

Effects of acceleration training 24 weeks after anterior cruciate ligament reconstruction on proprioceptive and dynamic balancing functions

KEUN OK AN, PhD¹⁾, GI DUCK PARK, PhD^{2)*}, JOONG-CHUL LEE, PhD³⁾

¹⁾ Department of Kinesiological Medical Science, Graduate School of Dankook University, Republic of Korea

²⁾ Department of Leisure Sport, Kyungpook National University: 386 Gajangdong, Sangju 742-711, Republic of Korea

³⁾ Department of Exercise Prescription, Dongshin University, Republic of Korea

Abstract. [Purpose] The present study aimed to investigate whether the effects of rehabilitation exercise performed after anterior cruciate ligament reconstruction on proprioceptive sensory and dynamic balancing functions differ between males and females. [Subjects and Methods] Eighteen subjects aged between 20–30 years enrolled in this study. The ages did not significantly differ between the males and females. The rehabilitation exercise program was performed three times per week for 12 weeks (3 months), and was initiated immediately after anterior cruciate ligament reconstruction. Thereafter, the patients visited the hospital once per week to perform rehabilitation exercise during weeks 12–24 (3–6 months), and education on self-exercise and assessments were conducted during the visits. Self-exercise was performed two times per week according to the determined program. [Results] The extension active joint position sense, extension passive joint position sense, and flexion passive joint position sense of the affected and unaffected knees did not show any interaction effects between the measurement periods or between the groups. In the case of the affected knee, the results of two-way repeated-measures analysis of variance showed no significant difference between the measurement periods or between the groups; moreover, no, interaction effects were observed between the measurement periods or between the groups. In the case of the unaffected knee, although no significant difference was observed between the measurement periods, significant differences were observed between the groups. [Conclusion] In conclusion, this study revealed that most knee rehabilitation exercise training programs can be applied to both genders during the recovery period after ACL reconstruction, except for the knee rotational feedback/feedforward function exercise that may exhibit different effects based on the gender.

Key words: Anterior cruciate ligament, Reconstruction, Proprioceptive

(This article was submitted Apr. 30, 2015, and was accepted Jun. 9, 2015)

INTRODUCTION

Damage to the anterior cruciate ligament is usually caused through the action of internal rotation on the tibia in relation to the femur. Previous studies have reported that damage to the anterior cruciate ligament frequently occurs when the knee joint experiences over flexion, abduction, and external rotation, and the frequency of accompanying damage in these cases is high^{1–4)}. Furthermore, it has been reported that knee joint abnormalities resulting from anterior cruciate ligament rupture can result in degenerative changes in the articular cartilage and rupture of the meniscus^{1–4)}. According to the previous questionnaire and video findings on the dam-

age to the anterior cruciate ligament, noncontact damage accounts for 72% of ACL injuries, with the most frequent causes being deceleration, followed by landing after a jump, overextension, and back landing. Moreover, contact damage accounted for 28% of the cases of anterior cruciate ligament damage, and the most frequent cause among these was knee joint collapse due to valgus stress, followed by knee joint collapse due to varus stress, overextension, direction change, and back landing. Thus, the number of cases of non-contact damage is much larger compared to that of contact damage⁵⁾. Female athletes account for 30% of all injuries to the knee, with 44% of these involving the anterior cruciate ligament⁶⁾. Furthermore, the rate of anterior cruciate ligament surgery among female athletes was 70%, which is five times more than, that observed in male athletes⁷⁾. Although studies have been conducted to determine the differences in the effects of rehabilitation exercise programs between males and females and to assess the differences in the ability to perform functional movements according to the graft type, studies on the differences in proprioceptive functions and the ability to perform functional movements between

*Corresponding author. Gi Duck Park (E-mail: prescrip@knu.ac.kr)

Table 1. Changes in the proprioceptive functions of the groups according to the measurement period

