Examination of training effect on low back pain using the center of gravity in unstable sitting.

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Abstract

[Background] Low back pain(LBP) occurs widely, with a lifetime prevalence ranging from 80% to 85%. According to the physical therapy guidelines, exercise therapy is effective for the improvement of pain and function in patients with chronic LBP. Previously, individuals with back pain have been demonstrated to have an obstacle to the control of local muscles involved in maintaining the cooperativeness and stability of the spinal column. On the basis of this finding, motor control exercise (MCE) has been developed for adjustment, control, and ability recovery.

[Purpose] In this study, we aimed to examine the effect of MCE in subjects with nonspecific chronic LBP and compare it with that of core stability exercise (CSE), focusing on the center of gravity(COG) sway while sitting on an unstable surface.

[Target] Twenty-two subjects with nonspecific chronic LBP (age, 21.5 ± 0.9 years) and 14 healthy subjects (age, 21.6 ± 0.8 years) were included in this study.

[Methods] The subjects were divided into two groups; one group performed CSE and the other performed MCE at home for 6 weeks. They performed home exercise for 6 weeks, one group performed a CSE and the other performed an MCE. Their COG sway was measured before and after the intervention. The severity of LBP was assessed over time using a questionnaire for subjects with LBP.

[Outcome] A significant decrease was observed in the intensity of LBP in both groups. And a significant decrease in COG sway was observed in both groups of subjects with LBP and in the CSE group of healthy subjects.

[Conclusion] Both MCE and CSE led to improvements in spinal stability and LBP after 3 weeks, but CSE was more effective.

Introduction

Low back pain(LBP) occurs in a wide range of people, from general adults to athletes. The prevalence of LBP in Japan (multiple responses, population per thousand, 2016) was 91.8 for men and 115.5 for women1). LBP was more prevalent than other subjective symptoms in both men and women. LBP is a serious health problem worldwide, with a lifetime prevalence of 80-85%. The causes of LBP can be broadly classified into five categories as follows: spinal, neurological, visceral, vascular, and psychogenic2). However, 85% of LBP cases are nonspecific chronic LBP. Thus far, studies have focused on abnormal cortical processing of the central nervous system, including cognitive, sensory, and motor disorders3).

With respect to the treatment of LBP, the physical therapy guideline, 1st edition, back pain physical therapy practice guideline indicates that exercise therapy is recommended as grade B or evidence level 2, and is slightly effective for improving bodily function and reducing pain in patients with chronic LBP. Active rehabilitation reduces pain in patients complaining of non-specific chronic LBP and has long-term effects (up to a year later)4). We focused on motor control exercise (MCE) in active rehabilitation. Subjects with LBP may present with impaired control of the deep trunk muscles (local muscles), which are involved in maintaining spinal coordination and stability. On the basis of this principle, MCE has been developed to restore coordination, control, and activity of the trunk muscles5). Moreover, MCE increases spinal stability6).

In a previous study, core stability exercise (CSE) increased lumbar spinal stabilization mechanisms and decreased center of gravity (COG) sway7). CSE reduced back pain by improving spinal stability and decreasing COG sway during loaded seated holding.

In this study, we hypothesized that CSE and MCE would reduce LBP and decrease COG sway. The purpose of this study was to investigate the effect of MCE in subjects with non-specific chronic LBP and to compare its effect with that of CSE, focusing on the COG sway while sitting on an unstable surface.

Methods

1. Participants

Twenty-two subjects with nonspecific chronic LBP (12 men and 10 women, aged 21.5 ± 0.9 years) and 14 healthy subjects (10 men, 4 women, aged 21.6±0.8 years) were included in this study. The subjects with LBP had only back pain for >3 months and had no history of orthopedic diseases such as lumbar disk herniation. Both the subjects with LBP and the healthy subjects were randomly divided into two groups, the CSE and MCE groups. Both groups were required to perform home exercises for 6 weeks. This study was approved by the Research Safety and Ethics Committee of Tokyo Metropolitan University, Arakawa Campus(approval no.18039).

