대한물리치료학회지 제11권 제3호
The Journal of Korean Society of Physical Therapy
Vol. 11, No. 3 pp 71~79, 1999.

The Effect of Balance Training using Force Platform on Postural Control and Central Somatosensory Pathway in Adults with C. N. S. Disorders

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Force Platform을 이용한 평형성 훈련이 중추신경계 손상자의 자세조절 및 중추 감각신경전도로에 미치는 영향

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<국문초록>

본 연구의 목적은 균형 훈련이 중추신경계 손상자들의 자세 조절 및 중추감각신경전도로에 미치는 영향을 규명하는데 있다. 연구대상자는 중추신경계 손상자로써 실험군 10명, 통제군 10명 등 총 20명을 선정하였으며, 실험군은 본 연구의 훈련 프로그램에 따라 12주간 force platform을 이용하여 균형훈련을 실시토록 하였다.

자세조절 변인의 측정은 운동처치 전, 처치 후 8주 및 12주 후에 대상자들의 동적 및 정적 자세에서의 흔들림을 Dynamic Balance System을 이용하여 측정하였고, 체성감각 유발전위의 말초신경 근위부 유발전위(N_9) 잠복기, 척수 유발전위(N_{13}) 잠복기, 뇌 유발전위(N_{20}) 잠복기는 Neurotec을 이용하여 측정 · 분석한 결과 다음과 같은 결론을 얻었다.

1. 정적 자세 조절 요인의 경우, 좌우 흔들림과 전후 흔들림은 실험군에서 8주 후부터 유의하게($p<.05$) 감소하였고, 실험군이 통제군에 비해 운동처치 8주 및 12주 후에 각각 유의하게($p<.05$, $p<.01$) 흔들림이 감소하였다.
2. 전후 이동면과 전후 기울기면에서 동적 자세 조절의 변화는 전후 이동면에서 좌우 흔들림과 전후 흔들림은 실험군에서 8주 후부터 유의하게($p<.05$) 감소하였으며, 실험군이 통제군에 비해 운동처치 8주 및 12주 후에 각각 유의하게($p<.05$, $p<.01$) 흔들림이 감소하였다.

※ The author wishes to acknowledge the financial support of the Korea Foundation made in the program year of (1998)

3. 체성감각 유발전위의 잠복기 변화는 실험군과 통제군에 있어서 말초신경 근위부 유발전위(N_9) 잠복기와 척수 유발전위(N_{13}) 잠복기가 다소 증가하였으나 유의한 차이는 나타나지 않았으며, 실험군에 있어서 뇌 유발전위(N_{20}) 잠복기는 8주 후부터 유의하게($p<.05$) 증가하였다.

이상의 결과를 종합해 볼 때, 12주의 균형 훈련은 자세 조절에 있어서 전후와 좌우의 흔들림을 감소시킴으로써 정적인 상태나 동적인 상태에서의 자세 안정성을 증가시킬 수 있음을 시사하고 있다. 이는 자세 조절에 필요한 항중력근의 긴장성 수축을 유발시킬 뿐만 아니라 근육 긴장분포를 조절할 수 있다는 것으로 신경근 조절 기능의 향상을 의미하는 것으로 사료된다. 또한 뇌 유발전위(N_{20}) 잠복기의 증가는 중추신경계의 감각기능의 신경학적 회복을 의미하는 것으로 중추신경계의 감각 운동통합에도 영향을 미쳐 운동기능의 향상을 기대할 수 있을 것으로 사료된다.

Ⅰ. INTRODUCTION

Although the human body seems to be in a static condition when it is standing up (or not moving), it is a continuous process in which the human posture is being constantly controlled or adjusted in details so that the center of gravity of the body can be stably maintained on the base(Kang, Chung-sik, 1989). In recent reports, postural sway has been measured on the force platform and used as an index of stability, and the measure of postural sway has been used as an index of sensory-motor impediments, rather than a measurement of functional performance abilities(Michael & Albert, 1987).

