility and functional stability. The patients were told to contact the physician treating them whenever necessary.

The neuromuscular training method, based on biomechanical and neuromuscular principles, aims to improve neuromuscular control and achieve compensatory functional stability [44]. Physical therapists specializing in knee injury training were in charge of the training sessions. All patients were given information about the function of the ACL, symptoms associated with the injury, the role of the muscles in knee joint stabilization, and advice on how to avoid giving way. Training started within a week of arthroscopy and continued for 5 to 8 months. During the first period after injury, active movements in synergies of all the joints in the injured extremity [26] were included to improve the mobility of the injured knee. The movements started with the uninjured extremity, initiating the normal movement and applying bilateral transfer effect of motor learning to the injured leg [9, 17]. To improve functional stability, movements were performed in closed kinetic chains [21, 24] in different positions (e.g., lying, sitting, standing), to obtain low, evenly distributed articular surface pressure [5, 33] by muscular co-activation [5]. The model emphasized the enhancement of antigravity postural functions of weight-bearing muscles, and the provocation of postural reactions in the injured leg by using voluntary movements in the other lower extremity, trunk, and arms [7, 9]. The goal was to achieve equilibrium of loaded segments in static and dynamic situations without undesirable compensatory movements, with the aim of acquiring postural control in situations resembling conditions of daily life and more strenuous activities. The level of training, progression, and recommended physical activity was guided by the patient's neuromuscular function and not by time after injury. Strength coordination, balance, and proprioception were all included in the movements. To achieve the desired requirement of postural activity, the patients performed the exercises on sloping boards, to obtain axial loading of joints by muscular co-activation. Progression was provided by varying the angles of the sloping board in relation to the gravity line, by varying the number, direction, and velocity of the voluntary movements, and also by training more complex functions, cardiovascular endurance, and sports-specific skills. Training ceased when muscular postural reactions, provoked by voluntary movements, were clinically evaluated as occurring without delay and were the same as those on the uninjured side (based on visual inspection and palpation) [40]. Examples of exercises in this training method have been described by Zätterström et al. [44].

The patients in the *self-monitored training* group were given oral and written instructions by physical therapists at the time of the initial arthroscopic evaluation. The intention regarding this group was to resemble the natural course so far as possible, based on the assumption that patients were able to carry out training on their own without supervision or continuous guidance. Training consisted of traditional exercises (at the time of inclusion in this study) for joint mobility and knee muscles to regain range of motion and muscle strength. Movements were performed in non-weight-bearing positions, training isolated muscles in the injured leg selectively, e.g., knee extensions and straight leg raises. The patients were instructed and encouraged to continue the exercises for up to 12 months [40]. At the six-week follow-up, 49%

of these patients were transferred to the neuromuscular supervised training group because of restricted joint mobility and/or considerable muscle atrophy [40]. Consequently, the majority of the patients underwent neuromuscular supervised training.

Activity modification

Depending on the perceived instability, the patients were advised to modify their physical activities in order to cope with the ACL insufficiency. All patients were advised to avoid contact sports, particularly soccer, basketball and team handball.

ACL reconstruction

Patients with more than one significant re-injury, who would not accept a further prophylactic decrease in activity level, or those with a symptomatic reparable meniscal tear, were advised to undergo ACL reconstruction (n=22). Reconstructed patients were subsequently excluded, since the treatment model without reconstruction had not succeeded, i.e., these patients were regarded as treatment failures [18, 40].

Assessment

One-leg hop test for distance

We used a modified version of the one-leg hop test [35], with the arms free, aiming at a more functional execution of the hop, thus making it easier to balance the body [40]. The subjects were told to hop as far as possible, taking off and landing on the same foot. The test was performed three times with each leg, alternating the right and left leg, the hop distance being measured from toe to toe. A trial one-leg hop preceded the measurements. The subjects wore shoes, e.g., sneakers. The best value of the three hops was used in the analysis. The reliability of this test is high in non-injured subjects (ICC 0.96)[3], (ICC 0.92) [25] and in individuals with ACL injury (ICC 0.89) [25].

