J. Phys. Ther. Sci.
25: 1239–1241, 2013

Effects of Closed Kinetic Chain Exercises on Proprioception and Functional Scores of the Knee after Anterior Cruciate Ligament Reconstruction

Sung-Hyoun Cho, PT, PhD[1)], Chang-Hwan Bae, PT, MS[1)*], Hwang-Bo Gak, PT, PhD[2)]

[1)] *Department of Physical Therapy, Graduate school of Physical Therapy, Daegu University: Naeri-ri, Jinlyang, Gyeongsan-si, Kyeongsangbuk-do 15, Republic of Korea*
[2)] *Department of Physical Therapy, Daegu University, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to examine the effect of closed kinetic chain exercises performed by an unstable exercise group (UEG) and a stable exercise group (SEG) on the knee joint, proprioception, and functional scores of patients who underwent anterior cruciate ligament (ACL) reconstruction. [Subjects] Twenty-eight patients participated in this study. The exclusion criteria were fracture or neurological disease. [Methods] The subjects were randomly assigned to one of two groups, each with 14 people. Each group took part in a 60-minute exercise program, three times a week for six weeks. [Results] The results of the clinical evaluation at 45°proprioception showed statistically significant differences between the two groups. The results of the clinical evaluation at 15°proprioception showed no statistically significant differences between the two groups. [Conclusion] The proprioception and functional scores of the patients in the UEG who underwent ACL reconstruction were superior to those in the SEG group.
Key words: Closed kinetic chain exercise, Proprioception, Functional score

(This article was submitted Apr. 8, 2013, and was accepted May 15, 2013)

INTRODUCTION

The anterior cruciate ligament (ACL) plays an extremely important role in resistance to anterior tibia deformation and rotational load on the knee joints[1)]. The treatment goal in ACL rupture is to stabilize the knee joint and to recover the range of motion of the knee joint and the muscle strength to a normal level, to restore smooth functioning of the knee joint[2)]. To improve the range of motion of patients following ACL reconstruction, various exercise programs together with electrical therapy, are conducted with the aim of achieving passive joint movement and pain control[3)].

In closed-chain exercise simultaneous resistance is exerted on the proximal and distal areas while the distal area of the upper and lower extremities remains in a fixed position[4)]. Closed-chain exercise involves simultaneous contraction of the muscles to improve their dynamic stability. When eccentric contraction is predominant, it reduces the shearing force with a joint compression force, thereby providing stability to the joints. Sensitive mechanoreceptors respond to changes in the pressure of the articular capsules and promote proprioception[5)].

Impairment of proprioceptive sense has been reported to cause instability of the knee joint[6)]. Proprioception plays an important role in inducing and promoting voluntary and involuntary movements by transmitting basic information to the motor control areas involved in regulating equilibrium and the vestibular senses[7)]. According to one study, information pertaining to motor control or location is provided largely by muscle spindles[8)], whereas ligaments, the subacromial bursa, and capsules perform the role of mechanoreceptors[9)].

Proprioceptive exercises may recover impaired motor senses. To completely recover the functioning of motor senses, proprioceptive exercises should be initiated as early as possible in the early stages of the rehabilitation process[10)]. In particular, proprioceptive senses are known to affect the preciseness of the articular angles of the knee joint and proprioceptive rehabilitation exercise improves the proprioceptive senses of the operated side after ACL construction[11)]. In a study of the knee joint stability of patients who had undergone ACL reconstruction, closed-chain exercise on an unstable surface increased activation of the vastus medialis muscle[12)]. In a comparison of closed-chain exercise and open-chain exercise, the closed-chain exercise stimulated the mechanoreceptors and increased the muscle mobilization rate more than the open-chain exercise, effectively increasing the strength of the quadriceps femoris muscle and the hamstring muscle[13)]. Therefore, the present study examined the effects of closed-chain exercise performed on a stable surface and on an unstable surface on proprioceptive functions and a functional index of the knee joints.

SUBJECTS AND METHODS

The subjects were patients who had undergone ACL reconstruction between September 2012 and March 2013

*To whom correspondence should be addressed.
E-mail: bae5306@hanmail.net

and consented to participation in this study. The subjects were 28 male patients who had undergone ACL reconstruction and received exercise treatment in the manual therapy room of G hospital. The stable exercise group (SEG) performed exercise on a stable floor, and the unstable exercise group (UEG) performed exercise on a balance pad. All the subjects voluntarily consented to participate in this study. Those who had cruciate ligament damage accompanied by multiple fractures or collateral ligament damage, or who had undergone meniscus repair surgery, were excluded from the experiment. The general characteristics of the subjects are presented in Table 1.

