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Effects of Progressive Resistance Training Integrated with Foot and Ankle Compression on Spatiotemporal Gait Parameters of Individuals with Stroke

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Abstract. [Purpose] The purpose of this study was to investigate the effect of progressive resistance training (PRT) integrated with foot and ankle compression on the gait ability of post-stroke patients. [Subjects and Methods] Participants were randomly allocated to two groups: the PRT group (n=14) and the control group (n=14). Subjects in the PRT group received training for 30 minutes, five days per week, for a period of six weeks. Gait ability was evaluated using the RsScan system. [Results] Use of PRT integrated with foot and ankle compression resulted in significant improvements in temporal parameters (gait velocity, step time, and double limb support) and spatial parameters (step length, stride length, and heel-to- heel base of support). [Conclusion] Progressive resistance training integrated with foot and ankle compression improved the gait ability of stroke patients. These results suggest the feasibility and suitability of integration of PRT with foot and ankle compression for individuals with stroke.

Key words: Progressive resistance training, Stroke, Gait

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INTRODUCTION

Hemiparesis, one of the most common impairments after stroke, contributes to limitation of activity, such as reduced gait performance[1)], which in turn can lead to restrictions in perceived participation[2)]. Even though the majority of stroke survivors are able to walk independently six months after stoke[3, 4)], many patients cannot walk with sufficient speed, have to use a walking aid, or are restricted in their indoor and outdoor mobilities[5)]. Gait ability, which determines, to a large degree, the level of independence of daily living, has been reported by patients to be the most important goal for rehabilitation[1)].

Recently, progressive resistance training (PRT) has been shown to be an effective way of increasing strength in the neutrally-intact muscles of able-bodied individuals, provided that training is performed with sufficient resistance, and it is appropriately progressed[6)]. In particular, the benefits of PRT integrated with foot and ankle compression are becoming increasingly accepted and employed in clinical settings. PRT exercises are typically performed with the feet fixed on a stable object to generate compressive forces on the hip, knee, and ankle joints. PRT integrated with foot and ankle compression has been shown to increase neuromuscular control of the lower extremities of young athletes[7, 8)].

Many previous studies have investigated the effect of PRT on muscle activation of the lower limbs of orthopedic patients, however, no study on the effects of integration of PRT with foot and ankle compression on hemiplegic gait has been reported. The aim of this study was to determine whether rehabilitation, delivered as PRT integrated with foot and ankle compression, would increase the walking performance of stroke patients.

SUBJECTS AND METHODS

This study recruited 28 patients who were admitted to K hospital in Korea after being diagnosed with stroke (Table 1). The subjects understood the contents of the study and agreed to participation. The inclusion criteria were as follows: a Brunnstrom stage higher or equal to stage 3; presence of hemiparesis resulting from a single stroke that had occurred in the past six months; ability to communicate and understand with a Mini-Mental Status Examination score of over 24 points; no known musculoskeletal conditions that might have affected patients ability to walk safely and repeatedly; and ability to walk 10 m, independently, with or without use of an assistive device. All of the participants understood the purpose of this study and gave their written informed consent before experimental involvement. The study was performed in compliance with the Declaration of Helsinki, and was approved by the local committee of the Institutional Review Board of a university hospital.

PRT integrated with foot and ankle compression was performed in a sitting position, with the paretic foot fixed on the pedal of a Leg Press Rehap exercise machine with

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Table 1. Baseline characteristics of each group

Variables	PRT group	Control group
Sex (male/female)	9/5	8/6
Age (years)	60.3±7.5	61.1±8.6
Type of stroke (ischemic/hemorrhagic)	9/5	7/7
Paretic side (right/left)	8/6	7/7
Time since stroke onset (month)	19.2±5.2	18.3±6.3
Height (cm)	167.4±4.4	166.3±6.5
Weight (kg)	72.1±10.1	71.5±10.8

Table 2. Comparison of the gait abilities of the PRT and control groups

	PRT group		Control group	
	Pre	Post	Pre	Post
Step length (cm)	30.4±1.6	36.2±2.0*†	31.0±2.2	31.8±2.1
Stride length (cm)	71.0±1.1	77.1±1.2*†	70.5±1.0	71.9±1.1
H-H BOS (%)	13.6±0.6	11.3±0.6*†	13.8±0.4	13.4±0.4
Step time (sec)	0.98±0.28	0.83±0.07*†	1.06±0.06	1.00±0.07
Double support (%)	40.4±0.7	36.4±1.1*†	40.6±0.9	39.3±0.5
Gait velocity (m/s)	0.64±0.07	0.81±0.03*†	0.67±0.07	0.70±0.07