Knee muscle strength

Measurements of isometric and concentric isokinetic strength of the knee muscles, used and described previously in this patient group [40], were performed with a Biodex Multi-Joint System II isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, New York, NY, USA) with Biodex Advantage software, version 4.5. The Biodex dynamometer has been shown to be reliable (ICCs > 0.90) and valid [34, 37]. The standard Biodex knee unit attachment was used. Subjects were placed in an upright position with 90º hip flexion on the Biodex dynamometer chair, and were secured with straps across the chest, pelvis, thigh and ankle. The resistance pad was placed as distally as possible on the tibia while still allowing full dorsiflexion at the ankle. The center of motion of the lever arm was aligned as accurately as possible with the slightly changing flexion-extension axis of the knee joint. The subjects gripped the edge of the chair in order to stabilize the body during the test. Standardized verbal instructions and encouragement were given. The subjects were allowed trial tests in order to familiarize themselves with the equipment and the test procedure. Measurements of isometric muscle strength were followed by isokinetic muscle strength testing. *Isometric muscle strength test:* With the knee in 60º flexion, three maximum isometric contractions of the knee extensors and flexors were performed. The contraction time and relaxation time were both 5 seconds. Peak torque (Nm) was used in the analysis. *Isokinetic muscle strength test:* The isokinetic concentric knee muscle strength was measured by 40 consecutive maximal reciprocal contractions at an angular velocity of $90^{\circ}\cdot s^{-1}$. The range of motion of the knee joint was defined as 0 to 100º. Peak torque and total work (Nm or J) were used in the analysis.

Statistical analysis

Since factors other than the knee injury may affect muscle strength and hop distance over a period of several years, such as age and/or a decrease in activity level, comparisons of absolute values were deemed not to be appropriate. Moreover, the Cybex II device, which was used at the 1- and 3-year follow-ups [40], was no longer available at the 15-year follow-up. The fact that different isokinetic devices were used at the follow-ups also makes comparisons of absolute values over time inappropriate. Therefore, to reduce the effect of confounding factors in the analysis, the Limb Symmetry Index (LSI), i.e., dividing the result for the injured leg by that of the uninjured leg and multiplying by 100, was used for comparisons over time. An LSI greater than or equal to 90% for an individual was considered normal [8, 23].

The primary comparison over time was between the 1- and the 15-year follow-ups, since active training may be needed up to 1 year (or less) after the injury [28, 40], and since it has been suggested that the maximum capacity of knee function is reached about 1 year after injury/reconstruction and training [10]. However, improvements in neuromuscular function have been observed up to 18 months or more after injury [16, 28, 39, 41]. For this reason, we also analyzed the LSI between the 3- and the 15-year follow-up, to elucidate whether improvements at median term follow-up were maintained at long-term follow-up. The primary outcome was the LSI for the one-leg hop test, where a 5% difference was considered clinically relevant. A sample size calculation estimated that at least 38 patients would be required to show a 5% difference in LSI between the 1- and the 15-year follow-up for the one-leg hop test (SD_{diff} 11.0) with 80% power at the 5% significance level.

No differences were observed in LSI values between men and women or between the training groups (according to the initial randomization, i.e., intention-to-treat). There were too few patients with OA (n=5) to permit comparisons of LSI values between those with and without OA. Subgroup analysis was performed regarding LSI values at the 15-year follow-up in patients with and without major meniscal tear.

The paired t-test was used for the intra-group comparisons, and the independent t-test for the inter-group comparisons. A level of $P \leq 0.05$ was chosen to indicate statistical significance.

RESULTS

One-leg hop test for distance

Mean (SD), LSI, and mean differences (95% CI) between follow-ups are given in Table 3. Mean LSI values at the follow-ups were greater than 94%. The LSI was higher at the 3-year follow-up than at the 15-year follow-up (P=0.004) (Table 3). The number of subjects with normal LSI, i.e., ≥90%, was 40 (77%) at the 1-year follow-up, 46 (89%) at the 3-year follow-up, and 44 (85%) at the 15-year follow-up (Figure 2). No differences were observed between the patients with and without meniscal tear at the 15-year follow-up.