Category			Prior to the operation	12 weeks after the operation	24 weeks after the operation	Hypothesis test result
Affected side	Extension	Male	41.1±7.4	40.4±7.8	38.0±8.2	A*
	AJPS (°)	Female	43.6±8.1	43.7±9.7	45.3±7.3	
	Extension	Male	53.3±7.9	54.1±3.0	53.5±4.5	
	PJPS (°)	Female	58.8±6.9	53.0±6.9	51.7±7.6	
	Flexion	Male	35.0±6.3	37.7±6.1	39.3±7.6	
	PJPS (°)	Female	33.3±6.9	41.3±10.5	40.8±6.4	
Unaffected side	Extension	Male	41.8±4.7	42.8±3.9	41.4±7.0	A***
	AJPS (°)	Female	44.1±8.6	45.1±4.8	48.7±7.0	
	Extension	Male	50.1±9.7	50.5±8.3	49.1±4.7	
	PJPS (°)	Female	55.7±10.7	52.1±7.5	53.5±8.0	
	Flexion	Male	30.6±5.5	36.6±5.1	38.8±5.8	
	PJPS (°)	Female	29.7±9.1	33.8±8.2	38.5±7.6	

AJPS: Active Joint Position Sense, PJPS: Passive Joint Position Sense

Values are presented as mean ± SD

A: Period

*p < 0.05, ***p < 0.001

males and females to determine when an athletes can return to sports are insufficient. Therefore, research is required to determine the length and type of rehabilitation programs that are necessary to prevent re-injury of the anterior cruciate ligament following reconstruction; moreover, it is important to elucidate whether these factors are different for males and females. Therefore, the present study aimed to investigate whether the proprioceptive and dynamic balancing effects of rehabilitation exercises performed after anterior cruciate ligament reconstruction are different between males and females.

SUBJECTS AND METHODS

Eighteen subjects volunteered for the present study and included individuals aged between 20 and 30 years; the age did not differ significantly between the male and female subjects. The subjects were limited to patients who had undergone anterior cruciate ligament reconstruction, with autografts, performed by the same surgeon, and who were assessed as having no difference in anatomical stability based on radiographic and magnetic resonance imaging. The subjects were divided into a male group (n = 10; mean ± standard deviation; age, 29.2± 7.2 years; height, 175.3 ± 5.7 cm; weight, 72.3 ± 9.6 kg; body mass index (BMI), 23.9 ± 2.6 kg/m²) and a female group (n = 8; age, of 24.8 ± 5.8 years; height, 175.3 ± 5.7 cm; weight, 72.3 ± 9.6 kg; BMI 22.1 ± 2.3 kg/m²). An initial rehabilitation exercise program was separately designed and implemented (Table 1) based on the accelerated rehabilitation program after anterior cruciate ligament reconstruction presented by Shelbourne and Nitz⁸). During the rehabilitation period, the exercises were performed three times per week for 12 weeks (3 months), beginning immediately after anterior cruciate ligament the reconstruction. The patients then visited the hospital once a week to perform the rehabilitation exercise during weeks 12–24 (3–6 months). Education on self-exercise and as-

sessments were also conducted during the hospital visits. Self-exercise was performed two times per week according to the specific program. Active joint position sense (AJPS) was evaluated with the knee at 90° of extension. During measurement, the subject was instructed to be seated with the knee at 90° of extension, and with the eyes, closed; the subject was asked to fully concentrate on the position of the knee. The subject extended the knee, and the tester informed the subject when the knee reached an angle of 45°, after which the subject returned the knee to the initial position. The subject was then instructed to actively extend the knee, and press a stop switch when they thought that they had reached a knee angle of 45°. The tester evaluated the extent by which the knee angle was close to an angle of 45°. Passive joint position sense (PJPS) was also evaluated during knee extension. The subject was instructed to maintain the knee at 90° flexion, and then actively extend the knee; the tester informed the subject when the knee reached an angle of 45°, after which the subject returned the knee to the initial position. Thereafter, the subject's knee was passively extended by an isokinetic dynamometer at an angular speed of 0.5°/s. The subject pressed a stop switch when they thought that they had reached a knee angle of 45°. The tester evaluated the extent by which the knee angle was close to an angle of 45°. Furthermore, dynamic balance was measured using a new balance system manufactured by Biodex Medical System Co. (USA) After confirming that the subject's feet were placed on the center of a round target, the tester pressed the start button, following which the self-regulating program installed in the dynamic balancing equipment progressed from level 8 to level 1 for 30 s, depending on the subject's relative ability to maintain balance. To verify the hypothesis of the present study, the test data obtained from the experiments were analyzed using the SPSS 12.0 program. Two-way repeated-measures analysis of variance (ANOVA) was conducted for individual dependent variables in relation to the measurement periods (before the operation,

Table 2. Changes in the dynamic balance functions of the groups according to the measurement period