2. COG sway measurement

All the study subjects were assessed for COG sway during seated holding at the beginning of the experiment (pre - intervention) and at 3 weeks (intermediate) and 6 weeks after the intervention (post-intervention). COG sway was measured with a COG sway meter (Gravicorder GS-11, Anima) at a sampling frequency of 20 Hz. The following parameters were measured: total trajectory length (LNG), unit trajectory length (LNG/TIME), left-right trajectory

Fig.1 Unstable sitting position with the shoe sole above the ground. The subject is seated on a balance cushion.

length (MEAN OF X:MX), and front-back trajectory length (MEAN OF Y:MY). A wooden board and gravimeter were placed on a liftable bed, and COG sway was measured while sitting. One side of the gravimeter was placed in line with the edge of the bed. The subjects were seated in the mid-pelvic sitting posture with both upper limbs folded in front of the chest. The bed height was adjusted to set the subject' s hip and knee angles to the right angles, with their soles in contact with the ground. In the unstable sitting posture, a balance cushion was placed on the gravimeter, and the subject was held in the sitting posture with the sole ungrounded (Fig. 1). The end of the balance cushion was aligned with the bed end and the edge of the gravimeter, and the sitting posture was such that the ischium was in the posterior quarter of the balance cushion. For all the measurements, the subjects looked at the target with a 3-cm diameter placed 2 m away and held the position for 30 seconds. The target was adjusted to the height of subject' s eyes. Measurements were taken for the last 20 seconds. COG sway was measured twice each for plantar-grounded, ungrounded, and unstable sitting, with a 2-minute rest period after each measurement. Before the measurement in the unstable sitting position, a practice period of 1 minute was allowed to enable the subjects to sit for 1 minute, and then a 2-minute rest period was given. The measurement method was based on that reported by Suzuki et al[8].

3. Pain intensity assessment

Pain was assessed using the scores in the functional assessment questionnaire (Japan Low Back Pain Evaluation Questionnaire[JLEQ][9]) for subjects with chronic LBP. The JLEQ is a self-administered questionnaire developed to evaluate the effectiveness of exercise and conservative treatment for subjects with chronic LBP, with a maximum score of 120 and lower values indicating a better status. As a subjective pain assessment, this rating scale was used to investigate the extent to which LBP affects daily life. The participants were asked to fill out a questionnaire about their most recent life situation, and the scores were compiled and compared.

4. Home exercises

MCE was performed, as shown in Fig. 2. The subjects stood 90 cm from the wall, with their feet shoulder-width apart and a laser pointer attached to their waist (anterior superior iliac spine) with a band. They traced the figure attached to the wall with the light of a laser pointer for 1 minute, followed by a rest period of 1 minute; 3 such sets were performed per day. The following three types of target figures were prepared: (1) a star-shaped target, (2) a flower-shaped target with only curves, and (3) a target with a mixture of straight and curved lines. The subjects performed the exercise randomly. The subjects were instructed to trace the line as slowly as possible without going beyond the line, and to control the light not by flexion of the knee joint but by pelvic tilting.

With respect to the CSE group, CSE was performed, as shown in Fig. 2. One set of exercises involved raising the right and left legs horizontally from a four-crawl position

Fig. 2 Posture assumed by the subjects when performing the home exercise.
(1) Posture during motor control exercise (2) Posture during core stability exercise

for 15 seconds, followed by immediately switching the sides and holding for 15 seconds. The subjects then rested for 30 seconds, and 5 such sets were performed per day. The subjects were instructed regarding the posture to be maintained during the exercises when measurements were recorded at the pre-intervention and intermediate time points; they were also instructed to minimize the performance of compensatory movements such as trunk and lumbar extension and pelvic rotation.

The participants were asked to perform the exercises 4 days a week for 6 weeks and to record the days of their performance on a training record sheet. They sent us the record sheet every week to track their progress. For MCE, the subjects recorded the number of figures used for the exercise on the sheet.

5. Statistical analysis

A statistical analysis was performed between the CSE and MCE groups using two-way repeated-measures analysis of variance for the JLEQ score, followed by the main effect and multiple comparison tests for items that were significantly different.

Regarding the measurement of COG sway, the differences between the mean values of the LBP and healthy groups before the intervention were tested, and whether the two groups had a significant difference was assessed. In addition, a correlation analysis was performed using the JLEQ scores of each COG sway measurement in the LBP group before the intervention to determine whether a correlation exists between pain intensity and COG sway. A three-way analysis of variance (ANOVA) was performed on three time COG sway measurements in the healthy and LBP groups, and simple main effect and multiple comparison tests were performed on the items that showed significant differences in main effect.

The statistical procedures were performed using IBM SPSS Statistics 24 at a 5% significance level.

Results

1. JLEQ score

We observed a significant decrease in the scores and subjective LBP in the pre-intervention, intermediate, and post-intervention (Fig. 3). The scores were not significantly different between the two groups (p = 0.597). A gradual decrease in the scores between the three measurements was observed, but the rate of change was greater between the pre-intervention and intermediate measurements than between the intermediate and post-intervention. The main effect test for the time factor was significant only in the CSE group (CSE: p = 0.010, MCE group: p = 0.066). A multiple comparison test for the time factor in the CSE group revealed a significant difference between the pre-intervention and intermediate measurements (p = 0.004; intermediate vs. post-intervention: p = 0.332).