Knee muscle strength

Mean (SD), LSI, and mean differences (95% CI) between follow-ups are also given in Table 3. Mean LSI values for the various measurements ranged from 88.2% (SD 15.4%) to 100.6% (SD 30.8%) at the 1-year follow-up, from 94.6% (SD 20.6%) to 103.0% (SD 25.6%) at the 3-year follow-up, and from 96.5% (SD 15.9%) to 102.2% (SD 14.3%) at the 15-year follow-up. Five LSI values were over 100%; these were all observed in measurements of knee flexor strength (Table 3). The LSI of peak torque isometric extension was higher at the 15-year follow-up than at the 1-year follow-up (P=0.001) (Table 3). The number of subjects with normal LSI generally increased over time (Table 4, Figure 3). The percent of subjects with normal LSI for the various measurements ranged from 42% to 56% at the 1-year follow-up, from 54% to 68% at the 3-year follow-up, and from 69% to 82% at the 15-year follow-up (Table 4). No differences were noted between the patients with and without meniscal tear at the 15-year follow-up.

DISCUSSION

In this prospective longitudinal study, 100 consecutive patients with ACL injury at a non-professional, recreational or competitive, activity level were followed for 15 years. The primary intention was to treat all individuals with rehabilitation, without ACL reconstruction. They were also advised to modify their activities in order to cope with their injury. We hypothesized that with our treatment regimen, the long-term follow-up would reveal: i) a unilateral non-reconstructed ACL injury in the majority of the patients; ii) good objective and subjective knee function and acceptable activity level in the patients with unilateral non-reconstructed ACL injury, and iii) low prevalence of knee OA in this patient cohort. Good subjective knee function and acceptable activity level [18], as well as low prevalence of knee OA (16%; P. Neuman, unpublished data, personal communication) have been reported in these patients at the 15-year follow-up. The main finding of the present study was that good functional performance and knee muscle strength were maintained over the 15-year follow-up in the majority of the patients with unilateral non-reconstructed ACL injury.

Regarding the primary outcome, the one-leg hop test, high mean LSI values (i.e., a small difference in hop distance between the legs) were found at all follow-ups. The LSI was statistically significantly higher at the 3-year follow-up than at the 15-year follow-up (Table 3), which may be interpreted as a decrease in functional performance over time. However, the difference was 3.7%, whereas the pre-defined clinically relevant difference was set at 5%.

Thus, the clinical relevance of this difference can be questioned. In line with our study, Myklebust et al. [22] reported a small difference between the injured and uninjured legs in the one-leg hop test at a long-term follow-up (mean 9.4 years after injury, range 7 to 11 years) of team handball players with and without ACL reconstruction. We found that more than 77% of the patients had a normal LSI, i.e., greater than or equal to 90% (Figure 2), at the follow-ups. At the 15-year follow-up, only 15% of the patients showed abnormal LSI values in the one-leg hop test. Salmon et al. [32] followed 97 patients with ACL reconstruction over 13 years. At 7 and 13 years after surgery, 93% and 66% of the patients, respectively, had normal LSI in the one-leg hop test. Contrary to our results, these authors found a significant deterioration in the one-leg hop test over time [32].

Mean LSI values ranged from 88.2% to 98.6% for the knee extensor muscle strength variables, and from 94.5% to 103.0% for the knee flexor muscle strength variables at the follow-ups. The lower LSI values for the knee extensors than for the knee flexors probably reflect the difficulty in restoring quadriceps muscle strength after an ACL injury [27]. The LSI for peak torque isometric extension was statistically significantly higher at the 15-year than at the 1-year follow-up (Table 3). The difference in LSI was 9% (95% CI 3.7% to 14.4%), which was considered a clinically relevant difference. This result indicates that improvements in muscle strength can be achieved after more than one year, which also has been reported by others [28, 39]. At the 1-year follow-up, about half of the subjects had normal LSI values for knee muscle strength, at the 3-year follow-up more than 50% had normal LSI values, and finally at the 15-year follow-up about 75% of the subjects showed normal LSI values (Table 4). This result reflects improvements in limb symmetry over time in knee muscle strength. The LSI values at the 15-year follow-up are higher than the side-to-side differences in knee muscle strength (total work at $60^{o}\cdot s^{-1}$ and $240^{o}\cdot s^{-1}$) reported in team handball players about 9 years after injury [22], indicating better results in our study. However, since different muscle strength variables were used in these studies, the results are not completely comparable.

