



Muscle recovery at 1 year after the anterior cruciate ligament reconstruction surgery is associated with preoperative and early postoperative muscular strength of the knee extension

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Abstract

Background The anterior cruciate ligament (ACL) injury often occurs in young athletes, but it also occurs in middle-aged individuals and the elderly during recreational sports activities. Clinical outcomes after the ACL reconstruction depend on postoperative recovery of muscular strength. The current study aimed to evaluate the recovery of knee extension and flexion strength after ACL reconstruction surgery and to examine the relationship between preoperative and postoperative muscle strength by age and the type of graft used.

Methods From 2007 to 2010, 32 patients (17 men, 15 women; average age, 31 years; range, 14–66 years) who underwent two-bundle ACL reconstruction surgery using hamstrings, i.e., semitendinous and gracilis tendon (STG) graft, and 25 patients (15 men, 10 women; average age, 28 years; range, 15–59 years) who underwent the ACL reconstruction surgery using bone–patellar tendon–bone (BTB) graft were included in this study. The muscular strength of the knee extension and flexion compared to non-injury side was measured by an isokinetic dynamometer at a velocity at 60°/s preoperatively, and postoperative measurements were performed at 6, 9 months, and 1 year after the ACL reconstruction surgery.

Results Covariates that influenced the outcome of the force of knee extension at 12 months were the preoperative muscular strength [$p=0.045$, odds ratio (OR): 1.105, 95% confidence interval (CI): 1.002–1.219] and muscular strength at 6 months after surgery ($p=0.040$, OR: 1.155, 95% CI: 1.006–1.326). Only muscle strength at 6 months after surgery influenced the outcome of the force of the knee flexion at 1 year after surgery. In sub-analysis, muscular strength of the knee extension and flexion was greater in the STG group than in the BTB group at 6 months after surgery although there was no difference between muscular strength of the knee extension in the STG group and that in BTB group at 1 year.

Conclusions Recovery of knee extension strength at a year after ACL reconstruction was significantly associated with preoperative muscular strength and muscle recovery at 6 months. Age and graft type might be related to the muscle strength recovery. Preoperative and early postoperative strength training could improve the recovery of knee extension strength, which would support an earlier return to sports after ACL reconstruction.

Keywords Anterior cruciate ligament · Reconstruction · Muscle strength · Bone–patellar tendon–bone · Hamstrings

Introduction

There is a high incidence rate of anterior cruciate ligament (ACL) injury among athletes during sports activities [1]. Although sport-related ACL injuries are more common in young athletes, these injuries also do occur in middle-aged and elderly individuals during recreational activities. Currently, ACL reconstruction is indicated for all patients with symptoms of knee instability who participate in high activity level sports, regardless of age [2–5]. The most cases with the ACL injury need over 1 year until return to the sports activity after the ACL reconstruction surgery, and the clinical

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outcome after the ACL reconstruction surgery depends on the patient's age [2–7] and muscle strength recovery [8–13]. Several reports have described *good-to-excellent* clinical and functional outcomes after the ACL reconstruction surgery in patients ≥ 50 years of age [2–5], whereas other reports have described *fairly good* results with conservative treatment in this age [6, 7]. Patients can have muscle weakness after the ACL reconstruction surgery, especially of the quadriceps muscles, which prevents their functional ability [14], and age and muscle strength are associated with each other. Particularly, quadriceps strength is associated with patient's satisfaction and knee function [8, 9].

Although factors such as sex, the type of graft, the duration from injury to surgery, and muscle recovery in the early postoperative phase may affect the clinical results of the ACL reconstruction, several reports also described the effects of preoperative exercise on the outcomes after the ACL reconstruction [11, 13, 15–18]. However, the possible effects of age, sex, and graft type on muscle strength recovery after ACL reconstruction have not been fully clarified. In particular, there was no report comparing surgical procedures of the ACL reconstruction surgery on postoperative recovery of muscle strength. Therefore, the purpose of our study was to evaluate the recovery of knee extension and flexion strength after ACL reconstruction, as a function of age, type of graft, preoperative muscle strength, and early postoperative muscle strength.