According to McRae, et al.(1994), the postural control measurement on the force platform has very high reliability and validity because the postural sway of the subjects with hemiparesis is significantly decreased at static posture after they take six dynamic balance training programs. Thus, the sensory-motor function is regarded as the physiological function of the central nervous system(CNS).

Recently, it has been reported that the normal sensory-motor feedback by exercise reorganizes the CNS functionally by reconstructing neural plasticity(Bobath, 1990; Davis, 1990). In the past, it was believed that the damage of neuron in the CNS is not reproduced, but recently, it has been reported that brain has plasticity (Bach & Rita, 1981; Bishop, 1982). Consequently, it is stated that the nervous system undergoes its special structural and physiological variations.

These researches suggest the neural injurers with motor function impediment during exercise, as well as general patients, can be recovered.

Many researchers have studied the somatosensory evoked potential(SEP) discovered by Dawson(1947). The SEP measures the variation of the potential occurring on sensory pathways when the somatosensory is stimulated. The SEP is a test to recognize the neurophysiological state of semisphere, and it can also be used as an index to assess the brain disorder and the neurophysiological state.

The purpose of this study was to investigate the effect of balance training on the postural control ability and the somatosensory pathway of adults with the CNS disorders.

Ⅱ. METHODS

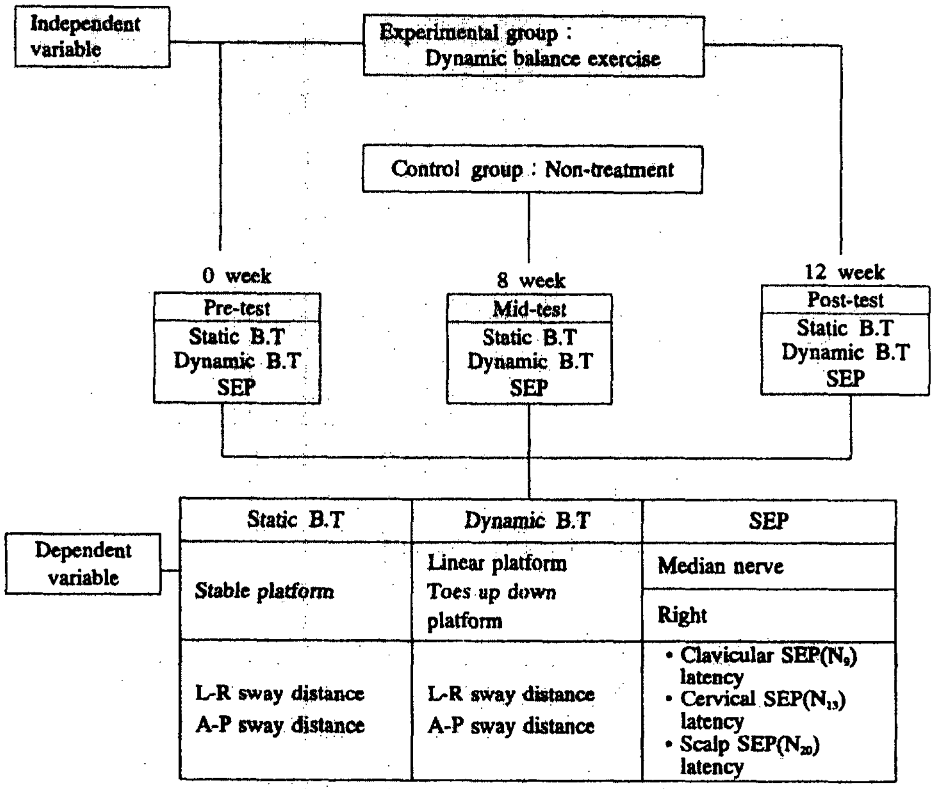
1. Subjects

The subjects of this study consist of 20 male adults who were divided into the experimental group of 10 and the control group of 10(Table 1). All subjects can stand up, but can't be normal-gaited. They can respond to

