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The Effect of Using Trunk Control Pelvic Movement Exercise in the Sitting and Standing Positions on the Relative Impulse of Hemiplegic Patients

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Abstract.[Purpose] The purpose of this study was to investigate the effect of using trunk control pelvic movement (TCPM) exercises with changes in the body position on the relative impulse in hemiplegic patients. [Subjects] Thirty-seven hemiplegic patients were randomly divided into 3 groups: control group (CG, n=12), sitting exercise group (SIEG, n=12), and standing exercise group (STEG, n=13) [Methods] A F-Scan System was used to measure the relative impulse of foot pressure on the hemiplegic side during walking. [Results] After the exercise, the relative impulses of the hallux and 2nd, 3rd metatarsal heads in SIEG and STEG were significantly increased during walking. [Conclusion] These results suggest that TCPM exercise in the sitting and standing positions is effective at improving foot pressure on the hemiplegic side. In addition, propulsion during push off was increased in the standing position.
Key words: Pelvic movement, Relative impulse, Body position

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INTRODUCTION

Hemiplegic patients exhibit asymmetry of the trunk and pelvis due to weakened muscle strength and loss of sense on the affected side[1)]. This problem increases the postural body sway and impairs hemiplegic patients' ability to maintain standing balance and walking, leading to difficulties in independent living[2)].

Thus, it is important to recover the symmetry of the pelvis so that hemiplegic patients can walk and carry out functional activities[3)]. Pelvic tilting exercises affect the lower trunk[4)], and in the physical therapy of hemiplegic patients, using trunk control pelvic movement (TCPM) exercises influences the asymmetric pelvis, and improves the walking ability of hemiplegic patients by improving the stability of the body and the balance reaction[5)]. TCPM can be done in both the sitting and standing positions[6)]. Depending on the position, there are differences in the abdominal muscles and trunk muscles involved in pelvic movement, the sense information used for positional control, and the biomechanical load[7)]. Therefore, it is likely that there are differences in the effects of TCPM exercises in different positions, such as sitting and standing. However, in earlier studies, TCPM exercise has primarily been performed in the sitting[8)] and side lying positions[5)], and scientific research on TCPM in the standing position is currently insufficient. That is, there are few studies on the effects of TCPM in the standing position on the walking of hemiplegic patients and on the differences between the effects of TCPM in the standing position and other positions.

Thus, in this study, the relative impulse of foot pressure was measured after performing TCPM in both the standing and sitting positions, and the effects of TCPM in these positions on relative impulse of foot pressure were compared to provide basic data for the treatment of hemiplegic patients.

SUBJECTS AND METHODS

The subjects of this study were patients hospitalized after being diagnosed with stroke by CT or MRI in the D University Hospital in Daegu, Republic of Korea, who understood and voluntarily agreed to participate in this study, and who met the criteria set by this study. Twelve patients received only physical therapy, 13 patients performed TCPM in the standing position in addition to traditional physical therapy, and 12 patients performed TCPM in sitting position. All the patients were randomly chosen and assigned to the control group (CG), sitting exercise group (SIEG), and the standing exercise group (STEG). The subjects were patients who had been

Table 1. General Characteristics of Subjects (Mean ± SE)

Variables	CG (n=12)	SIEG (n=12)	STEG (n=13)
Gender (Male/Female)	7/5	7/5	8/5
Age (yr)	55.85 ± 3.15	57.92 ± 2.15	52.00 ± 1.92
Height (cm)	165.69 ± 1.81	166.50 ± 1.98	168.83 ± 1.70
Weight (kg)	64.08 ± 2.28	65.75 ± 3.28	67.42 ± 3.13
Foot size (mm)	259.62 ± 3.47	256.67 ± 3.39	258.33 ± 1.98
Duration (month)	42.31 ± 4.85	38.67 ± 4.20	31.33 ± 3.36
Affected side (Right/Left)	5/7	4/8	5/8
Cause (Infarction/Hemorrhage)	8/4	9/3	9/4

* $p<0.05$, CG = control group, SIEG = sitting exercise group, STEG = standing exercise group.

hemiplegic for at least 3 months due to stroke; who could maintain the standing position for at least one minute without any help; who could walk independently for at least 30 m in an indoor environment; who had no orthopedic disease in their legs or trunk; whose modified Ashworth scale of the leg on the affected side was G2 or lower; who could understand and follow the directions of the researcher; and, who voluntarily participated in this study. The general characteristics of the subjects are listed in Table 1.