Materials and methods

Patients

From 2007 to 2010, 57 patients who underwent ACL reconstruction surgery and followed up until 1 year after surgery were included in this study. In the preoperative sports activity of the patients, there were ten patients in level 9, 14 in level 7, 15 in level 6, 8 in level 5, 8 in level 4, and 2 in level 3 by Tegner activity level score [19]. Thirty-two patients (17 men and 15 women) with an average age of 31 years (range, 14–66 years) who underwent two-bundle ACL reconstruction surgery using hamstrings, i.e., semitendinous and gracilis tendon (STG) graft, and 25 patients (15 men and ten women) with an average age of 28 years (range, 15–59 years) who underwent the ACL reconstruction using bone–patellar tendon–bone (BTB) graft were included in this study. All patients did not have osteoarthritis of the knee by the radiograph. One orthopedic surgeon performed those surgeries at a single hospital. The surgical procedure was decided by the intention of a surgeon. Mainly, ACL reconstruction surgery was performed using BTB in the early phase of this period and using STG in the late phase. Same postoperative rehabilitation was performed in spite of age and sex.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Methods of measurement and evaluation of the muscle strength

Knee extension and flexion strength was evaluated using a Biodex isokinetic dynamometer, at a velocity of $60^\circ/\text{s}$. Measures were obtained before surgery and postoperatively at 6, 9 months, and 1 year. In this study, for between-subject comparison, muscle strength on the operative side was calculated as a ratio of the maximum extension and flexion strength on the non-injured side. Eitzen et al. [11] reported that a deficit in quadriceps strength of $> 20\%$ was associated with more significant impairment in functional knee scores. Based on this information, we require in our institution that patients recover $\geq 80\%$ of knee extension strength by 9 months or 1 year after reconstruction prior to returning to their preoperative sports activities.

Statistical analysis

Factors influencing muscle recovery at 1 year after surgery were identified using logistic regression analysis, with muscle recovery $\geq 80\%$ at the final follow-up used as the dependent variable and age, sex, type of surgical graft repair (STG or BTB), preoperative muscle strength, and muscle strength at 6 and 9 months after surgery entered as independent variables. A binomial logistic regression analysis was first performed. We subsequently performed a sub-analysis for each significant factor identified. Differences in muscle strength by type of graft repair and sex were analyzed using a repeated measure analysis of variance (ANOVA). The strength of the correlation between age and muscle strength was evaluated using a simple regression analysis. An analysis of the temporal recovery of postoperative muscle strength, compared to preoperative muscle strength, was performed using a repeated measure ANOVA. All analyses were performed using IBM SPSS statistics (version 21), with a p value of 0.05 considered significant.

Results

At 1 year after the ACL reconstruction surgery, 30 patients (52.6%) achieved a muscle recovery $\geq 80\%$ and had returned to their sports activities. There was no incidence of complications, including infection, limitation in range of motion, and re-rupture. The muscular strength at 9 months after surgery was strongly correlated with muscular strength at 1

year; therefore, we did not include the strength at 9 months in our evaluation of muscle recovery at 1 year.

Results of the binomial logistic regression analysis, including all independent variables, are reported in Table 1. Significant factors associated with knee extension strength at 1 year included: preoperative muscle strength [$p=0.045$; odds ratio (OR), 1.105; 95% confidence interval (CI), 1.002–1.219] and muscular strength at 6 months after surgery ($p=0.040$; OR, 1.155; CI, 1.006–1.326). Age, sex, and type of graft were not retained as significant factors of extension strength recovery at 1 year. By comparison, only flexion strength at 6 months after surgery predicted flexion strength at 1 year ($p=0.009$; OR, 1.231; CI, 1.009–1.444).

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and type of graft were not retained as significant factors of extension strength recovery at 1 year. By comparison, only flexion strength at 6 months after surgery predicted flexion strength at 1 year ($p=0.009$; OR, 1.231; CI, 1.009–1.444). Knee extension strength at 6 months was greater in the STG group than in the BTB group ($p<0.001$), although there was no difference between the groups at baseline or at 1 year (Table 2A). Similarly, knee flexion strength was greater in the STG group than in the BTB group at 6 months ($p=0.003$; Table 2B).

There was no difference in muscular strength between men and women at all time points of measurement (Table 3A, B).

The association between age and extension strength at preoperative and postoperative 1-year time points is shown in Fig. 1. Age correlated with knee extension at 1 year (correlation coefficient, -0.325 ; $p=0.023$), but not with preoperative muscle strength (correlation coefficient, -0.151 ; $p=0.301$). Age did not correlate with knee flexion strength (Fig. 1b).

