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The Effects of Sensorimotor Training on Anticipatory Postural Adjustment of the Trunk in Chronic Low Back Pain Patients

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Abstract. [Purpose] This study aimed to examine the effects of sensorimotor training on the anticipatory postural adjustment (APA) of chronic low back pain (CLBP) patients. [Subjects and Methods] Fourteen CLBP patients were randomly assigned to Group II (ordinary physical therapy, n=7) and Group III (sensorimotor training, n=7). In addition, a normal group (Group I) consisting of seven subjects was chosen as the control group. The two CLBP groups received their own treatment five times per week, for four weeks, for 40 minutes each time. Changes in pain and functional performance evaluation were examined by the visual analogue scale (VAS) and the Oswestry Disability Index (ODI). In order to look at the change in APA, muscle onset time was examined using electromyography (EMG). [Results] Group III showed significant changes in both VAS and ODI. According to comparison of the results for muscle onset time, there were significant decreases in Group III's transversus abdominis muscle (TrA) and external oblique muscle (EO) in the standing and sitting positions. There were significant differences between Group II and III in terms of the TrA in the sitting position. [Conclusion] Sensorimotor training makes patients capable of learning how to adjust muscles, thereby alleviating pain and improving muscle performance.
Key words: Anticipatory postural adjustments, Chronic low back pain, Sensorimotor training

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INTRODUCTION

About 80% of the population experiences low back pain more than once throughout their lives[1)]. Those experiencing acute low back pain, 90% recover within two months, but chronic low back pain (CLBP) triggers physical atrophy and psychological problems[2)]. Low back pain sustained for more than 12 weeks is called chronic low back pain (CLBP)[3)].

Movement is a complex process in which the central processing system integrates and processes information and the musculoskeletal system responds to it[4)]; static and dynamic location senses, in other words, proprioceptive senses, are known to maintain the stability and orientation of the body during movement[5)]. Anticipated responses programmed in the central nervous system are called anticipatory postural adjustments (APAs)[6)].

CLBP patients experience trunk muscular atrophy[7)], muscle response delays[8)], and decreased postural adjustment ability[9)] and in particular undergo changes in APAs[10)]. Existing exercise methods applied to low back pain patients focus only on strengthening of muscles and ignore mobilization order and coordination ability of muscles[11)].

Reconditioning of proprioceptive senses and sensorimotor training that increases one's muscle adjustment ability maximizes the sensory input in different parts of the body and aids in improving one's motor adjustment ability[12–14)]. Abnormal postures, support surfaces, and stimuli progress centered on gravity through sensorimotor training[15)], and stabilization of the joints increases through changes in such things muscle strength, sensorimotor abilities, and muscle tone[16)]. Sensorimotor training has recently been found to be quite helpful in increasing motor performance and coordination when compared with previous methods[17–20)].

CLBP patients differ in muscle activation time and degree in relation to APAs[21)]. In treatment of CLBP patients, it is important to illuminate how they differ from normal people[22)]. In order to compare muscle adjustment differences in APAs, EMG was used to measure the time required to reach the threshold of each muscle, which makes it possible to understand the order of muscle initiation[23)]. In CLBP patients, the time required to initiate the contraction of the TrA is delayed, and therefore motor adjustment of the trunk muscles is insufficient and trunk muscles are not activated[24)]. Therefore, this study intends to apply sensorimotor training in CLBP patients and examine how it affects APAs during voluntary movement of the upper extremities.

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Table 1. Characteristics of study participants

Parameters	Group I (n=7)	Group II (n=7)	Group III (n=7)
Age (years)	45.85±9.24	44.85±7.92	45.71±8.55
Sex (male/female)	3/4	4/3	4/3
Height (cm)	164.42±8.50	164.71±6.57	163.71±7.73
Weight (kg)	63.14±9.90	65.14±11.43	68.28±6.75
BMI (kg/m^2)	23.26±4.03	21.62±3.23	20.68±2.32
Pain duration (months)	-	11.42±3.20	10.57±3.04

All data are expressed as the mean with standard deviation (SD).

