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Original Article

Effects of 4 weeks preoperative exercise on knee extensor strength after anterior cruciate ligament reconstruction

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Abstract. [Purpose] After an anterior cruciate ligament injury and subsequent reconstruction, quadriceps muscle weakness and disruption of proprioceptive function are common. The purpose of this study was to examine the effects of a 4 weeks preoperative exercise intervention on knee strength power and function post-surgery. [Subjects and Methods] Eighty male patients (27.8±5.7 age), scheduled for reconstruction surgery, were randomly assigned to two groups, the preoperative exercise group (n=40) and a no preoperative exercise group (n=40). The preoperative exercise group participated in a 4-week preoperative and 12-week post-operative programs, while the no preoperative exercise group participated only in the 12-week postoperative exercise program. Isokinetic measured of quadriceps strength were obtained at 4 weeks before and 3 months after surgery. [Results] The knee extensor strength deficits measured at 60°/s and 180°/s was significantly lower in the preoperative exercise group compared with the no preoperative exercise group. At 3 months after surgery, the extensor strength deficit was 28.5±9.0% at 60°/sec and 23.3±9.0% at 180°/sec in the preoperative exercise group, whereas the no preoperative exercise group showed extensor strength deficits of 36.5±10.7% and 27.9±12.6% at 60°/sec and 180°/sec, respectively. The preoperative exercise group demonstrated significant improvement the single-leg hop distance. [Conclusion] Four week preoperative exercise may produce many positive effects post reconstruction surgery, including faster recovery of knee extensor strength and function, as measured by single-leg hop ability.

Key words: Anterior cruciate ligament, Preoperative exercise, Knee extensor strength

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INTRODUCTION

Anterior cruciate ligament (ACL) injuries are one of the most common and devastating knee injuries associated with sport participation[1)]. Surgical repair of complete rupture of the ACL is recommended to prevent knee joint instability. While surgery corrects the structural defect, post-operative impairments in knee strength, function and endurance are inevitable corollary problems associated to the repair. Many patients experience some degree of muscle weakness post-ACL reconstruction (ACLR), especially weakness of the quadriceps muscles, which can limit their functional ability[2)]. Palmieri-Smith et al.[3)] assessed the deficit in quadriceps muscle strength between the reconstructed and non-injured knees in patients six months after ACLR. They reported deficits in isokinetic quadriceps strength ranging between 24% and 40.5%. Several studies have suggested use of an accelerated progression of knee strength, function and endurance following ACLR to improve outcomes[4, 5)]. While most recent studies have focused on the effects of postoperative rehabilitation protocols, only a few studies exist that have studied about effects of preoperative exercise on post-ACLR outcomes[6–8)]. Keays et al.[7)] reported on the beneficial effects of a 5-week home-based exercise program for improving quadriceps strength and knee function early post-ACLR injury. Based on available research evidence, if a preoperative program of exercise can restore muscle strength and function before surgery, it could be of benefit to improve outcomes post-surgery. Based on the study Eitzen et al.[9)] the preoperative quadriceps strengthening may be a significant predictor of knee function two year after ACLR[9)]. Preoperative deficits in quadriceps strength of greater than 20% have been associated with significant persistent muscle weakness two years after ACLR. However, there is still little evidence regarding the benefits of preoperative exercise on improving postoperative knee weakness.

We hypothesized that a preoperative program of exercise would improve functional outcomes post-ACLR. Therefore, the aim of the present study was to examine the effects of a 4 week, hospital-based preoperative program of exercise, focusing on quadriceps strengthening and single-leg hop function, on after ACLR outcomes.

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Table 1. A summary of the Preop exercise program

Exercise category	Exercise	Repetitions and sets
Cardio exercise	Stationary bike	20 min
Range of motion exercise	Seat flexion/extension Wall slides	10 min
Strengthening exercise		
Open-chain strengthening	Short arc extension	10×2
	Straight leg raises	10×2
	Leg curl (isometric)	10×2
Close-chain strengthening	Leg extension (ROM 30–80°)	10×2
	Leg press	15×2
	Half squat	15×2
Balance/Proprioception	Single-leg standing	30 sec×3
	Balance board	30 sec×3

SUBJECTS AND METHODS

A prospective, randomized, controlled study was initiated to evaluate the effectiveness of a 4 weeks preoperative program of exercises on after ACLR knee strength and function. Patients with ACL rupture were recruited from Samsung Medical Orthopedics Centers from April 2012 to August 2014. The inclusion criteria were men between the ages of 20 and 35 years, presenting with an isolated ACL rupture in the knee. The exclusion criteria were previous ACLR or meniscus repair, injury to other ligaments in the same knee, and any associated fractures. The 80 patients were randomly assigned into two groups, the preoperative exercise group (PEG, n=40) and no preoperative exercise group (NPEG, n=40). The mean height and body weight PEG were 173.8±5.6 cm and 75.2±8.9 kg; for the NPEG, they were 172.8±4.4 cm and 74.31±9.77 kg. There were no significant between-group differences in height and weight between groups.

The PEG participated in a 4-week exercise program preoperatively and in a 12 week postoperative program, while the NPEG only participated in the 12 weeks postoperative program. Knee muscle strength and function were measured at 4 weeks before surgery and 3 months after surgery. All patients were supervised at least three times a week in a sports medicine center.

