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Original Article

The effect of weight-bearing exercise and non-weight-bearing exercise on gait in rats with sciatic nerve crush injury

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Abstract. [Purpose] The purpose of this study was to access the effect of weight bearing exercise (treadmill exercise) and non-weight-bearing exercise (swimming exercise) on gait in the recovery process after a sciatic nerve crush injury. [Subjects and Methods] Rats were randomly divided into a swimming group (n=3) with non-weight-bearing exercise after a sciatic nerve crush and a treadmill group (n=3) with weight bearing exercise after a sciatic nerve crush. Dartfish is a program that can analyze and interpret motion through video images. The knee lateral epicondyle, lateral malleolus, and metatarsophalangeal joint of the fifth toe were marked by black dots before recording. [Results] There were significant differences in TOK (knee angle toe off) and ICK (knee angle at initial contact) in the swimming group and in TOK, ICA (ankle angle at initial contact), and ICK in the treadmill group. In comparison between groups, there were significant differences in TOA (ankle angle in toe off) and ICA at the 7th day. [Conclusion] There was no difference between weight bearing and non-weight-bearing exercise in sciatic nerve damage, and both exercises accelerated the recovery process in this study.
Key words: Sciatic nerve crush injury, Weight-bearing exercise, Gait

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INTRODUCTION

Owing to the development of transportation and increased leisure time, the frequency of damage in nervous tissue, especially in peripheral nerves, is on the rise[1)]. The clinical problems of peripheral nerve damage are motor paralysis of muscle, sensory paralysis, and functional loss, and such neurological injuries are mostly caused by strong crushing and cutting due to an external force[2)]. Additionally, pain from sciatic nerve damage can be caused by herniated nucleus pulposus (HNP), spinal stenosis, and piriformis muscle syndrome and may lead to hip pain and functional loss and paresthesia of lower extremities[3)]. Peripheral nerve damage eventually generates partial or total loss of the motor, sensory, and autonomic nervous systems including body segments[4)].

Compensation for a functional disorder caused by neurological injury consists of reinnervation of neural paralysis by regeneration of damaged axon terminals, reinnervation from neighboring undamaged axon terminals to dendritic branches, and reformation of neural system circuits relating to lost functions[1)]. However, this mechanism does not come with satisfying functional restoration and it is hard to expect recovery in the case of severe neurological injury[4)].

Microsurgical techniques such as neurorrhaphy and nerve grafting are used to repair severe neurological injury. Lundborg[5)] proved that acute electrical stimulation after sciatic nerve damage accelerated muscle reinnervation improvement and axonal regeneration. In addition, long-term moderate-intensity treadmill exercise with acute electrical stimulation in the beginning of nerve regeneration was found to be more effective[6)]. Previous studies reported that active and passive exercise using bicycle training was effective for sciatic nerve damage[7)], treadmill exercise accelerated functional recovery and decreased neuropathic pain[8)], and swimming exercise after a sciatic nerve crush injury accelerated muscle recovery[9)]. A number of recovery methods for peripheral nerve damage have been analyzed as mentioned above, but these analyses only focused on the exercise method or intensity, and there are few studies about weight-bearing and non-weight-bearing exercise. Therefore, the purpose of this study was to access the effect of weight-bearing exercise (treadmill exercise) and non-weight-bearing exercise (swimming exercise) on gait in the recovery process after a sciatic nerve crush injury.

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Table 1. Comparison of gait for each group

Variable		3 days	7 days	13 days
TO-A	TMG	40.03±5.47	43.85±3.94	46.10±7.87
	SMG	44.37±10.40	51.47±7.91[b]	45.10±6.77
TO-K	TMG	71.80±10.70	71.02±8.21	53.54±5.62[a]
	SMG	75.21±12.30	78.53±12.91	51.70±12.45[a]
IC-A	TMG	60.06±9.69	64.47±6.22	70.32±8.21
	SMG	55.66±75.03	75.03±8.07[b]	65.57±15.46[a]
IC-K	TMG	84.70±10.95	91.11±5.61	77.18±2.09[a]
	SMG	87.50±14.61	93.00±4.04	68.75±12.99[a]

*p<0.05. TO-A: ankle angle at toe off; TO-K: knee angle toe off; IC-A: ankle angle at initial contact; IC-K: knee angle at initial contact; TMG: treadmill exercise group; SMG: swimming exercise group. [a]Significant difference between periods. [b]Significant difference between TMG and SMG

SUBJECTS AND METHODS

This study was conducted with 6 male white Sprague-Dawley rats at 8 weeks of age. These rats weighed 250–300 g and were bred three rats per cage in a breeding room at a temperature of 23±2 °C and humidity of 50±5% during the test. A 12/12-h light/dark cycle was used each day. Solid feed (Cargill Agri Purina Inc., Seongnam, Republic of Korea) and water were provided without limitation to the rats. This study was conducted in compliance with the guide for the care and use of laboratory animals and with the permission of our Institutional Animal Care and Use Committee.