Category			Prior to the operation	12 weeks after the operation	24 weeks after the operation	Hypothesis test result
Affected side	Overall actual score	Male	1.6±0.5	1.5±0.9	1.6±1.0	B*
		Female	1.5±0.6	1.1±0.3	1.0±0.4	
Unaffected side	Overall actual score	Male	1.8±0.8	1.5±0.4	1.8±1.0	
		Female	1.4±0.5	1.1±0.4	1.0±0.6	

Values are presented as mean ± SD

B: Group

*p < 0.05

at 12 weeks after the operation, and at 24 weeks after the operation) and genders (male and female) as independent variables. Post hoc tests were conducted for variables that showed significant differences. A statistical significance level of 0.05 was chosen. All the subjects understood the purpose of this study and provided written informed consent prior to their participation in the study in accordance with the ethical standards of the Declaration of Helsinki.

RESULTS

In the case of the affected knee, AJPS during extension (extension AJPS) and PJPS during extension (extension PJPS) did not show any significant difference between the measurement periods or between the groups. Moreover, PJPS during flexion (flexion PJPS) showed an improvement; the improvement was significantly different between the measurement periods ($p < 0.05$) but was not significantly different between the groups. The extension AJPS, and extension PJPS, and flexion PJPS of the affected knee did not show any interaction effects between the measurement periods or between the groups. In the case of the unaffected knee, extension AJPS and extension PJPS did not show any significant difference between the measurement periods or between the groups. Moreover, flexion PJPS showed an improvement; the improvement was significantly different between the measurement periods ($p < 0.001$) but was not significantly different between the groups. The extension AJPS, extension PJPS, and flexion PJPS of the unaffected knee did not have any interaction effects between the measurement periods or between the groups.

The changes in the dynamic balancing function in each of the male and female groups are as shown in Table 2. As presented in Table 2, in the case of the affected knee, the results of the two-way repeated-measures ANOVAs showed no significant difference or any interaction effect between the measurement periods or between the groups. In the case of the unaffected knee, although no significant difference was found between the measurement periods, significant differences were observed between the groups ($p < 0.05$). However the results showed no interaction effects between the measurement periods or between the groups.

DISCUSSION

Joint position sense tests were conducted to evaluate the proprioceptive function of the knee after the application of

a rehabilitation exercise program following anterior cruciate ligament reconstruction. According to the results, in the case of the affected knee, only flexion PJPS showed a significant improvement over time. The results of post hoc tests did not show any significant change over time in any group. However, although flexion PJPS improved from $35.0^\circ \pm 6.3^\circ$ before the operation to $39.3^\circ \pm 7.6^\circ$ at 24 weeks after the operation in the male group, it improved from $33.3^\circ \pm 6.9^\circ$ before the operation to $40.8^\circ \pm 6.4^\circ$ at 24 weeks after the operation in the female group, indicating that the rate of improvement in the female group tended to be slightly higher than that in the male group. In the male group, although flexion PJPS improved from $35.0^\circ \pm 6.3^\circ$ before the operation to $37.7^\circ \pm 6.1^\circ$ at 12 weeks after the operation, it improved from $37.7^\circ \pm 6.1^\circ$ at 12 weeks after the operation to $39.3^\circ \pm 7.6^\circ$ at 24 weeks after the operation, indicating that the improvement between 12 and 24 weeks after the operation tended to be lower than the improvement between before the operation and 12 weeks after the operation. In the female group, while flexion PJPS markedly improved from $33.3^\circ \pm 6.9^\circ$ before the operation to $41.3^\circ \pm 10.5^\circ$ at 12 weeks after the operation, it did not improve between 12 and 24 weeks after the operation (from $41.3^\circ \pm 10.5^\circ$ to $40.8^\circ \pm 6.4^\circ$, respectively). In another study, Danny et al.⁹⁾ measured proprioceptive senses using joint position sense tests wherein the subjects were requested to determine joint positions at diverse knee joint angles such as 15° , 30° , 45° , and 60° by using a Biodex system, with the same method employed in the present study. They reported that the proprioceptive senses affected the ability to recognize the angles. In the present study, extension and flexion AJPS did not show any significant improvement over time or any clear tendency of improvement. These results may be attributed to the fact that mechanoreceptors of the joints may not only be present in the ROM, but may also be present in the articular capsules, medial ligament, posterior cruciate ligament, and meniscus. The improvement in flexion PJPS at 12 weeks after the operation is considered to result from the application of an appropriate myoneural control training program in the early stage for the recovery of proprioceptive function. The finding that proprioceptive sense exercise is a highly important element in the process of rehabilitation exercise was also observed in the present study. Proprioceptive sense exercise should be initiated as early as possible in the rehabilitation process, as proprioceptive sense exercise can prevent injuries and restore the impaired motor sensation. Moreover, Mehmet et al.¹⁰⁾ indicated that the visual analog scale scores and knee flexion significantly improved after