* significant difference between pre- and post-test ($p<0.05$), † significant difference from the control group ($p<0.05$), H-H BOS: heel-to-heel of support

pneumatic resistance (pressure resistance 10 bar) (HUR, Finland). Participants were asked to fully extend the paretic leg and then slowly flex the knee joint to 90 degrees of knee flexion. Then they were asked to extend and slowly flex the knee joint to the starting position. PRT integrated with foot and ankle compression was performed five times per week for six weeks. Participants in the control group maintained routine activities, but did not participate in any regular exercise programs. Training sessions started with a warm-up of four repetitions of 25% of their individual 1-repetition maximum (1RM), followed by three sets (eight to 10 repetitions per set) performed at 70% of 1RM. Training intensity was adjusted weekly with reassessments of 1RM. All exercise was performed individually and supervised by a physical therapist. Prior to each session, participants' feedback regarding adverse effects, such as post exercise pain and stiffness, were also considered in the progression of the exercise.

Gait abilities were measured using an electrical walkway system (RsScan Ltd., German). The system, which captures temporal and spatial gait parameters, consists of an 1.95 × 0.32 m instrumented mat with 16,384 embedded pressure sensitive sensors, arranged in a 48 × 576 grid, evenly spaced at 2.6-cm intervals. The data sampling rate was 500 Hz. Data were input to a computer and analyzed using gait analysis software (RsScan International). Subjects were instructed to walk at a comfortable gait speed in all three trials. In order to maintain gait speed on the mat, subjects initiated and terminated walking at a minimum of 3 m from the start and end of the walkway. A verbal command was given to initiate walking and one of the examiners accompanied the subject in order to prevent a fall during walking. Step length, stride length, heel-to-heel base of support (H-H BOS), step time, double support period, and gait velocity of the paretic leg were measured.

Statistical analyses were performed using SPSS version 17.0 software. Tests for normality were performed for all continuous variables. Pre- and post-intervention data were examined using the paired t-test within each group of subjects and the independent t-test was used for between-group comparisons. The level of statistical significance was chosen as 0.05.

RESULTS

After six weeks of intervention, the gait velocity, step length, and stride length showed significant increases in the PRT group ($p<0.05$) compared to their pre-intervention values. In addition, step time, double support, and H-H BOS showed significant decreases in the PRT group, compared to pre-intervention ($p<0.05$). However, no significant differences were observed in the control group ($p>0.05$).

Changes in temporal parameters (step time, double support time, and gait velocity) and spatial parameters (step length, stride length, and H-H BOS) after six weeks differed significantly between the PRT group and the control group ($p<0.05$) (Table 2).

DISCUSSION

The purpose of this study was to investigate the effect of PRT integrated with foot and ankle compression on the gait ability of stroke patients. Our results demonstrate that PRT integrated with foot and ankle compression is an effective form of training that improves the functional mobility of stroke patients by improving their gait abilities. This type of training can be actively utilized in physical therapy clinics.

Stroke patients have a characteristic gait pattern which shows a slow gait cycle and gait speed, short stride length and stance phase on the affected side, and a relatively long swing phase[9]. During abnormal walking, a shortened weight-supporting time of the lower extremity is usually seen on the affected side, and balance control during gait becomes difficult due to a prolonged period of double limb support, leading to a decline in energy efficiency[10]. In this study, regarding temporal parameters, significant decreases in step time and double support time were observed in patients in the PRT group, compared to the control group, and the gait velocity increased following training. Regarding the spatial parameters, patients in the PRT group showed significant increases in step length and stride length after the exercise, while the heel-to-heel base of support showed a significant decrease.

It is possible that PRT integrated with foot and ankle compression helps to strengthen lower limb muscles while simultaneously[11] using the hip, knee, and ankle joints. This would therefore provide feedback from the entire lower extremity, and increase stimulation of the mechanoreceptors around the joint and firing of muscle spindles[12, 13]. In addition, increased neuroplasticity and brain reorganization in response to repeated PRT integrated with foot and ankle compression would improve the gait function of stroke patients through motor re-learning.

PRT integrated with foot and ankle compression is one of the most important treatment methods for enhancement functional ability. A limitation of this study was that subjects with very good gait abilities and very bad gait abilities were excluded; therefore, its results cannot be generalized to all stroke patients. In addition, the subjects' daily living activities were not completely limited during the study period; therefore, the effect of daily living activities on the change in gait ability observed cannot be completely excluded.

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