



Original Article

# The immediate intervention effects of robotic training in patients after anterior cruciate ligament reconstruction

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**Abstract.** [Purpose] The purpose of this study was to examine the immediate effects of robot-assisted therapy on functional activity level after anterior cruciate ligament reconstruction. [Subjects and Methods] Participants included 10 patients (8 males and 2 females) following anterior cruciate ligament reconstruction. The subjects participated in robot-assisted therapy and treadmill exercise on different days. The Timed Up-and-Go test, Functional Reach Test, surface electromyography of the vastus lateralis and vastus medialis, and maximal extensor strength of isokinetic movement of the knee joint were evaluated in both groups before and after the experiment. [Results] The results for the Timed Up-and-Go Test and the 10-Meter Walk Test improved in the robot-assisted rehabilitation group. Surface electromyography of the vastus medialis muscle showed significant increases in maximum and average discharge after the intervention. [Conclusion] The results suggest that walking ability and muscle strength can be improved by robotic training.

**Key words:** Robot-assisted rehabilitation, Anterior cruciate ligament reconstruction, Walking ability

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## INTRODUCTION

The anterior cruciate ligament (ACL) is the most frequently injured knee ligament, and accounts for about 50% of all ligament injuries<sup>1</sup>). Approximately 91% of ACL injuries occur during sports activities; most are caused by noncontact injury mechanisms, such as landing from a jump and rapid deceleration<sup>2</sup>). Patients with an ACL injury often have symptoms of knee instability, which may lead to functional change and damage in other joint structures, and interfere with activities of daily living<sup>3</sup>). Patients with ACL injuries have difficulty recovering normal walking ability and full function of the lower limbs<sup>4</sup>).

In recent years, robot-assisted therapy (RAT) rehabilitation, which simulates normal walking, has also been used to help patients with spinal cord injury or stroke<sup>5</sup>). RAT is widely used during the recovery process. The major difference between robot-assisted weight-supported treadmill training and existing supported ambulation training is the addition of a mechanical assistant in the former, so that alternative steps with both feet can be achieved by patients<sup>6</sup>). Moreover, simulation of a normal walking pattern facilitates input from the peripheral nerves; in this manner, the remaining central nervous system can be stimulated so that regeneration of the nerves involved in traumatic spinal cord injury can be completed. Recent studies have shown that this method is associated with significant improvement in reaction time and bowel function<sup>7, 8</sup>).

Reconstructive techniques have been refined to achieve better stabilization of the knee and other joints in order to improve functional recovery<sup>9</sup>). It has been suggested that the lack of full recovery of knee function after ACL reconstruction is due to sensory and motor behavior deficits. Proprioceptive afferent neural input is also important in functional control during sports activities<sup>10</sup>). In the clinic, patients are always asked to walk normally, but few methods provide normal proprioceptive input

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during walking training.

The aim of this study was to examine the immediate effects of RAT rehabilitation on functional activity levels after ACL reconstruction.

## SUBJECTS AND METHODS

This study recruited 10 patients who underwent arthroscopic ACL reconstruction in hospitals in Beijing, China, between September and December 2015. Patients performed rehabilitation exercises for at least 2 months at the department of physical therapy. The subjects were limited to patients who had undergone ACL 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 characteristics of the 10 subjects (8 males and 2 females) are shown in Table 1. The subjects participated in RAT and treadmill groups on different days. The purpose and content of this research were explained to the subjects, who gave informed consent to participate in the study. The study was approved by the Research Ethics Committee of China Rehabilitation Research Center (IRB no. 2014-K-005).

In the treadmill group, subjects were asked to walk on the treadmill independently, but with monitoring by the physical therapist. In the RAT group, the same rehabilitation training was carried out as with the treadmill training team, but walking training used a rehabilitation training robot (MBZ-CPM1, ManBuZhe [Tian Jin] Rehabilitation Equipment Co., Ltd. China). In the treadmill and RAT groups, the initial training speed was 1.5 km/h, which was progressively increased to 1.8 km/h as quickly as possible while maintaining gait quality<sup>11</sup>). In the RAT group, the body weight system was initiated at 35%, and 70% guidance force was provided for the participants<sup>12</sup>). Both groups underwent walking training for 20 min. The experiments measured extension strength of the knee joint and walking and balance ability in both groups before and after the experiment.

To measure walking ability, we used the 10-Meter Walk test (10MWT) and the Timed Up-and-Go (TUG) test. To measure balance ability, we used the Functional Reach Test (FRT). For the assessment of knee extension strength, surface electromyography (sEMG) and the maximal extensor strength of the knee joint were measured with the subjects seated and the knee flexed at 45°.

In the sEMG evaluation of the vastus lateralis and vastus medialis muscles, maximum isometric contraction in the start position was maintained for 5 s, during which the maximum and average discharge of the muscle were measured by an sEMG system (Telemetry 2400T; Noraxon, Scottsdale, AZ, USA). We measured the maximal extensor strength of isokinetic movement of the knee joint. An isokinetic dynamometer (Prima Plus, Easytech, Italy) was used. All measurements were carried out by one physiotherapist.

Two-way analysis of variance (ANOVA) and multiple comparisons (Bonferroni test) were used to test for statistically significant differences, and the factors were intervention and group. If a significant interaction was found, a paired t-test was performed to compare results before and after the intervention. Data were analyzed using SPSS Ver. 17.0 for Windows. The level of statistical significance was chosen as 0.05.