Table 1. Physical characteristics of subjects

Group	N	Sex	Age (yrs)	Height (cm)	Weight (kg)
Experimental	10	Male	39.4±1.72	171.2±4.70	69.38±5.88
Control	10	Male	40.2±1.27	170.4±4.42	68.22±6.13

Mean ± SD



B.T : Balance test, SEP : Somatosensory evoked potential,
A-P : Anterior to posterior, L-R : Left to right

Fig. 1. Experimental design.

verbal stimulation, and recognize the names of things, and the concepts of timing and space. All subjects have been under rehabilitation therapy, but they don't have labyrinth and visual impediment that can have an effect on keeping the balance.

2. Research design

The research design of this study is shown in Fig. 1.

3. Experimental procedure

1) Prescription of exercise program

The exercise period for the experimental group was 12 weeks. The frequency, intensity, and duration of exercise are shown in Table 2, and the balance training program shown in Table 3.

4. Experimental equipments

Table 4 shows the experiment equipments used in this study to examine the balance training and the somatosensory evoked potential(SEP).

Table 2. Exercise prescription for experimental groups

Group	Exercise	Intensity				Frequency (days/week)	Duration (min/day)
		0~3 weeks	4~6 weeks	7~9 weeks	10~12weeks		
Experimental	Balance	Level Ⅰ	Level Ⅱ	Level Ⅲ	Level Ⅳ	4	60
Control				Non-treatment			

Table 3. Balance training program for experimental groups

Level	Exercise program	Platform movement	Time(min)	Platform speed(sec/cycles)	Target size (inch)
I	C LR AP FQ	Stable Linear Toes up/down	50	15	2
II	C LR AP FQ	Stable Linear Toes up/down	50	12.5	1½
III	C LR AP FQ	Stable Linear Toes up/down	50	10.4	1
IV	C LR AP FQ	Stable Linear Toes up/down	50	8.3	½

C : Circle, LR : Left to right, AP : Anterior to posterior,
FQ : Four quadrant

Table 4. Experimental equipments

Apparatus(Model)	Manufactory(Nation)	Usage
Dynamic balance systems	Chattanooga Inc.(U.S.A)	Balance training & postural balance test
Neurotec viking4. P	Neurotec(U.S.A)	Somatosensory evoked potential

5. Data analysis

The PC/SAS program is used in this study program to analyze the data and test the hypothesis. More specific analyses are made as follows :

1) T-test was used to compare the difference between each group's measured timing.

2) ANOVA with repeated measures was used to test the difference between the number of variables depending on each group's measured timing.

3) One-way ANOVA was used to test the difference between each group's measured timing, whereas Duncan's multiple range test was used to verify the post-hoc test.

The significance level of all tests was assumed to be $p<.05$ in this study.

Ⅲ. RESULTS

1. Variation of postural control

1) Static postural control

(1) Left to right sway distance

Left to right sway distance of the experimental group had a lower significantly($p<0.01$) at 8(5.11±2.33cm) and 12 weeks(3.29±1.64cm) compared with those(8wks : 8.07±2.14cm, 12wks : 7.67±2.25cm) of the control group.

Left to right sway distance of the experimental group was decreased significantly($p<0.01$) at 8(5.11±2.33cm) and 12 week(3.29±1.64cm) compared with that(7.21±3.36cm) of pre-test(Table 5).

(2) Anterior to posterior sway distance

Anterior to posterior sway distance of the

Table 5. Values of L-R sway distance between treatment time and group at stable platform (cm)

Group \ Time	Pre[A] M SD	Mid[B] M SD	Post[C] M SD	F-value	Post-hoc
Experimental	7.21±3.36	5.11±2.33	3.29±1.64	5.74**	A:B, A:C, B:C
Control	8.26±2.77	8.07±2.14	7.67±2.25	1.98	-
t-value	0.77	2.96**	4.96**		

** : p < .01

experimental group had a lower significantly(p<0.01) at 8(4.79±1.74cm) and 12 weeks(3.02±1.04cm) compared with those(8wks : 7.27±2.39cm, 12wks : 7.42±2.45cm) of the control group.