The results of high mean LSI values at the follow-ups, the majority of the patients showing normal LSI, and no deterioration in LSI over time, show that good functional performance, measured by the one-leg hop test for distance, and good knee muscle strength can be achieved and maintained over time. From the results of the present study, and previous results from the same patient cohort [40, 41], we conclude that good neuromuscular function can be achieved in the majority of patients with ACL injury, with neuromuscular rehabilitation and activity modification, without recourse to reconstructive surgery. Since elite athletes (Tegner level 10) and those unwilling to accept a decrease in activity level were excluded from this study, we determine whether that conclusion could be applied to those groups of individuals.

No differences were observed in LSI of the one-leg hop test or knee muscle strength in the subgroup analysis of meniscal tear vs. no meniscal tear. However, previous studies have shown reduced quadriceps muscle strength in patients with meniscal injury [6, 15]. Further studies in a larger group of patients are needed to elucidate the short- and long-term effects of meniscal injury on neuromuscular function. More research is also needed on the role of neuromuscular function in future joint problems, such as OA, after knee injury [29].

At the 15-year follow-up, only 6 patients were lost to follow-up, yielding a 94% return. Seventy-one percent of the subjects had a unilateral non-reconstructed ACL injury, 23% had undergone ACL reconstruction, and 6% had bilateral ACL injuries. Patients undergoing ACL reconstruction were considered as treatment failures and were subsequently excluded. A limitation of our study is that we cannot analyze the effect of surgical intervention in this patient cohort. Randomized controlled trials are needed in order to establish the role of reconstructive surgery in the overall outcome after ACL injury. Such a study is now ongoing [14]. Sixty-seven patients (71%) with non-reconstructed unilateral ACL injury remained at the 15-year follow-up, and 56 (84%) of these were assessed regarding neuromuscular function. However, the eleven patients that did not attend the assessment of neuromuscular function did not differ from those who attended the assessment, with regard to individual factors or subjective function. Thus, the 56 patients appear to be a representative sample of the patients with unilateral non-reconstructed ACL injury.

Another limitation of this study is that no control group of uninjured subjects was included initially and followed prospectively. It has been reported that neuromuscular function is affected in both legs after a unilateral ACL injury [2, 38]. Thus, high LSI values may reflect poor performance in both legs. Therefore, a subject for further study is to compare the patients in the present study with uninjured controls in a cross-sectional design at the 15-year follow-up.

CONCLUSIONS

Good functional performance, measured by the one-leg hop test for distance, and good knee muscle strength can be achieved and maintained over time in the majority of the subjects with unilateral non-reconstructed ACL injury with initial treatment consisting of neuromuscular rehabilitation and activity modification.