Table 2. Sensorimotor training program

Position	Exercise methods
Hollowing exercise	Contract the abdominal muscles, raising the center of movement towardthe naval in a quadruped position.
Single leg raising in the quadruped position (Rt/Lt)	Raise one leg and maintain it in a quadruped position, and apply the same movement to the opposite leg.
Contralateral arm and leg raising in the quadruped position (Rt/Lt)	Raise the opposite arm and leg simultaneously in a quadruped position, and maintain them in that postition; apply the same movement to the opposite side.
Abdominal bracing	Flex the hip and knee joints at 90° in a supine position; push out the lower abdomen during inhalation, and contract the lower abdomen during exhalation.
Holding a bridging position	Apply so that the legs do not spread apart in the bridging position.
Single leg raising in the bridging position (Rt/Lt)	Extend one leg in a bridging position, and raise and maintain it. Apply the same movement to the opposite side.

SUBJECTS AND METHODS

Subjects

The subjects in this study included seven healthy people and 14 CLBP patients. Those who had not had low back pain for the past six months were selected as healthy subjects. The criteria for inclusion were: those whose low back pain continued for more than 12 weeks; whose low back pain recurred at least three times; whose LBP was defined as pain localized between lumbar levels 2–4 and the inferior gluteal folds; who did not have lumbar surgery because of orthopedic problems; whose visual analogue scale (VAS) and Oswestry Disability Index (ODI) scores were five or higher; who did not have severe deformations or spinal fractures shown on x-rays; who did not have sensory nervous system, vestibular system, nervous system, or respiratory system disorders; who did not take medications that would have affect this experiment; and whose dominant side was the right side. Prior to participation in this study, all subjects gave voluntary consent. Data collection was initiated after approval was obtained from the A University Institutional Review Board. The characteristics of the subjects are shown Table 1.

Methods

The seven healthy subjects were allocated to Group I. By picking either a blue or yellow ball, the 14 CLBP patients were equally assigned to an experimental group (Group II) to whom ordinary physical therapy was applied and an experimental group (Group III), the members of which received sensorimotor training. For ordinary physical therapy, a hot compress (20 minutes), ultrasound (1.5 W/cm^2, five minutes, Jireh Medical, Korea), and transcutaneous electrical nerve stimulation (4 pps, 15 minutes, Hanawoo Medical, Korea) were applied to the L1-2 and L4-5 areas for 40 minutes each time, five times per week, for a total of four weeks. For sensorimotor training, which is an exercise that activates self-receptors of the trunk muscles, a wobble board was used. The contact surface was made small so that balance skills and force of the lumbar muscles were able to be effectively delivered[25]. A total of six kinds of exercises were conducted for 40 minutes each time, five times per week, for four weeks. Table 2 shows how the exercises were conducted in detail.

As the clinical standard for changes in pain in patients, VAS was employed, and for functional performance evaluation, ODI was used. Using electromyography (EMG) (PocketEMG, BTS S.p.A, Milan, Italy), the time of muscle onset related to movement during flexion of the upper extremities was measured. The electrodes were attached to the deltoid anterior (DA), TrA, and EO. The frequency bandwidth for signal collection was set at between 20 and 500 Hz for analysis. For measurement, subjects flexed the shoulder joint on their nondominant side at 90° in a standing position and in a sitting position on a backless chair. With the DA as the standard point, when contraction of the TrA and EO trunk muscles was initiated first, the value was assumed to be negative, and when contraction of the muscles was initiated later, the value was assumed to be positive. Each experi-

Table 3. VAS and ODI changes for each group (mean±SD)

Parameters	Group II		Group III	
	Pre	Post	Pre	Post
VAS (score)	5.71±0.61	6.14±0.95	5.83±0.38	4.57±0.78*
ODI (score)	7.19±0.95	6.65±0.87	7.54±1.11	6.23±0.54**

A paired t-test was performed to analyze in-group changes prior to and after the exercise (*p<0.05; **p<0.01).