Anterior to posterior sway distance of the experimental group was decreased significantly(p<0.01) at 8(4.79±1.74cm) and 12 weeks(3.02±1.04cm) compared with that(6.68±2.23cm) of pre-test(Table 6).

2) Dynamic postural control

(1) Linear platform

① Left to right sway distance

Left to right sway distance of the experimental group had a lower significantly(p<0.05, p<0.01) at 8(4.78±1.73cm) and 12 weeks(3.02±1.03cm) compared with those(8wks : 7.27±2.39cm, 12wks : 7.42±2.45cm) of the control group.

Left to right sway distance of the experimental group was decreased significantly(p<0.01) at 8(4.78±1.73cm) and 12 week(3.02±1.03cm) compared with that(6.68±2.23cm) of pre-test(Table 7).

② Anterior to posterior sway distance

Anterior to posterior sway distance of the experimental group had a lower significantly(p<0.01) at 8(7.37±1.51cm) and 12 weeks(5.00±1.18cm) compared with those(8wks : 10.33±3.60cm, 12wks : 10.00±3.26cm) of the control group.

Anterior to posterior sway distance of the

Table 6. Values of A-P sway distance between treatment time and group at stable platform (cm)

Group \ Time	Pre[A] M SD	Mid[B] M SD	Post[C] M SD	F-value	Post-hoc
Experimental	6.68±2.23	4.79±1.74	3.02±1.04	4.98*	A:B, A:C, B:C
Control	7.51±2.18	7.27±2.39	7.42±2.45	2.14	-
t-value	0.85	2.66*	5.23**		

* : p < .05, ** : p < .01, A-P : Anterior to posterior

Table 7. Values of L-R sway distance between treatment time and group at linear platform (cm)

Group \ Time	Pre[A] M SD	Mid[B] M SD	Post[C] M SD	F-value	Post-hoc
Experimental	6.68±2.23	4.78±1.73	3.02±1.03	5.69**	A:B, A:C, B:C
Control	7.51±2.18	7.27±2.39	7.42±2.45	0.47	-
t-value	0.84	2.65*	5.22**		

* : p < .05, ** : p < .01

Table 8. Values of A-P sway distance between treatment time and group at linear platform (cm)

Group \ Time	Pre[A] M SD	Mid[B] M SD	Post[C] M SD	F-value	Post-hoc
Experimental	10.31±2.37	7.37±1.51	5.00±1.18	7.13**	A:B, A:C, B:C
Control	10.38±3.31	10.33±3.60	10.00±3.26	0.52	-
t-value	0.05	2.39*	4.54**		

* : p < .05, ** : p < .01

experimental group was decreased significantly(p<0.01) at 8(7.37±1.51cm) and 12 week(5.00±1.18cm) compared with that(10.31±2.37cm) of pre-test(Table 8).

(2) Toes up-down platform

① Left to right sway distance

Left to right sway distance of the experimental group had a lower significantly(p<0.05, p<0.01) at 12 weeks(4.30±2.16cm) compared with that(12wks : 8.87±4.47cm) of the control group.

Left to right sway distance of the experimental group was decreased significantly(p<0.01) at 8(6.49±3.37cm) and 12 weeks(4.30±2.16cm) compared with that(9.11±4.35cm) of pre-test(Table 9).

② Anterior to posterior sway distance

Anterior to posterior sway distance of the experimental group had a lower significantly(p<0.05, p<0.01) at 8(10.20±4.21cm) and 12 weeks(6.73±2.72cm) compared with those(8wks : 14.50±6.42cm, 12wks : 14.16±6.29cm) of the control group.

Anterior to posterior sway distance of the experimental group was decreased significantly(p<0.01) at 8(10.20±4.21cm) and 12 weeks(6.73±2.72cm) compared with that(14.48±5.89cm) of pre-test (Table 10).