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FIGURES

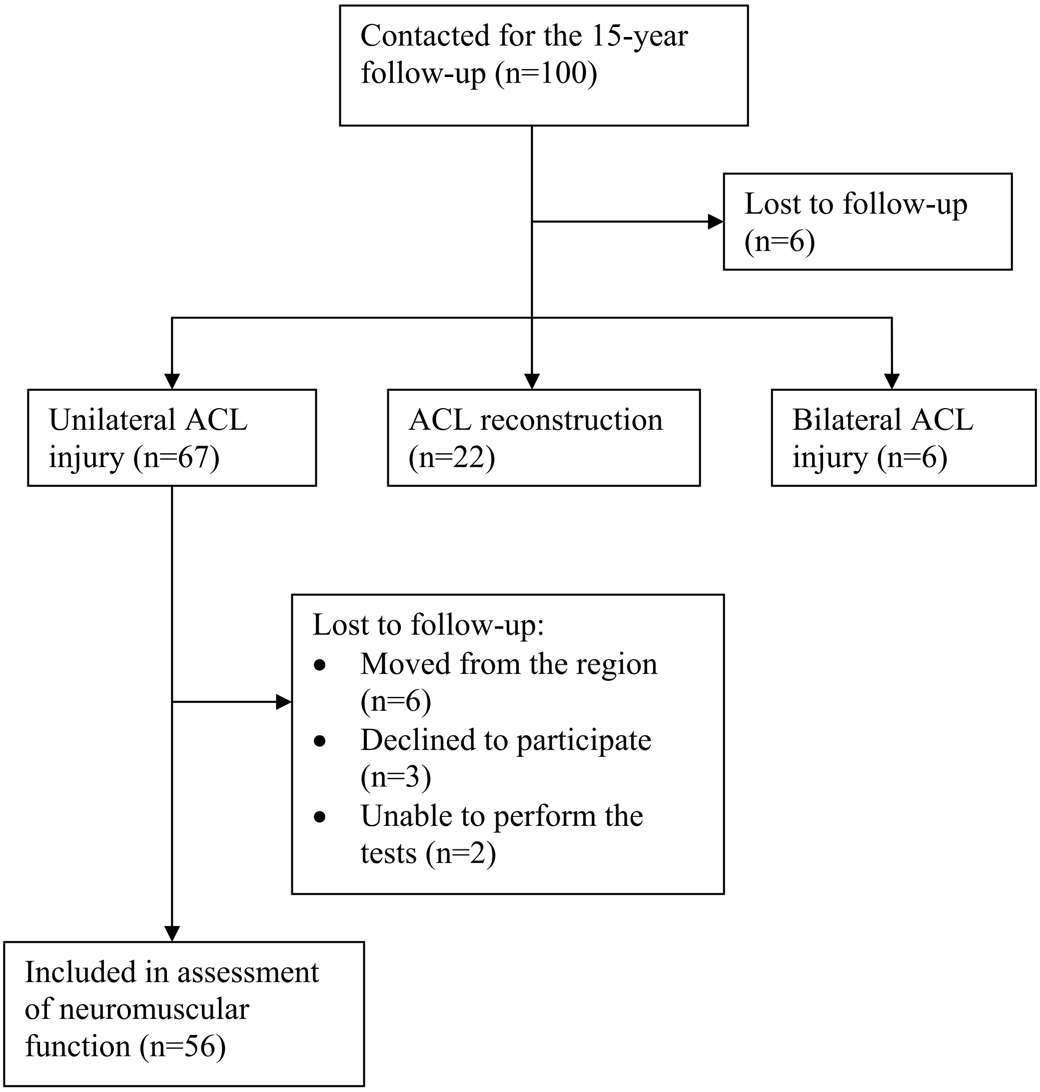

Figure 1. Flow of participants at the 15-year follow-up.
Note: One of the subjects with bilateral ACL injury had also undergone ACL reconstruction.