The Biodex system III (Biodex Medical Systems, Shirly, NY, USA) was used to measure the proprioceptive sensory functions of the knee joints on the operated side prior to the exercise and six weeks after the exercise. The subjects' thighs and abdomen were firmly fixed with straps to ensure that they were vertical at 90° against the knee joints and the dynamometer tube axis, and the isometric muscle strength was measured. The subjects' ranges of motion were then determined. The differences in the proprioceptive sense functions of the knee on the operated side at 15° and 45° were measured. With the subjects' two eyes blinded, the examiner instructed the subjects to perceive the angles that had been measured and to remember them; the angles were maintained for 10 seconds. After the 10 seconds had elapsed, the subjects were asked to adopt the same angles of the knee joints. The measurements were made three times at 15° and 45°, and the average values of the three measurements were recorded.

The knee joint functional index questionnaire was administered prior to the exercise and after six weeks of exercise. The Lysholm knee scale, which evaluates the function of the knee joint after knee joint ligament surgery, was used for the functional score test of the knee joints[14]. This scale assesses the following: a normal gait (5 points), instability during activities like gait, running, and jumping (30 points), pain (30 points), the degree of edema (10 points), and femoral amyotrophy (5 points). The maximum score that can be obtained is 100 points. Scores of, zero to 6l, 62 to 81, 82 to 90, and 91 to 100 represent to poor, average, good, and excellent knee function, respectively.

The data were processed with SPSS 20.0 for Windows. Descriptive statistics are reported as means ± standard deviations (M±SD). The paired t-test was conducted to verify differences in the proprioceptive functions and the functional index within each group, and the independent t-test was conducted to verify differences in the proprioceptive functions and the functional index between the groups. The significance level was chosen as p =0.05.

RESULTS

The between- and within-group changes in the proprioceptive functions of the knee joints and the functional index are presented in Table 2 and 3, respectively. The stable exercise group (SEG) showed statistically significant differences in the proprioceptive functions and the Lysholm score at 15° ($p<0.05$). The unstable exercise group (UEG) exhibited statistically significant differences in the proprioceptive functions and the Lysholm score at 15° and 45° ($p<0.05$). Prior to the exercise, there were no statistically significant differences between the two groups in any of the variables ($p>0.05$). After 6 weeks of exercise, the two groups showed a statistically significant difference in proprioceptive functions at 45° ($p <0.05$).

Table 1. General characteristics of subjects (M±SD)

	SEG (n=14)	UEG (n=14)
Age (yrs)	28.78±7.24	29.92±5.46
Height (cm)	172.64±5.90	174.28±3.68
Weight (kg)	70.00±4.27	71.28±5.26
Affected side (Right/Left)	8/6	7/7

M±SD: Mean ± standard deviation, SEG: Stable exercise group, UEG: Unstable exercise group

Table 2. Comparison of proprioception and knee functional scores between the pre-test and post-test in each group

Group		Pre-test	Post-test
SEG (n=14)	15˚ Proprioception*	4.82±1.19	2.87±0.86
	45˚ Proprioception	5.36±1.41	4.72±2.10
	Lysholm score*	45.79±9.89	83.79±5.65
UEG (n=14)	15˚ Proprioception*	4.26±1.09	2.45±0.95
	45˚ Proprioception*	4.31±0.95	2.80±0.93
	Lysholm score*	48.00±5.05	85.29±7.50

* $p<0.05$, M±SD: Mean ± standard deviation, SEG: Stable exercise group, UEG: Unstable exercise group

Table 3. Comparison of proprioception and knee functional scores between the groups

Variables	SEG	UEG
15˚ Proprioception	1.95±1.04	1.81±1.20
45˚ Proprioception*	0.64±1.71	1.51±1.01
Lysholm score	−38.00±8.66	−37.29±8.35

* $p<0.05$, M±SD: Mean ± standard deviation, SEG: Stable exercise group, UEG: Unstable exercise group

DISCUSSION

Proprioceptive senses play an important role in correcting motor performance and play an important role in neurological senses related to motor skills[15]. The Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Shirley, New York, USA) is a contemporary isokinetic dynamometer with an electrically controlled servomechanism which is used in both clinical and research settings. The Biodex System 3 performs with acceptable mechanical reliability and the validity of its measurements has tested[16]. A previous study evaluated proprioceptive functions prior to and after ACL surgery following rehabilitation exercise and found that the proprioceptive function of both the operated

side and the non-operated side significantly improved[17]. Another study measured the proprioceptive functions of the knee joint at angles of 15° and 45° after a rehabilitation program comprising four weeks of proprioceptive exercises and reported that the proprioceptive functions of the operated sides were enhanced[18]. In the present study, the six-week exercise program following ACL reconstruction significantly improved the proprioceptive functions at the knee angles of 15° and 45°. In the between-group comparison, the proprioceptive functions were significantly different at 45°, but not at 15°. In the UEG, the improvement in the proprioceptive senses and the scores of the functional index showed that the exercise was effective. Our results demonstrate that closed kinetic chain exercise on an unstable floor promoted proprioception more than closed kinetic chain exercise on a stable floor. A prior study examined knee joint function after ACL reconstruction and reported that a swiss ball exercise group showed greater improvement than a control group[19]. Similarly, in the present study, there were significant differences in the knee joint functional scores after the exercise in both groups, but no significant differences between the two groups.