2. Variation of somatosensory evoked potential

1) Variation of right latency

① N_9 latency

The latency of the SEP, N_9 was showed no significant difference between groups and durations of treatment(Table 11).

Table 9. Values of L-R sway distance between treatment time and group at toes up-down platform (cm)

Group \ Time	Pre[A] M SD	Mid[B] M SD	Post[C] M SD	F-value	Post-hoc
Experimental	9.11±4.35	6.49±3.37	4.30±2.16	6.12**	A:B, A:C, B:C
Control	9.53±4.96	9.53±4.63	8.87±4.47	1.26	-
t-value	0.20	1.67	2.90*		

* : p < .05, ** : p < .01

Table 10. Values of A-P sway distance between treatment time and group at toes up-down platform (cm)

Group \ Time	Pre[A] M SD	Mid[B] M SD	Post[C] M SD	F-value	Post-hoc
Experimental	14.48±5.89	10.20±4.21	6.73±2.72	7.43**	A:B, A:C, B:C
Control	14.92±6.38	14.50±6.42	14.16±6.29	0.17	-
t-value	0.16	1.76*	3.42**		

* : p < .05, ** : p < .01

Table 11. Values of right N_9 latency between treatment time and group at somatosensory evoked potential (msec)

Group \ Time	Pre[A] M SD	Mid[B] M SD	Post[C] M SD	F-value	Post-hoc
Experimental	6.26±4.44	7.65±2.92	8.22±2.43	2.10	-
Control	7.11±1.12	7.95±2.94	8.55±0.97	1.97	-
t-value	0.59	0.23	0.39		

② N_{13} latency

The latency of the SEP, N_{13} was showed no significant difference between groups.

N_{13} latency of the experimental group was increased significantly($p<0.05$) at 8(13.19±1.46 msec) and 12 weeks(12.72±1.31 msec) compared with that(9.04±0.99 msec) of pre-test(Table 12).

③ N_{20} latency

N_{20} latency of the experimental group was increased significantly($p<0.05$) at 8(17.84±3.53 msec) and 12 weeks(16.81±3.09 msec) compared with those(8wks : 11.35±8.14 msec, 12wks : 11.45±5.86 msec) of the control group.

N_{20} latency of the experimental group increased significantly($p<0.05$) at 8(17.84±3.53 msec) and 12 weeks(16.81±3.09 msec) compared with that(11.59±5.13 msec) of pre-test(Table 13).

Ⅳ. DISCUSSION

1. Variability of postural control

Bohannon, et al.(1993) reported that the sway of stroke patients were two times as high as that of the control group with the same age. This study showed almost the same result as the previous report in the right to left sway distance and the anterior to posterior sway distance before treatment.

In this paper, the sway distance of experimental group decreased significantly ($p<.01$) 8 and 12 weeks after exercise, compared with the sway distance before (exercise) treatment. However, the control group didn't vary during 12 weeks at the right to left sway distance and the anterior to posterior sway

Table 12. Values of right N_{13} latency between treatment time and group at somatosensory evoked potential (msec)

Group \ Time	Pre[A] M SD	Mid[B] M SD	Post[C] M SD	F-value	Post-hoc
Experimental	9.04±0.99	13.19±1.46	12.72±1.31	3.96*	A:B, A:C
Control	10.73±1.27	11.28±1.38	11.41±1.02	1.10	-
t-value	0.83	0.84	0.82		

* : $p < .05$

Table 13. Values of right N_{20} latency between treatment time and group at somatosensory evoked potential (msec)

Group \ Time	Pre[A] M SD	Mid[B] M SD	Post[C] M SD	F-value	Post-hoc
Experimental	11.59±5.13	17.84±3.53	16.81±3.09	3.71*	A:B, A:C
Control	11.10±4.97	11.35±8.14	11.45±5.86	0.36	-
t-value	0.14	2.16*	2.36*		

* : $p < .05$

distance. This result is regarded as an effect of balance training.