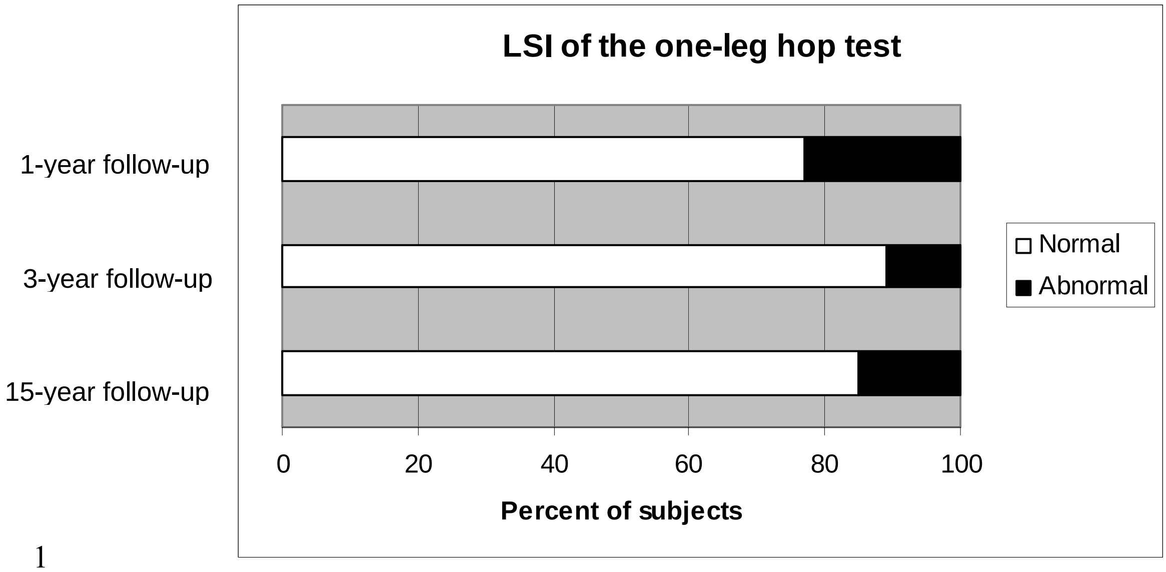

Figure 2. Percent of subjects with normal LSI (≥ 90%) and abnormal LSI (< 90%) in the one-leg hop test at the follow-ups.