The preoperative exercise program was based on known impairments associated with ACL injuries, focused mainly on strengthening, functional balance, muscle control, and co-contraction[7]. The exercise program was adapted to patients' specific condition and needs. The exercise program mainly focused on lower limb strengthening, with particular attention paid to strengthening of the quadriceps muscles. Prior to performing the main strength training program, subjects completed 20 minutes of stationary cycling. After completion of the warm-up, subjects proceeded to a series of lower-body strengthening exercises, short arc extension, wall squat, leg press, isometric leg extension, and leg curls as well as other exercises (Table 1). Selected exercises reduced anterior shear force across the tibio-femoral joint and, therefore, helped strengthen the muscles without risk of damaging intra-articular structures of the knee. The postoperative exercise program was based on a combination of evidence-based exercises identified from the scientific literature.

Immediately after ACLR, the limb was immobilized in a postoperative functional brace, and patients were instructed to perform straight leg raising and quadriceps setting exercises. Patients were allowed to undergo partially weight bearing at 2 weeks after their surgery and to move through full-range of knee joint motion and perform closed chain exercise at 4 weeks after surgery. All patients underwent assessment of knee extensor strength and distance on single-leg hop 4 weeks prior to surgery and again at 3 months after surgery. Isokinetic strength and endurance were measured using a CSMI isokinetic dynamometer (CSMI Medical solution, Stoughton, MA, USA). Knee strength was measured through the range of 0 to 90° at an angular speed of 60°/sec, with four repetitions completed at an angular speed of 180°/sec, with 20 repetitions completed to calculate average power[10]. The highest peak torque value for each velocity was compared with the uninjured side and described as percent of strength deficit. For the single-leg hop for test, the mean average distance was quantified by limb symmetry index (LSI) using the following formula: (distance for injured leg/distance for uninjured leg) × 100[11].

To investigate the change in knee extensor strength and single-leg hop distance between the PEG and NPEG, a repeated measures analysis using the independent sample t-test. P values less than 0.05 were considered to be significant.

RESULTS

The knee extensor strength deficit was calculated as the percentage difference between the injured and uninjured side. The knee extensor strength deficits was significantly different between the groups, both at an angular velocity of 60°/s (p=0.018) and 180°/s (p=0.033). Patients in the PEG showed a significantly greater improvement in post-operative strength than patient in the NPEG at 60°/s, and180°/s (Table 2).The PEG also showed significant improvement in the single hop distance test (p=0.029).

Table 2. Change in knee extensor muscle strength and single-leg hop function

Main outcome measurement	PEG (n=40)	NPEG (n=40)
Knee extensor 60°/sec deficit (%)		
Preop	22.8±13.7	23.5±15.8
Post-op	28.5±9.0*	36.5±10.7
Knee extensor 180°/sec deficit (%)		
Preop	16.6±10.6	17.5±11.9
Post-op	23.3±9.0*	27.9±12.6
Single-leg hop LSI (%)		
Preop	75.1±10.3	76.5±8.9
Post-op	85.3±7.4*	80.5±9.6

Date represent the mean±SD.
PEG: preop exercise group; NPEG: no pre-op exercise group.
*$p<0.05$

DISCUSSION

The purpose of this study was to examine the effects of a 4 weeks preoperative program of the knee extensor muscle strengthening on post-operative quadriceps muscle strength and knee function. Outcomes confirmed the benefits of the PEG in significantly lowering post-operative deficits in quadriceps strength and improving single-leg hop distance compared to patients who did not participate in a preoperative exercise program.

Knee extensor strength deficit following ACLR is a common problem which has been reported in previous studies[12, 13]. In a recent review of the literature, 11 studies including research by Palmier-Smith et al.[3], reported knee extensor muscle strength deficit, ranging between 24% and 40.5%, 6 months after ACLR, while another 10 studies reported a residual, deficit in quadriceps strength of 10% to 27%, 12 months after ACLR[3]. Furthermore, long-term negative outcomes of strength deficits on knee function for sports activities and even during daily activities. Thus, the recovery of quadriceps muscles strength is one of the most important factors after ACLR[14].

Recent studies have investigated the relationship between pre and postoperative quadriceps muscle strength deficits and function. According Eitzen et al.[9] reported patients with greater than 20% deficit in quadriceps strength to have a significantly greater impairment on functional knee scores and strength. Further, Shelbourne et al.[8] reported that the postoperative quadriceps muscle strength to be significantly higher in patients with greater preoperative strength than in patients with poor preoperative strength. These studies provide strong evidence that preoperative quadriceps muscle strength positively affects postoperative muscle strength and function. Therefore, adequate and suitable program of exercise before surgery would have an important role of improving post-operative muscle strength. In our study, there was a significant difference in postoperative knee extensor strength deficit between the NPEG and PEG groups, with a mean strength deficit of 36.5% for the NPEG compared to 28.5%. Various functional tests were performed to evaluate knee function after ACLR[15, 16]. Restoration of muscle strength, which was measured by performance on the single leg-hop distance test, is considered to be an important determinant for a successful return to sports after ACLR[9, 17]. The limb symmetry index (LSI) has been the most frequently reported criterion for comparing muscle strength and hop performance with the uninjured side[18].

Our study demonstrated that patients in the showed PEG significantly improved in the single leg-hop distance compared to the NPEG. The results indicate that the greater improvements in quadriceps strength in the PEG had a positive effect on knee function test, such as the single-leg hop, compared to the NPEG. The result indicated that preoperative exercises not only prevented quadriceps weakness, but also accelerated the recovery of muscle strength, which helped patients to quickly adapt to the rehabilitation environment. It is also anticipated that possible re-injury could be prevented by having better strength and function.

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