## RESULTS

Two-way ANOVA revealed significant interactions for the 10MWT and TUG test between the two groups, indicating that the changes between the groups were significantly different (Table 2). Walking ability was enhanced by RAT intervention.

Two-way ANOVA showed the main effects in the different groups. The paired t-test showed significant increases in the maximum and average discharge of the vastus medialis muscle on sEMG after RAT intervention.

In the FRT, the extensor strength of the knee joint and the sEMG of the vastus lateralis showed no significant interactions or main effects between the RAT group and treadmill groups.

## DISCUSSION

Compared with the treadmill group, the TUG test and 10MWT times for the RAT group were reduced, and the maximum and average discharge of the vastus medialis muscle on sEMG were significantly increased after RAT treatments.

The reason for these results is that compared with standard walking training and treadmill use, robotic walking training enabled the bilateral lower limbs to perform alternative and circulatory movements<sup>11-12</sup>), which can effectively adjust lower limb movement after ACL reconstruction; in this manner, walking ability can also be improved.

These results suggest that walking ability and muscle strength can be improved by robotic walking training. Future studies with more subjects are needed to investigate the effects of different walking models using RAT after long-term intervention in patients with ACL reconstruction.

**Table 1.** Subject characteristics

	Mean ± SD (N=10)
Age (yrs)	33.1 ± 6.5
Height (cm)	170.5 ± 7.9
Weight (kg)	72.4 ± 21.5

**Table 2.** Effects of RAT and treadmill

	a. Treadmill group before intervention	b. Treadmill group after intervention	c. RAT group before intervention	d. RAT group after intervention	
10MWT (s)	9.3 ± 1.4	9.0 ± 1.2	9.2 ± 1.6	8.0 ± 0.9	a,b,c>d**
TUG test (s)	12.5 ± 1.9	11.8 ± 1.9	13.2 ± 2.7	10.9 ± 2.1	a,b,c>d**
FRT (cm)	27.9 ± 9.1	32.6 ± 8.3	29.6 ± 9.8	29.2 ± 10.1	
sEMG maximum discharge of vastus lateralis (µv)	1,069.5 ± 196.4	1,194.8 ± 201.1	831.1 ± 201.6	722.1 ± 175.1	
sEMG average discharge of vastus lateralis (µv)	173.2 ± 119.3	216.5 ± 103.3	190.7 ± 89.8	207.1 ± 77.1	
sEMG maximum discharge of vastus medialis (µv)	907.7 ± 193.4	1,175.2 ± 183.6	1,111.5 ± 162.6**	1,443.9 ± 118.7**	c<d**
sEMG average discharge of vastus medialis (µv)	160.2 ± 53.2	191.7 ± 59.1	137.5 ± 41.7*	184.2 ± 50.2*	c<d*
Maximum extensor strength (NM)	49.7 ± 19.6	55.3 ± 20.1	46.1 ± 20.5	48.1 ± 18.7	
Average extensor strength (NM)	45.7 ± 17.8	50.0 ± 19.1	40.5 ± 18.4	43.7 ± 17.6	

\*p&lt;0.05; \*\*p&lt;0.01

## REFERENCES

- 1) 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]
- 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) Arnold JA, Coker TP, Heaton LM, et al.: Natural history of anterior cruciate tears. *Am J Sports Med*, 1979, 7: 305–313. [Medline] [CrossRef]
- 4) 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]
- 5) Anwer S, Equebal A, Palekar TJ, et al.: Effect of locomotor training on motor recovery and walking ability in patients with incomplete spinal cord injury: a case series. *J Phys Ther Sci*, 2014, 26: 951–953. [Medline] [CrossRef]
- 6) Dietz V, Colombo G, Jensen L, et al.: Locomotor capacity of spinal cord in paraplegic patients. *Ann Neurol*, 1995, 37: 574–582. [Medline] [CrossRef]
- 7) Tang Q, Huang Q, Hu C: Research on design theory and compliant control for underactuated lower-extremity rehabilitation robotic systems code: (51175368); 2012.01–2015.12. *J Phys Ther Sci*, 2014, 26: 1597–1599. [Medline] [CrossRef]
- 8) Huang Q, Zhou Y, Yu L, et al.: The reliability of evaluation of hip muscle strength in rehabilitation robot walking training. *J Phys Ther Sci*, 2015, 27: 3073–3075. [Medline] [CrossRef]
- 9) Shim JK, Choi HS, Shin JH: Effects of neuromuscular training on knee joint stability after anterior cruciate ligament reconstruction. *J Phys Ther Sci*, 2015, 27: 3613–3617. [Medline] [CrossRef]
- 10) An KO, Park GD, Lee JC: Effects of acceleration training 24 weeks after anterior cruciate ligament reconstruction on proprioceptive and dynamic balancing functions. *J Phys Ther Sci*, 2015, 27: 2825–2828. [Medline] [CrossRef]
- 11) Wirz M, Colombo G, Dietz V: Long term effects of locomotor training in spinal humans. *J Neurol Neurosurg Psychiatry*, 2001, 71: 93–96. [Medline] [Cross-Ref]
- 12) Bae YH, Ko YJ, Chang WH, et al.: Effects of robot-assisted gait training combined with functional electrical stimulation on recovery of locomotor mobility in chronic stroke patients: a randomized controlled trial. *J Phys Ther Sci*, 2014, 26: 1949–1953. [Medline] [CrossRef]