Table 1 Binomial logistic regression analysis of the muscular strength at 1 year

The independent variables	Extension strength			Flexion strength		
	<i>p</i>	OR	95% CI	<i>p</i>	OR	95% CI
Age	0.120	0.900	0.787–1.028	0.853	0.999	0.905–1.103
Gender (men, women)	0.636	0.524	0.036–7.583	0.363	5.371	0.338–85.401
Procedure (BTB, STG)	0.667	0.425	0.009–20.889	0.077	1.006	0.045–22.608
Preoperative Biodex	0.045	1.105	1.002–1.219*	0.925	1.024	0.943–1.132
Postoperative 6-month Biodex	0.040	1.155	1.006–1.326*	0.009	1.231	1.009–1.444*

OR odds ratio, CI confidence interval

* $p<0.05$

Table 2 A: Comparison of the strength of the knee extension, between STG group and BTB group. B: Comparison of the strength of the knee flexion between STG group and BTB group

(A)			
Extension strength (%)	Graft		<i>p</i>
	STG	BTB	
Preoperatively	68.3 (19.1)	60.7 (18.0)	$p=0.159$
6 months postoperatively	75.6 (14.9)	52.6 (14.8)	$p<0.001^*$
1 year postoperatively	82.6 (13.7)	74.9 (25.3)	$p=0.102$
(B)			
Flexion strength (%)	Graft		<i>p</i>
	STG	BTB	
Preoperatively	83.4 (21.6)	75.2 (26.1)	$p=0.250$
6 month postoperatively	87.3 (13.8)	76.0 (11.9)	$p=0.003^*$
1 year postoperatively	92.0 (11.8)	92.8 (12.4)	$p=0.842$

Data show the leg symmetry index is calculated (injured/non-injured * 100=%) and represents “mean (standard deviation)”

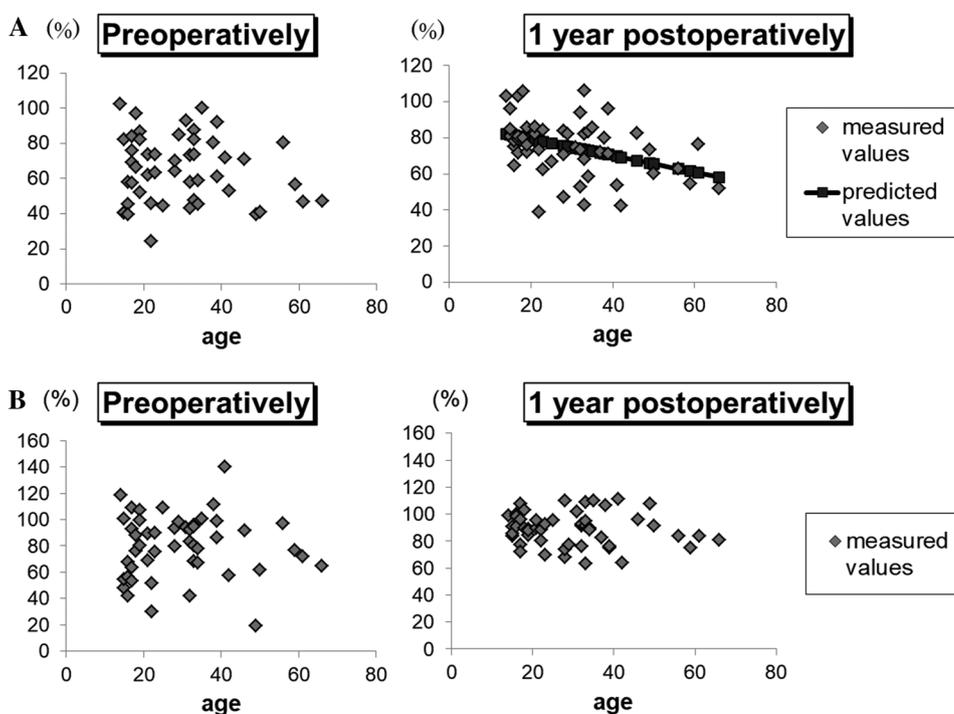
* $p<0.01$

Table 3 A: Comparison of the strength of the knee extension between men and women. B: Comparison of the strength of the knee flexion between men and women

(A)			
Extension strength (%)	Men	Women	
Preoperatively	67.2 (17.5)	62.0 (20.9)	$p=0.371$
6 months postoperatively	66.9 (18.5)	64.8 (19.3)	$p=0.693$
1 year postoperatively	81.1 (21.4)	77.0 (15.8)	$p=0.537$
(B)			
Flexion strength (%)	Men	Women	
Preoperatively	78.6 (20.6)	81.9 (28.5)	$p=0.646$
6 months postoperatively	83.3 (14.5)	81.6 (13.7)	$p=0.681$
1 year postoperatively	88.6 (12.0)	92.0 (10.2)	$p=0.476$