In the experimental group, the variation of sway due to treatment time was shown significantly($p<.01$) after 8 weeks and the sway was so decreased even after 12 weeks. This nearly accords with that of Hocherman, et al.(1984).

It is suggested in this study that the postural balance is increased by balance training, and that there are also particular variations in the special muscle reaction performed by the accuracy of muscle function and the stimuli of force platform. The left to right and the anterior to posterior sway distance at the linear platform decreased significantly($p<.01$) in the experimental group from 8 weeks to 12 weeks after exercise. But the control group showed no significance. The left to right sway distance at toes up-down platform decreased significantly($p<.01$) after 12 weeks, and the anterior to posterior sway distance decreased significantly($p<.01$) after 8 weeks. It is suggested that the decrease of dynamic postural sway by balance training have a good influence on the muscle strength exhibition and the neuromuscular control due to the improvement of dynamic postural balance.

2. The latency of the somatosensory evoked potential(SEP)

Kakigi & Jones(1985), La Joie, et al.(1982) and Shigemori(1987) have studied the functional recovery and prognosis of stroke patients. They reported that the median nerve SEP can help the prognosis of nervous system disorders' sensory function. Especially, Kakigi & Jones(1985) reported that the SEP by touch stimuli showed variation at the SEP, and Wu, et al(1979) reported that muscle strength had a relation to the recovery of the SEP response. The latency of the SEP, N_{13}, and N_{20} in this study increased significantly($p<.05$, and $p<.01$, respectively) 8 and 12 weeks after exercise in the experimental group, but not in the control group. It is suggested that the balance training during 12 weeks have an influence on the domain of central nerve of sensory stimuli pathway, which means the result can support the plasticity of central nervous system.

V. CONCLUSION AND SUGGESTIONS

The purpose of this dissertation was to analyze the effect of balance exercise at force platform on the postural control and the somatosensory pathway in adults with central nervous system disorder.

The subjects of this study were twenty adults with central nervous system disorder : the experimental group(10), the control group(10).

The experimental group has done balance training at force platform for 12 weeks. The Postural control was measured by Dynamic Balance System at stable, linear and toes up-down for somatosensory pathway, and the somatosensory evoked potential was measured by Neurotec.

This study analyzes the anterior to posterior(A-P), the left to right (L-R) sway distance and the latency of the SEP, N_9, N_{13} and N_{20}. All of subjects were tested 3 times : pre-, mid-, and post-exercise.

The results were as follows:

1. It is shown that the A-P and the L-R sway distances at stable platform, in the experimental group have decreased significantly($p<.05$) 8 to 12 weeks after exercise, and these sway distances of the experimental group have decreased significantly($p<.05$, or $p<.01$, respectively) either for 8 or 12 weeks after exercise, compared with those of the control group.

2. It is shown that the A-P and the L-R sway distances at linear and toes up-down platform, in the experimental group have decreased significantly($p<.05$) 8 weeks after exercise, and these sway distances of the experimental group have decreased significantly($p<.05$, or $p<.01$, respectively) either for 8 or 12 weeks after exercise, compared with that of control group.

3. The latency of the SEP, N_9 had no significant

difference not only between the groups but also between the durations of treatment. But N_{13} of the experimental group has increased significantly($p<.05$) 8 weeks after exercise, and N_{20} has increased significantly($p<.05$) either 8 or 12 weeks after exercise, compared with that of the control group.

To sum up, the balance exercise for 12 weeks could increase the postural stability on the dynamic or static condition by decreasing the A-P and L-R sway distances. And it not only aroused the phasic contraction of antigravity muscle needed for postural control, but also could control muscle tone, which means the improvement of neuromuscular control.

In addition, the increase of the latency of scalp(N_{20}) means the neural restoration of a sensory function of the CNS, and so exercise may expect the improvement of CNS disorders' motor function because it has an effect on the sensory-motor integration of the CNS.

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