The control group received the conventional physical therapy. The conventional physical therapy consisted of exercise therapy for 30 minutes, functional electrical stimulation (FES) for 15 minutes, and rehabilitation ergometer training for 15 minutes. The sitting exercise group performed TCPM in the sitting position while receiving conventional physical therapy. The standing exercise group performed TCPM in the standing position while receiving the conventional physical therapy. For the sitting position, the patients sat at the depth of 2/3 of the femoral length on the edge of the treatment bed, the height of which was adjustable, bent their knees to 90°, touched the floor with their both feet, and put both their arms comfortably on their knees. For the standing position, the patients maintained hip joint flexion of 30°, knee joint flexion of 80°, and ankle joint dorsal flexion of 20° as though riding a horse. For the TCPM exercise, the patients performed separate selective pelvic exercises together with the therapist in which the pelvis was tilted forward, backward, and sideways, at first as a passive exercise, and gradually as an active-assistive exercise and then as an active exercise. The subjects performed the TCPM exercise for 20 minutes each time, four times a week, for 8 weeks.

For the measurement of foot pressure, a F-scan system (Tekscan, Inc., USA) was used to measure the relative impulse of each subject's foot pressure measured throughout the entire stance phase. This system consists of a flexible cuttable thin pressure sensor with a thickness of 0.2 mm in which 960 pressure sensing locations are evenly distributed in a lattice pattern at intervals of 560 mm. The sensor has transducers that can be attached to the legs, cables for connection between the transducers and the computer, and software and a computer for analysis of foot pressure.

The subjects wore the same type of slippers, which had no arch support to reduce errors caused by arch support, with pressure sensors attached to them that had been cut to the foot lengths of the subjects. The subjects were asked to walk at a comfortable and normal speed on a straight path for 10 seconds. During walking, the relative impulse of foot pressure was measured at 6 points: the hallux of the affected side foot, the 1st metatarsal head, the 2nd and 3rd metatarsal heads, the 4th and 5th metatarsal heads, the midfoot, and the heel. For natural walking, the subjects walked at their usual speed. The tests were conducted three times and individual averages were used in the analysis. The relative impulse of foot pressure was measured when the sole of the foot contacted the floor surface throughout the entire stance phase in the walking cycle.

The experimental results were statistically analyzed using SPSS 12.0 KO (SPSS, Chicago, IL, USA). After the general characteristics of the subjects were determined, a t-test was used to compare the changes in the foot pressure patterns of each group before and after TCPM. A one-way analysis of variance was performed and the LSD post-hoc test was used. The statistical significance level, α, was chosen as 0.05.

RESULTS

The differences in the relative impulse of foot pressure on the affected side between before and after exercise in the sitting and standing exercise groups (Student's t-test $p<0.05$) showed statistically significant differences at the hallux and the 2nd and 3rd metatarsal heads (Table 2).

In the one-way analysis of variance for the differences in the relative impulse of foot pressure on the affected side between before and after exercise, each group showed statistically significant differences at the hallux. Furthermore, the LSD post-hoc test found statistically significant differences between the control group and the standing exercise group ($p<0.05$) (Table 3).

DISCUSSION

Hennig and Rosenbarm reported that the relative impulse was greatest at the hallux and central forefoot in normal adults[9]. Since hemiplegic patients cannot put their weight fully onto their hemiplegic leg, nor mobilize the muscles in their hemiplegic leg when adjusting in the balance reaction, the weight support of the hemiplegic foot mainly occurs through the forefoot and lateral margin of the foot due to the imbalance of the ankle joint muscles[10]. In this study, the

