



Original Article

Long-term interventions effects of robotic training on patients after anterior cruciate ligament reconstruction

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Abstract. [Purpose] The aim of this study was to examine the long-term interventions effects of robot-assisted therapy rehabilitation on functional activity levels after anterior cruciate ligament reconstruction. [Subjects and Methods] The subjects were 8 patients (6 males and 2 females) who received anterior cruciate ligament reconstruction. The subjects participated in robot-assisted therapy lasting for one month. The Timed Up-and-Go test, 10-Meter Walk test, Functional Reach Test, surface electromyography of the vastus lateralis and vastus medialis, and extensor strength of isokinetic movement of the knee joint were evaluated before and after the intervention. [Results] The average value of the of vastus medialis EMG, Functional Reach Test, and the maximum and average extensor strength of the knee joint isokinetic movement increased significantly, and the time of the 10-Meter Walk test decreased significantly. [Conclusion] These results suggest that walking ability and muscle strength can be improved by robotic walking training as a long-term intervention.

Key words: Robot-assisted therapy, Anterior cruciate ligament, 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 injuries¹⁾. ACL injury is a common cause of knee instability and alters the kinematics of the knee²⁾. Approximately 91% of ACL injuries occur during sports activities. Most are caused by non-contact injury mechanisms, such as landing from a jump, or rapid deceleration³⁾. An ACL injury typically occurs during the landing portion of a jump in ordinary sports activities and has a greater incidence among women than among men⁴⁾. ACL deficiency may lead to degenerative changes such as tears of the meniscus. Meniscus damage may be correlated to an increased incidence of knee arthrosis. Patients with ACL injury often have symptoms of knee instability, which may lead to functional change in and damage to other joint structures, and interfere with activities of daily living⁵⁾. Patients with ACL injuries have difficulty recovering normal walking ability and full function of the lower limbs⁶⁾.

Knee instability following ACL injury results in various negative factors, which can be circumvented using ACL reconstruction. Reconstructive techniques have been refined to achieve better stabilization of the knee and other joints in order to improve functional recovery⁷⁾. It has been suggested that the lack of full recovery of knee function after ACL reconstruction is due to sensory and motor behavior deficits. Muscle strength, endurance, flexibility and balance training are used as therapeutic exercises in rehabilitation settings. Proprioceptive afferent neural input is also important in functional control

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during sports activities⁸). In the clinic, patients are always asked to walk normally, but few exercise methods provide normal proprioceptive input during walking training.

In recent years, robot-assisted therapy (RAT) rehabilitation, which simulates normal walking, has also been used to help patients with spinal cord injury or stroke⁹). 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 RAT, so that alternative steps with both feet can be achieved by patients¹⁰). 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 improvements in reaction time and bowel function^{11, 12}).

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

SUBJECTS AND METHODS

This study recruited 8 patients who underwent arthroscopic ACL reconstruction in BoAi 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 showed no differences in anatomical stability based on radiographic and magnetic resonance imaging.

The characteristics of the 8 subjects (6 males and 2 females) are shown in Table 1. The subjects participated in RAT for one month. The purpose and content of this research were explained to the subjects, who gave their informed consent to participation in this study. The study was approved by the Research Ethics Committee of China Rehabilitation Research Center (IRB no. 2014-K-005).

In the RAT treatment, normal rehabilitation training was carried out as traditional physiotherapy, which included the muscle strength training, joint mobilization, balance training, and endurance training. The walking training used a rehabilitation training robot (MBZ-CPM1, ManBuZhe [Tian Jin] Rehabilitation Equipment Co., Ltd., China). In the treadmill and RAT training, 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 quality¹³). The body weight system was initiated at 35%, and 70% guidance force was provided for the participants¹⁴). The walking training lasted for 20 min a day, and was performed 5 times a week. The extension strength of the knee joint, and walking and balance abilities were measured before and after the one-month intervention.

Because of ethical considerations, a control group was not used in this experiment.

Walking ability was evaluated using the 10-Meter Walk test (10MWT) and the Timed Up-and-Go (TUG) test. Balance ability was assessed using 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 (VL) and vastus medialis (VM) muscles, maximum isometric contraction in the start position was maintained for 5 s, during which the maximum and average sEMG values of the muscle were measured by an sEMG system (Telemetry 2400T; Noraxon, Scottsdale, AZ, USA). The maximum and average extensor strengths of isokinetic movement of the knee joint were measured using an isokinetic dynamometer (Prima Plus, Easytech, Italy). All measurements were carried out by one physiotherapist. The Wilcoxon test was used to compare the 10 MWT, TUG, FRT, the maximum and average sEMG values of VL and VM, and the maximum and average extensor strengths of the knee joint isokinetic movement before and after the one-month intervention. Data were analyzed using SPSS Ver. 17.0 for Windows. The level of statistical significance was chosen as 0.05.

RESULTS

All the subjects in this study received RAT training 20 times over one month. The results of the 8 subjects are shown in Table 2.

The average sEMG value of VM, FRT, and the maximum and average extensor strengths of the knee joint isokinetic movement increased significantly. The time of 10MWT decreased significantly. However, the changes the maximum and average sEMG values of VL, the maximum sEMG values of VM and TUG were not significant.

DISCUSSION

According to the results, the walking ability, balance ability and the extensor strength of the knee joint were improved by the RAT treatment, and the average sEMG value of the vastus medialis muscle significantly increased.

The reason for these results is that robotic walking training enabled the bilateral lower limbs to perform alternative and circulatory movements, which can effectively adjust lower limb movement after ACL reconstruction. In this manner, walking ability can also be improved.

There was no significant change in the sEMG value of the vastus lateralis, presumably because weakness of knee joint muscle is often observed in the vastus medialis, which is the first muscle to show weakness among the quadriceps muscles¹⁵).

Table 1. Subject characteristics

	Mean \pm SD (N=8)
Age (yrs)	35.2 \pm 3.2
Height (cm)	173.4 \pm 8.6
Weight (kg)	79.5 \pm 16.8

Table 2. The long-term interventions effects of RAT

	10MWT (s)	TUG test (s)	FRT (cm)	Maximum sEMG value of lateralis(μ v)	Average sEMG value of lateralis(μ v)	Maximum sEMG value of medialis (μ v)	Average sEMG value of medialis (μ v)	Maximum extensor strength (NM)	Average extensor strength (NM)
Before one month RAT intervention	8.8 \pm 1.1*	10.0 \pm 0.8	19.3 \pm 5.1**	1,872.2 \pm 966.0	280.3 \pm 131.1	1,405 \pm 676.5	189.5 \pm 60.3*	41.0 \pm 22.3*	37.0 \pm 21.7**
After one month RAT intervention	7.3 \pm 0.3*	9.5 \pm 1.6	26.5 \pm 4.8**	1,915.7 \pm 827.4	315.0 \pm 113.5	1,590 \pm 261.7	230.3 \pm 67.2*	52.3 \pm 24.1*	47.7 \pm 22.5**

*p<0.05; **p<0.01.

10MWT: 10-Meter Walk test; TUG: Timed Up-and-Go; FRT: Functional Reach Test; RAT: Robot-assisted therapy

Many studies have attempted to suggest the best angular velocity during isokinetic exercise to selectively strengthen the vastus medialis¹⁶. However, compared to the vastus lateralis, the vastus medialis was clearly enhanced by RAT training.

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

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