Data show the leg symmetry index is calculated (injured/non-injured * 100= %) and represents “mean (standard deviation)”

Fig. 1 a Relationships between age and the preoperative and postoperative muscle strength of knee extension. The strength of knee extension at the final follow-up was associated with age ($R=-0.325$, $p=0.023$), although there was no correlation between age and the preoperative muscle strength ($R=-0.151$, $p=0.301$). R : correlation coefficient. **b** Relationships between age and the preoperative and postoperative muscle strength of knee flexion. There was no correlation between age and the preoperative muscle strength ($R=0.063$, $p=0.666$), and the flexion strength at the final follow-up ($R=0.198$, $p=0.322$). R : correlation coefficient



Discussion

Based on the present study, the most important findings suggest that the preoperative muscular strength and the muscular strength recovery until 6 months after the ACL reconstruction surgery, e.g., of the quadriceps, significantly affect the muscle recovery of the knee extension at 1 year after surgery and the return to sports activities. Second, age and graft type could have affected postoperative muscle strength. A few studies have shown that preoperative muscle strength is important for the muscle recovery after the ACL reconstruction [10–13, 15–18].

Therefore, an appropriate exercise protocol not only in the early phase after surgery but also preoperatively may have an important role in improving patient’s postoperative muscle strength. Although the preoperative assessment of the range of motion of the knee, for example, may result in decision making in patients who are being considered for the ACL reconstruction surgery, preoperatively strengthening muscle may be equally important as compared to the preoperative range of motion. However, in patients with meniscal tear or cartilage damage should be performed early operation. As reported by Kim et al. [13], preoperative exercises for definite period may be actually effective.

Although men should have greater muscle strength than women, in this study, the muscle recovery was independent of sex. The method, in which the muscle strength was assessed (i.e., as the ratio of muscle strength between the operative side and non-injury side), may have caused this result. Logerstedt et al. [12] also reported that sex did not influence the relationship between the quadriceps strength and IKDC2000 scores after the ACL reconstruction. Consequently, we considered that sex was not associated with the muscle recovery.

In our sub-analysis, older patients, even though they had no osteoarthritis of the knee, might have poor muscle recovery of knee extension compared to young patients. Thus, the force of knee extension should be carefully managed in older patients after the ACL reconstruction. The muscle recovery of knee extension was good for both the STG and BTB methods at the final follow-up. Aune et al. [20] reported that patients who underwent the ACL reconstruction with the hamstring tendon showed better isokinetic knee extension strength than those who underwent the ACL reconstruction with the patellar tendon after 6 months, but not after 12 and 24 months. In the current study, the strength of knee extension and flexion in 6 months after surgery was greater in patients who underwent the ACL reconstruction with STG graft than in those who underwent surgery with BTB graft. The postoperative strength of knee extension decreases with the BTB method because the mechanism of knee extension depends on the quadriceps. However, the force of knee flexion was lower in BTB group than that in STG group. The reason for this may be that the gastrocnemius and popliteus muscles as well as hamstrings are used for knee flexion. In addition, anterior knee pain might be more severe in BTB group in knee flexion position.

This study has certain limitations. First, this study had a small number of subjects. Therefore, further research using a larger number of subjects may be required to obtain definitive results. Second, the term of observation was relatively short. However, the results of this study are important because the goal of return to sports after ACL reconstruction is considered as approximately 6 months to 1 year after surgery. Third, we did not perform subjective evaluations of patients. The relationship between muscle strength and the feeling of instability in patients who underwent the ACL reconstruction was not identified. Fourth, meniscus tear was not involved in the evaluation of the effect on muscular recovery. Although the meniscectomy might not have much impact on postoperative muscular strength recovery, the suture surgery of meniscus might have a negative influence.

However, the current study showed that the preoperative muscle strength and the muscle strength recovery in early term after ACL reconstruction surgery are important factors for the muscle strength recovery at 12 months after surgery and affect return to sports activities.

Conclusions

Recovery of knee extension strength at 1 year after ACL reconstruction was significantly associated with preoperative muscular strength and muscle recovery at 6 months. Age and graft type might be related to the muscle strength recovery. Preoperative and early postoperative strength training could improve the recovery of knee extension strength, which would support an earlier return to sport after ACL reconstruction.

Compliance with ethical standards

Conflict of interest All authors declare no conflict of interest.

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