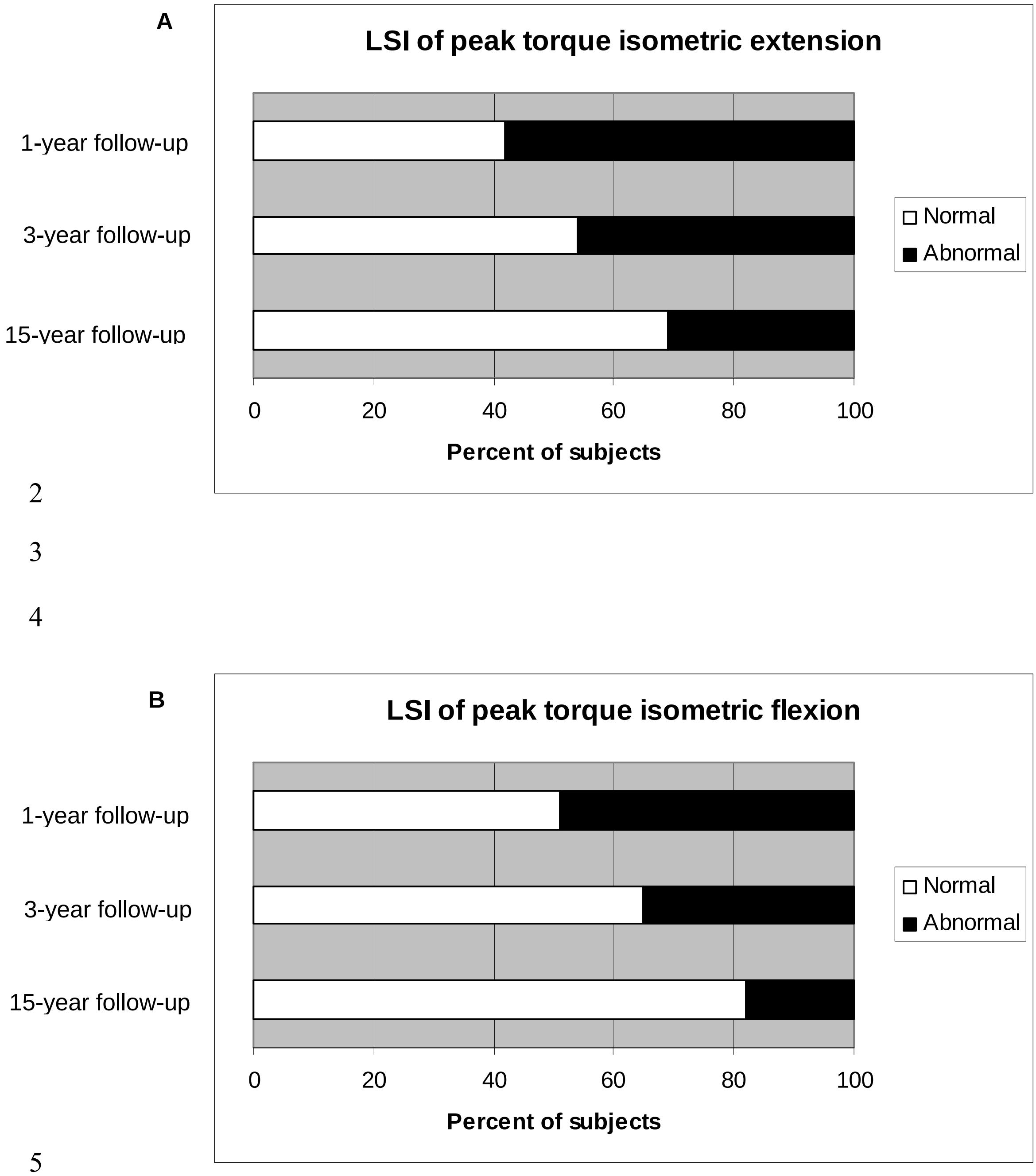

Figure 3. Percent of subjects with normal LSI (≥ 90%) and abnormal LSI (< 90%) in peak torque isometric extension (A) and flexion (B) at the follow-ups.

TABLES

Table 1. Characteristics of the patients at the 15-year follow-up.

Characteristics	**Women** (n=20) Mean (SD)	**Men** (n=36) Mean (SD)	**Total group** (n=56) Mean (SD)
Age (years)	41 (7)	44 (7)	43 (8)
Height (cm)	168 (7)	181 (6)	177 (9)
Weight (kg)	73 (14)	89 (17)	83 (18)
KOOS subscales	Mean (SD), 95%CI	Mean (SD), 95%CI	Mean (SD), 95%CI
Pain	88 (16), 80.1–95.7	93 (12), 88.4–96.6	91 (14), 87.3–94.6
Symptoms	88 (14), 80.8–94.2	89 (16), 83.2–94.0	88 (15), 84.1–92.3
ADL	92 (12), 86.3–98.0	97 (9), 93.5–99.5	95 (10), 92.2–97.8
Sport/Rec	73 (29), 59.3–86.2	79 (24), 71.3–87.4	77 (26), 70.1–83.8
QOL	73 (27), 60.1–85.5	77 (23), 69.7–85.2	76 (24), 69.3–82.3

Table 2. Tegner activity level and Lysholm knee score at the time of injury (Tegner activity level), and at 1, 3, and 15 years after the injury.

	Women (n=20)	**Men** (n=36)	**Total group** (n=56)
Tegner activity level			
Preinjury	6 (4–7)	7 (6–7)	7 (6–7)
1 year	5 (4–6)	6 (5–7)	6 (5–7)
3 years	6 (5–6)	6 (5–7)	6 (5–7)
15 years	3 (2–4)	4 (3–5)	4 (2–5)
Lysholm knee score			
1 year	96 (6)	96 (4)	96 (5)
3 years	95 (8)	96 (8)	96 (8)
15 years	83 (19)	87 (15)	86 (17)

Median (quartiles) is given for Tegner activity level scale. Mean (SD) is given for Lysholm score.

Table 3. Mean (SD) for the one-leg hop test, isometric (peak torque) and isokinetic (peak torque and total work) knee muscle strength (extension, flexion) in the injured (inj) and uninjured (uninj) legs and Limb Symmetry Index (LSI) in percent (%) at the 1-, 3-, and 15-year follow-ups, and mean difference (95% CI) between the 1- and 15-year follow-ups and the 3- and 15-year follow-ups.