Squat exercise on a balance pad or a balance board after ACL reconstruction may enhance proprioceptive functions of the knee joint and the knee joint functional index. Such exercise is also effective at minimizing cruciate ligament stress. Therefore, closed-chain exercise on an unstable surface early after surgery is a very important part of any rehabilitation program.

A limitation of this study is that it failed to control for other physical activities. Also, we did not control for physiological or psychological factors that may have affected the results. In addition, the subjects were confined to those who underwent cruciate ligament reconstruction at G hospital located in U city, therefore the generalizability of the findings is limited. To address these issues, further studies are required with greater numbers of participants to develop effective exercises programs for a variety of therapeutic interventions.

REFERENCES

1) Duthon VB, Barea C, Adrassart S, et al.: Anatomy of the anterior cruciate ligament. Knee Surg Sports Traumatol Arthrosc, 2006, 14: 204–213. [Medline] [CrossRef]
2) Clancy WG Jr, Ray JM, Zoltan DJ: Acute tears of the anterior cruciate ligament: surgical versus conservative treatment. J Bone Joint Surg, 1988, 70: 1483–1488. [Medline]
3) Shelbourne KD, Nitz P: Accelerated rehabilitation after anterior cruciate ligament reconstrucion. Am J Sports Med, 1990, 18: 292–299. [Medline] [CrossRef]
4) Kisner C, Colby LA: Therapeutic Exercise: Foundations and Techniques, 5th ed. Philadelphia: FA. Davis Co., 2007, pp 174–180.
5) Iwasaki T, Shiba N, Matsuse H, et al.: Improvement in knee extension strength through training by means of combined electrical stimulation and voluntary muscle contraction. Tohoku J Exp Med, 2006, 209: 33–40. [Medline] [CrossRef]
6) Wojtys EM, Huston LJ: Neuromuscular performance in normal and anterior cruciate ligament-deficient lower extremities. Am J Sports Med, 1994, 22: 89–104. [Medline] [CrossRef]
7) Shumway-Cook A, Woollacott M: Motor control: Theory and practical application, 2nd ed. Philadelphia: Willian Wilkins, 2001, pp 163–171.
8) Gooey K, Bradfield O, Talbot J, et al.: Effects of body orientation, load and vibration on sensing position and movement at the human elbow joint. Exp Brain Res, 2000, 133: 340–348. [Medline] [CrossRef]
9) Ide K, Shirai Y, Ito H, et al.: Sensory nerve supply in the human subacromial bursa. J Shoulder Elbow Surg, 1996, 5: 371–382. [Medline] [CrossRef]
10) Hoffman M, Payne VG: The effects of proprioceptive ankle disk training on healthy subjects. J Orthop Sports Phys Ther, 1995, 21: 90–93. [Medline]
11) 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]
12) Kim YJ, Park RJ: The effects of closed kinetic chain exercises of unstable floor on the stability of the knee joints of patients with anterior cruciate ligament reconstruction. The Korean Society of Physical Medicine, 2008, 3: 11–20.
13) Kwon SB: Effect of closed and open kinetic chain exercise after cruciate ligament reconstruction. J Korean Soc Phys Ther, 2005, 17: 297–310.
14) Tegner Y, Lysholm J: Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res, 1985, 198: 43–49. [Medline]
15) Barrack RL, Skinner HB: Knee joint proprioception revisited. J Sport Rehabil, 1994, 3: 18–42.
16) Drouin JM, Valovich-mcLeod TC, Shultz SJ, et al.: Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque and position measurements. Eur J Appl Physiol, 2004, 91: 22–29 Drouin. [Medline] [CrossRef]
17) Reider B, Arcand MA, Diehl LH, et al.: Proprioception of the knee before and after anterior cruciate ligament reconstruction. Arthroscopy, 2003, 19: 2–12. [Medline] [CrossRef]
18) Kim GH: The effects of 4 weeks postoperative rehabilitation to anterior cruciate ligament on knee joint proprioception. Master's thesis, Korea National Sport University, 2004.
19) Cho HY, Park YJ, Lee SK: Effects of swiss ball exercise on postural control and lymsholm score after ACL reconstruction with MCL injury. J Sport Leis Stud, 2010, 40: 731–740.