Table 2. Comparison of relative impulse of foot pressure between pre and post-intervention in each group

	group	pre	post		group	pre	post
Hallux	CG	3.83 ± 0.45	3.96 ± 0.58	M4,5	CG	13.55 ± 0.73	13.91 ± 0.77
	SIEG*	3.99 ± 0.43	4.93 ± 0.48		SIEG	14.61 ± 1.09	14.38 ± .1.25
	STEG*	3.23 ± 0.38	5.05 ± 0.68		STEG	12.44 ± 0.91	12.00 ± 0.81
M1	CG	3.86 ± 0.45	3.92 ± 0.45	Mid foot	CG	5.78 ± 0.49	5.64 ± 0.47
	SIEG	3.87 ± 0.41	4.08 ± 0.33		SIEG	5.51 ± 0.66	5.46 ± 0.63
	STEG	3.91 ± 0.53	3.97 ± 0.52		STEG	5.22 ± 0.51	5.40 ± 0.51
M2,3	CG	11.77 ± 0.56	12.32 ± 0.73	Heel	CG	29.46 ± 2.11	30.68 ± 2.17
	SIEG*	11.03 ± 0.93	12.31 ± 0.98		SIEG	28.17 ± 1.92	29.14 ± 2.00
	STEG*	12.54 ± 0.84	14.06 ± 0.96		STEG	34.40 ± 2.08	35.05 ± 1.90

M ± SE. Unit: %. * $p<0.05$.

Table 3. Relative impulse of hallux: difference between pre and post-intervention in each group

	CG	SIEG	STEG
Hallux*	0.13 ± 0.36	0.95 ± 0.42	1.82 ± 0.59
M1	0.07 ± 0.06	0.22 ± 0.15	0.06 ± 0.06
M2,3	0.55 ± 0.53	1.28 ± 0.54	1.51 ± 0.56
M4,5	0.36 ± 0.32	–0.23 ± 0.44	–0.44 ± 0.55
Mid foot	–0.14 ± 0.14	–0.05 ± 0.11	0.18 ± 0.12
Heel	1.21 ± 0.76	0.97 ± 0.74	0.65 ± 0.70

M ± SE. Unit: %. *$p<0.05$.

relative impulse of the hallux and the 2nd and 3rd metatarsal heads of the sitting exercise group and the standing exercise group significantly increased after exercise. The reason for this was that TCPM exercise in the sitting and standing positions shifts the lateral weight support of the hemiplegic patients to the medial side, which improves foot pressure closer to the normal pattern. When compared to the control group, the standing exercise group showed a more significant increase in relative impulse of the hallux compared to the sitting exercise group. This result suggests that, compared to other groups, the standing exercise group showed greater propulsion during push off. The strengthening of the hip extensor muscle is associated with a reduction in compensatory movement of the pelvis in the frontal plane and the generation of forward propulsion during the walking of stroke patients[11]. The strengthening of the ankle plantar flexor muscle increases forward acceleration of the trunk[12]. Furthermore, the improved muscular force and control of the legs through TCPM exercise in the standing position reduces the compensatory movement of the pelvis and increases the propulsion in walking.

The asymmetric trunk[2] and pelvis movement[13] also influence the relationship between the foot center of mass and the pelvis center of mass during the walking of hemiplegic patients. The anterior and posterior asymmetry of the foot center of mass of the affected side, and the pelvis center of mass of hemiplegic patients, is associated with the asymmetry of the step length and propulsion, and the inside and outside asymmetry is associated with the weight load of the affected side[14]. In this study, TCPM exercise in the standing position increased the relative impulse of the hallux. If this is interpreted as increased propulsion, the TCPM exercise in the standing position seems to have influenced the anterior and posterior asymmetry of the foot center of mass and pelvis center of mass whilst the hemiplegic patients were walking.

Based on this finding, we believe that TCPM exercise in both the sitting and standing positions is effective at improving the foot pressure pattern on the hemiplegic side by increasing the relative impulse of the hallux and the 2nd and 3rd metatarsal heads. Furthermore, judging from the increased relative impulse of the hallux of the standing exercise group compared to the control group, we believe TCPM improves the propulsion during push off. More accurate findings from research on the walking patterns of hemiplegic patients can be expected through continuous studies of the time and space elements of walking, and the qualitative aspects of walking such as the compensatory function of the arms.

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