open and closed kinetic chain rehabilitation exercise at 3 and 6 months after operation.

Furthermore, Lee et al.¹¹⁾ reported that extension and flexion at 60°/s significantly improved after accelerated rehabilitation training for 12 weeks after anterior cruciate ligament reconstruction. Moreover, the changes in the dynamic balance function were evaluated after the application of a rehabilitation exercise program following anterior cruciate ligament reconstruction, but no significant improvement was observed over time and no interaction effects were noted according to the groups and measurement periods in the affected knee. In the male group, no remarkable change was noted in the dynamic balance over time before the operation, 1.6 ± 0.5 points; 12 weeks after the operation, 1.5 ± 0.9 points; and 24 weeks after operation, 1.6 ± 1.0 points. However, in the female group, dynamic balance showed an improving tendency, with scores of 1.5 ± 0.6 points before the operation, 1.1 ± 0.3 points at 12 weeks after the operation, and 1.0 ± 0.4 points at 24 weeks after operation. With regard to the unaffected knee, the male and female groups showed similar tendencies in dynamic balance. Following a comprehensive evaluation, it can be concluded that the female group tended to have better dynamic balance than the male group at 24 weeks after the operation.

REFERENCES

- 1) Feagin JA Jr, Curl WW: Isolated tear of the anterior cruciate ligament: 5-year follow-up study. *Am J Sports Med*, 1976, 4: 95–100. [[Medline](#)] [[CrossRef](#)]
- 2) Staubi HU, Jakob RP: The knee and the cruciate ligament; Natural history of untreated tears of the anterior cruciate ligament, 1st ed. 1992, pp 237–245.
- 3) Clancy WG Jr, Ray JM, Zoltan DJ: Acute tears of the anterior cruciate ligament. Surgical versus conservative treatment. *J Bone Joint Surg Am*, 1988, 70: 1483–1488. [[Medline](#)]
- 4) Arnold JA, Coker TP, Heaton LM, et al.: Natural history of anterior cruciate tears. *Am J Sports Med*, 1979, 7: 305–313. [[Medline](#)] [[CrossRef](#)]
- 5) Boden BP, Dean GS, Feagin JA Jr, et al.: Mechanisms of anterior cruciate ligament injury. *Orthopedics*, 2000, 23: 573–578. [[Medline](#)]
- 6) Meeuwisse WH, Sellmer R, Hagel BE: Rates and risks of injury during intercollegiate basketball. *Am J Sports Med*, 2003, 31: 379–385. [[Medline](#)]
- 7) Chandy TA, Grana WA: Secondary school athletic injury in boys and girls: a three-year comparison. *Phys Sportsmed*, 1985, 13: 106–111.
- 8) Shelbourne KD, Nitz P: Accelerated rehabilitation after anterior cruciate ligament reconstruction. *Am J Sports Med*, 1990, 18: 292–299. [[Medline](#)] [[CrossRef](#)]
- 9) Pincivero DM, Bachmeier B, Coelho AJ: The effects of joint angle and reliability on knee proprioception. *Med Sci Sports Exerc*, 2001, 33: 1708–1712. [[Medline](#)] [[CrossRef](#)]
- 10) Uçar M, Koca I, Eroglu M, et al.: Evaluation of open and closed kinetic chain exercises in rehabilitation following anterior cruciate ligament reconstruction. *J Phys Ther Sci*, 2014, 26: 1875–1878. [[Medline](#)] [[CrossRef](#)]
- 11) Lee JC, Kim JY, Park GD: Effect of 12 weeks of accelerated rehabilitation exercise on muscle function of patients with ACL reconstruction of the knee joint. *J Phys Ther Sci*, 2013, 25: 1595–1599. [[Medline](#)] [[CrossRef](#)]