	1-year follow-up			**3-year follow-up**			**15-year follow-up**			**Mean difference (95% CI)**	
	Inj leg Mean (SD)	**Uninj leg** Mean (SD)	**LSI** Mean (SD)	**Inj leg** Mean (SD)	**Uninj leg** Mean (SD)	**LSI** Mean (SD)	**Inj leg** Mean (SD)	**Uninj leg** Mean (SD)	**LSI** Mean (SD)	**1- vs. 15-year follow-up**	**3- vs. 15-year follow-up**
One-leg hop test (cm) N=52*	180.8 (39.8)	188.2 (35.1)	95.7 (9.1)	185.6 (39.6)	187.9 (35.0)	98.5 (7.6)	158.2 (36.0)	166.9 (34.0)	94.8 (10.5)	-0.9 (-4.0–2.2)	-3.7 (-6.1– -1.2)
Peak torque isometric ext (Nm) N=52†	159.8 (69.7)	181.6 (73.4)	88.2 (15.4)	174.8 (73.2)	189.5 (80.4)	94.6 (20.6)	239.3 (64.1)	248.4 (64.5)	97.2 (13.7)	9.0 (3.7–14.4)	2.6 (-4.4–9.7)
Peak torque isometric flex (Nm) N=51†	81.9 (32.2)	85.4 (33.1)	100.6 (30.8)	85.4 (37.3)	88.9 (37.9)	97.6 (20.2)	113.9 (30.9)	112.9 (32.9)	102.2 (14.3)	1.6 (-8.3–11.5)	4.6 (-2.5–11.6)
Peak torque isokinetic ext (Nm) N=49†	74.9 (18.7)	81.6 (22.8)	94.1 (16.3)	80.7 (24.5)	83.5 (22.9)	97.9 (19.0)	163.9 (51.9)	171.4 (49.0)	96.5 (15.9)	2.4 (-4.1–8.9)	-1.4 (-8.4–5.7)
Peak torque isokinetic flex (Nm) N=48†	49.3 (19.0)	54.3 (22.6)	95.1 (26.3)	57.7 (21.9)	57.8 (22.3)	103.0 (25.6)	76.1 (24.2)	75.5 (24.5)	101.7 (13.9)	6.6 (-2.4–15.5)	-1.3 (-10.2–7.6)
Total work isokinetic ext (J) N=48†	3178.9 (788.9)	3451.5 (969.6)	94.5 (17.0)	3425.6 (1034.0)	3525.9 (961.9)	98.2 (18.5)	4400.7 (1167.8)	4475.7 (1082.8)	98.6 (13.7)	4.1 (-1.7–9.8)	0.4 (-6.0–6.9)
Total work isokinetic flex (J) N=47†	2078.6 (806.1)	2296.6 (944.3)	94.5 (26.0)	2440.5 (918.9)	2450.3 (929.8)	102.6 (25.8)	2067.9 (672.0)	2057.9 (661.6)	101.8 (19.8)	7.3 (-2.3–16.9)	-0.8 (-9.9–8.2)

* Patients attending all follow-ups are included in the analysis over time. Missing cases are those that did not attend the 1- or 3-year follow-up.
† Patients attending all follow-ups are included in the analysis over time. Missing cases are those that did not attend the 1- or 3-year follow-up or due to equipment problems on the test occasion.

Table 4. Number of subjects (percent) with normal LSI (≥ 90%) and abnormal LSI (< 90%) in the knee muscle strength variables at the follow-ups.

	1-year follow-up	**3-year follow-up**	**15-year follow-up**
	Normal LSI/abnormal LSI n (%)	Normal LSI/abnormal LSI n (%)	Normal LSI/abnormal LSI n (%)
Peak torque, isometric ext (Nm)	22/30 (42/58)	28/24 (54/46)	36/16 (69/31)
Peak torque, isometric flex (Nm)	26/25 (51/49)	33/18 (65/35)	42/9 (82/18)
Peak torque, isokinetic ext (Nm)	27/22 (55/45)	32/17 (65/35)	35/14 (71/29)
Peak torque, isokinetic flex (Nm)	27/21 (56/44)	31/17 (65/35)	38/10 (79/21)
Total work, isokinetic ext (J)	27/21 (56/44)	32/16 (67/33)	37/11 (77/23)
Total work, isokinetic flex (J)	25/22 (53/47)	32/15 (68/32)	35/12 (74/26)