Table 4. STP and SIP changes during the muscle reaction time (TrA& EO) in each group (mean±SD)

		Group I	Group II		Group III	
			Pre	Post	Pre	Post
STP (msec)	DA	0	0	0	0	0
	TrA	−0.50±6.07	70.44±9.91$^{1)###}$	65.27±7.43$^{1)###}$	87.29±6.76$^{2)###}$	5.70±7.70$^{***\ 2)###}$
	EO	35.20±7.08	82.00±8.57$^{1)###}$	77.83±7.32$^{1)###}$	101.79±8.63$^{2)###}$	40.54±11.83$^{***\ 2)###}$
SIP (msec)	DA	0	0	0	0	0
	TrA	−7.58±6.07	48.38±9.62$^{1)###}$	48.77±9.36$^{1)###}$	69.75±8.35$^{2)###}$	-2.45±4.13$^{***\ 3)###}$
	EO	23.37±4.72	56.16±10.82$^{1)###}$	58.66±10.32$^{1)##}$	91.12±10.31$^{2)###}$	32.66±5.72**

In order to examine muscle onset time changes between the groups, a one-way ANOVA was conducted, and as a post-hoc test, Turkey's multiple range test was also performed I–II$^{1)}$, I–III$^{2)}$, and II–III$^{3)}$ ($^{#}$p<0.05; $^{##}$p<0.01; $^{###}$p<0.001); a paired t-test was performed to analyze in-group changes (**p<0.01; ***p<0.001).
STP, standing position; SIP, sitting position
DA, deltoid anterior; TrA, transversus abdominis; EO, external oblique

ment was repeatedly measured three times, and a one-minute resting time was provided between each measurement.

For statistical analysis, the Windows version of SPSS 12.0 was used. A paired t-test was performed to analyze in-group changes in Group II and Group III. In order to examine the changes in muscle onset time between the groups, one-way analysis of variance (ANOVA) was conducted, and as a post-hoc test, Turkey's multiple range test was performed. The statistical significance level was set at α=0.05.

RESULTS

According to the clinical evaluation results following sensorimotor training, Group III's VAS and ODI decreased significantly (p<0.05) (Table 3).

The muscle onset time in relation to movement during flexion of the upper extremities after sensorimotor training decreased significantly in the TrA and EO of Group III in both the standing and sitting positions (p<0.01). According to the between-group comparison, there were significant differences in all items of Group II and Group III except for Group III's TrA and EO in a sitting position (p<0.001). When Group II was compared with Group III, there was a significant difference in the TrA in the sitting position (p<0.001) (Table 4).

DISCUSSION

APAs refer to the appearance of anticipated physical responses based on prior experiences[26]. Such APAs enable posture to be adjusted for movement by activating the motor memory of the central nervous system through learning[27].

Recently, significant attention has been paid to physical changes that trigger problems in CLBP patients[28–30]. CLBP patients undergo changes in the trunk muscles, and such changes cause a number of problems with functional activities and activities of daily living[21, 31]. CLBP patients also experience changes in muscle coordination and control strategies[32] and in APAs resulting from changes in nerve transmission[33].

Clinically, ordinary physical therapy and lumbar spine exercise programs have been typically used for CLBP patients. Accordingly, this study compared the effects of ordinary physical therapy and sensorimotor training in CLBP patients.

A VAS and ODI were used for the clinical evaluation, and we examined how changes in muscle onset time during voluntary upper extremity movements affected APAs. The VAS and ODI were significantly lower in patients in Group III who conducted sensorimotor training. This result suggests that sensorimotor training in VAS and ODI evaluation plays an important role in reducing pain[34].

Muscle onset time consists of the pre-motor reaction time from when stimuli are provided and before muscles contract on EMG and the motor reaction time from when muscles are contracted to when articular movement occurs[35]. This study applied sensorimotor training and examined APA changes in the TrA and EO. According to the analysis of changes in the TrA and EO in the standing and sitting positions, Group III had a significantly different muscle onset time than Groups I and II. This suggests that CLBP patients' trunk muscles were delayed compared with normal subjects but that their response time improved after sensorimotor training. Normal subjects' response time in the TrA during upper extremity movement[36] and CLBP patients' response time in the EO after motor control[37] both decreased.

Generally speaking, sensorimotor training increases intermuscular control, improving one's response to sensory information[15]. In this study, sensorimotor training was effective in improving CLBP patients' APAs and their muscle activity response.

Examination of whether low back pain patients' APAs differ from those of normal people is a crucial part of treatment[5, 23]. According to the present study results, CLBP patients experienced pain and also had delayed muscle response time. Such delays in muscle response negatively affected patients' overall physical functions. Sensorimotor training teaches patients how to adjust their muscles, thereby triggering muscle plasticity, alleviating pain, and improving muscle strength.

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