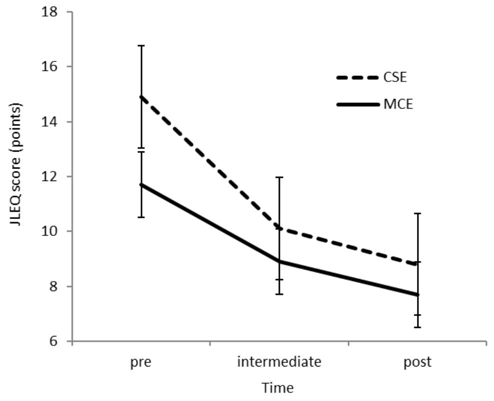

Fig. 3 Rate of change in the JLEQ score
There was no difference between two groups(p>0.05). But both groups show significantly decrease(p<0.05).

		CSE				MCE			
		pre	intermediate	after		pre	intermediate	after	
LBP	LNG(cm)	19.67 ± 6.00	15.58 ± 5.14	14.42 ± 5.25	*1*2	21.28 ± 6.74	17.85 ± 6.01	17.46 ± 6.39	*1*2
	LNG/TIME(cm/s)	0.98 ± 0.30	0.78 ± 0.26	0.72 ± 0.26	*1*2	1.06 ± 0.34	0.89 ± 0.30	0.87 ± 0.32	*1*2
	MX(cm)	13.58 ± 4.09	10.37 ± 4.09	9.45 ± 3.16	*1*2	13.49 ± 4.61	11.72 ± 4.25	11.15 ± 4.33	*1*2
	MY(cm)	11.30 ± 3.54	9.49 ± 2.95	8.94 ± 3.61	*2	13.10 ± 4.08	10.97 ± 3.43	11.05 ± 4.10	*1*2
healthy subjects	LNG(cm)	20.24 ± 5.61	17.26 ± 4.25	15.55 ± 4.59	*2	14.10 ± 5.06	13.44 ± 5.00	13.70 ± 3.73	
	LNG/TIME(cm/s)	1.01 ± 0.28	0.86 ± 0.21	0.78 ± 0.23	*2	0.71 ± 0.25	0.67 ± 0.25	0.69 ± 0.19	
	MX(cm)	13.44 ± 3.72	11.97 ± 3.23	10.17 ± 3.18	*1*2	9.06 ± 3.73	8.89 ± 4.12	8.88 ± 2.57	
	MY(cm)	12.30 ± 3.52	9.93 ± 2.24	9.59 ± 2.72		8.96 ± 2.91	8.21 ± 2.42	8.55 ± 2.27	

Table. 1 COG sway measurements during unstable sitting (mean value ± SD)
*1: significant difference between pre and intermediate ($p<0.05$), *2: significant difference between pre and after ($p<0.05$)

We found no correlation between the JLEQ score the pre-intervention, intermediate, and post-intervention.

2. Center of gravity sway

The COG sway measurements are shown in Table. 1. The SD of each pre-intervention measurement was large in both the healthy and LBP groups, indicating large individual differences. No significant differences in the mean values of each measurement and all measurements were found between the LBP and healthy groups.

Three-way ANOVA was performed for the three measurements of all the subjects, and the main effects of the time factor were significant in MX and RMS in the stable sitting position. The main effect of the time factor was significant in LNG, LNG/TIME, MX, and MY in the unstable sitting position. No interaction effect was found for any of the items.

When a simple main effect test was conducted on the time factor of the item that was significant as described above, many items were significant in the CSE group of subjects with LBP and healthy subjects and in the MCE group of subjects with LBP. We found no significant items in the MCE group of healthy subjects.

When multiple comparison tests were performed for the time factor in the above-mentioned items, significant differences were observed between the pre-intervention and intermediate measurements and between the pre-intervention and post-intervention, but no significant difference was found between the intermediate and final measurements. Both groups showed significant differences between the subjects with LBP and healthy subjects. Especially in the case of LNG, LNG/TIME, and MY of the CSE group and the MCE group of subjects with LBP, the effect of time was significant in the pre-intervention and final measurements.