Zoletil (Virbac Laboratories) and Rompun (Bayer Korea) mixed at a 1:1 ratio were intraperitoneally injected at 2 ml/kg body weight into the rats for general anesthesia. Pain avoidance response was observed to check for signs of anesthesia. The right femoral and knee joint region of the animals were shaved while they were fixed on the operating table to measure sciatic nerve crush injury and gait. Then, a 2 cm incision was made in the right posterior femoral region, the surrounding muscles were separated, and the proximal region (7 cm from the ankle joint, ahead of the tibial and non-tibial nerve branching off from the sciatic nerve) was compressed for 30 min using hemostatic forceps (Crile). The forceps were covered with soft plastic during application of pressure. Three-level forceps were used to apply constant force. After crushing, a suture using suture thread for animal testing was applied, and the skin was disinfected. The rats were allowed to acclimate to the environment in standard plastic cages (290 × 430 × 180 mm), three rats per cage, until the intervention.

The rats were randomly divided into a swimming group (n=3) with non-weight-bearing exercise after induction of the sciatic nerve crush injury and a treadmill group (n=3) with weight-bearing exercise after induction of the sciatic nerve crush injury.

Ankle and knee angles of all white rats were evaluated using the Dartfish program (ProSuite, Dfkorea, Seoul, Republic of Korea) at 3, 7, and 13 days after the intervention for motor behavioral motion analysis according to recovery from the sciatic nerve damage. Dartfish is a program that can analyze and interpret motion through video images. The knee lateral epicondyle, lateral malleolus, and metatarsophalangeal joint of the fifth toe were marked by black dots before recording. The rats walked on a transparent pathway (100 cm long, 8 cm wide, and 10 cm high) during recording. They did this three times to get used to the pathway and then repeated it three times for the evaluation. They were recorded with a digital video camera placed 1 m away from the pathway in the sagittal plane.

All measurements are described as the mean value ± standard deviation. The independent t-test was used for comparison of the results of the motor behavioral test between the two groups. One-way ANOVA was used to analyze significant differences among groups and measuring periods. The least significant difference (LSD) was used for post hoc analysis. IBM SPSS Statistics for Windows, Version 20.0, was used for statistical processing, and the statistical significance level was set to $\alpha = 0.05$.

RESULTS

There were significant differences in TOK (knee angle toe off) and ICK (knee angle at initial contact) in the treadmill group ($p<0.05$) and in TOK, ICA (ankle angle at initial contact), and ICK in the swimming group ($p<0.05$). In comparison between groups, there were significant differences in TOA (ankle angle at toe off) and ICA at the 7th day ($p<0.05$) (Table 1).

DISCUSSION

Peripheral nerves damage causes pain and deficits in sensory and motor nerves, and regeneration ability depends on damage level[10, 11].

There is no functional recovery method for severe nerve injury, and surgical repair is generally used[12]. In addition, owing to natural reinnervation and damage to neural factors necessary for recovery of damaged function, active neural redistribution may not be expected[13]. Therefore, proper intervention is needed to prevent severe nerve damage and paresthesia. There are many studies about intervention methods, particularly those using external stimulation.

In this study, a gait analysis was used as an effectiveness evaluation for therapeutic intervention, and the effect of weight-bearing exercise using a treadmill and non-weight-bearing exercise (swimming) on gait in the recovery process after a sciatic nerve crush injury was assessed.

After peripheral nerve damage, axons in the damaged region are disconnected from nerve cell bodies and degenerated, and neural responses and chromatolysis form in the damaged nerves. Wallerian degeneration generates a micro-environment in the distal region and causes neural responses for regeneration and elongation and regrowth of surviving axons.

In the axonal regeneration process in the damaged nerve, Schwann cells proliferate in the damaged area and move to the distal region, followed by axonal contact and regeneration. Schwann cells proliferate until complete regeneration, and a myelin sheath is ultimately formed[14)].

Neurotrophic factors are involved in the growth and differentiation of nerve cells, and all neurotrophins have similar biochemical characteristics. The expression level of neurotrophins and their acceptors can change according to neural activity. Neurotrophins are an important factor for sensorimotor function control[15, 16)].

After rats with sciatic nerve damage conducted wheel running exercise, neurotrophins and nerve regeneration increased[17)]. In a study by Udina et al.[7)], there was more axonal reinnervation in their bicycle training group.

Previous studies showed that exercise interventions were effective for nerve injury[18, 19)]. Gutmann and Jakoubek[20)] reported that swimming exercise for recovery from sciatic nerve damage increased axonal growth and that treadmill running exercise increased reinnervation, axonal elongation, and sprouting. These results are consistent with the results of this study, that is, that treadmill and swimming exercise were effective for nerve recovery.

There was a decrease in gait ability at the beginning of testing (first 7 days). This was a period of inflammatory response and recovery for other tissues and with Wallerian degeneration after 4 days, nerve function was considered to decrease[21)]. The results of the present study showed no substantial difference between treadmill and swimming exercise. Therefore, there was no difference between the effects of weight-bearing and non-weight-bearing exercise on sciatic nerve damage, and both exercises accelerated the recovery process in this study. A limitation of this research is that only gait ability was measured, so neurotrophins expression should be evaluated in further studies.

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