Discussion

Effectiveness based on the JLEQ score is judged differently. Some researchers judge effectiveness based on a decreasing rate, and others judge it based on a decrease in the score by >1 point[8, 10]. In this study, the rate of decrease in the JLEQ scores from the pre-intervention to the post-intervention was 40.9% in the CSE group and 34.2% in the MCE group. On the basis of the studies in which subjects were considered to have the same level of LBP severity as subjects in the present study, this decrease in JLEQ score was not considered a significant improvement[8]. However, as the score significantly decreased, we considered that both exercises contributed to the decrease in LBP severity. The rate of change between the pre-intervention and intermediate measurements was greater than between the intermediate and post-intervention in both groups, which suggests that both exercises were effective in improving the LBP within 3 weeks and that further improvement was observed with continuation of the exercises. In terms of the effects of muscle strengthening training, the initial maximum increase in muscle strength is largely due to the activity of the central nervous system, including an increase in the number of active motor units and synchronization of the activities of multiple motor units, and the muscle cross-sectional area increases with prolonged training11). The improvement in LBP at 3 weeks suggests that the LBP improved owing to the activity of the local muscles. This was not a result of the muscle strengthening in the CSE group, but the effect of the activation of muscle activity. The test results for the main effect of the time factor were significant only between the pre-intervention and intermediate measurements in the CSE group. However, the rate of change between the intermediate and final measurements was 12.9% in the CSE group and 13.5% in the MCE group, which was not significantly different between the two groups. This is because the subjects in the CSE group experienced slightly more severe LBP based on the mean JLEQ scores at the pre-intervention time point; therefore, the rate of decrease in the JLEQ score may have been greater in the CSE group. Considering this, the degree of improvement of LBP is expected to be the same in the two groups.

We found no correlation between the JLEQ score and pre-intervention measurement of COG sway or a significant difference in each pre-intervention measurement of COG sway between the two groups of healthy subjects and subjects with LBP. The standard deviation of each pre-intervention measurement was large in both the healthy and LBP groups, which suggests that individual differences are largely responsible for the difference in the magnitude of COG sway. Regarding the fact no relationship was observed between COG sway and pain intensity, the mean pre-intervention JLEQ score in the LBP group in this study was 14.9 ± 8.1 in the CSE group and 11.7 ± 8.1 in the MCE group. Considering the 120-point scale, the JLEQ score was severe enough to be significantly different from that of the healthy subjects. In a few individuals, LBP is considered to have no effect on COG sway, unless the LBP was severe. Pain intensity was scored subjectively, and the influence of individual differences in pain perception may be significant.

Regarding the changes in COG sway measurements, MCE had no significant effect on spinal column stabilization in the healthy subjects. However, in the healthy subjects, the COG sway before the intervention was smaller in the MCE group, and it is presumed that many subjects had high spinal stability as well. Therefore, the decrease rate in COG sway was considered small, and no significant differences were found.

Bergmark et al.12) classified muscles into superficial (global system) and deep muscles (local system) according to their functional role in joint stabilization. Global muscles are not directly attached to the vertebrae but are located superficially across the multi-segment and generate torque for spinal movement. On the other hand, initiation or cessation of local muscles in the lumbar spine refer to those muscles whose origin or cessation is in the lumbar vertebrae, which are involved in the stiffness and intervertebral relationship of the spinal segment and the postural control of the lumbar segment and spinal stability. Regarding the relationship between COG sway and spinal stabilization, Zadka et al.[13) stated that in the unstable sitting position, the right and left lumbar dorsal muscles, which are considered global muscles, break the forward tilt of the seat, and the right and left abdominal oblique muscles break the backward tilt of the seat. Zadka et al.[13) and Preuss et al.[14) reported that both the lumbar and contralateral lumbar dorsal muscles (the external and internal abdominal obliques and erector thoracic spinal muscles) break the lateral tilt of the seat in an unstable sitting position. In addition, Suzuki et al.[15) investigated trunk muscle activity in the unstable sitting position and found significant positive correlations between the global rectus abdominis and thoracolumbar spine muscles and COG sway. Conversely, no significant correlation was observed between the COG sway of the local muscles and that of the internal oblique and lumbar multifidus muscles. These results suggest that the activation of local muscle activity and static contraction improved spinal stability, and decreased COG sway during unstable sitting by breaking the tilt of the local muscle to the front and back, and to the left and right.

With respect to the effect of local muscle activity on COG sway, Hodges et al.[16) reported that afferent input from peripheral mechanoreceptors and other sensory systems must be interpreted, and then a coordinated response of the trunk muscle must be generated so that the muscle activity occurs at the correct time, with the correct amplitude, in response to unexpected challenges such as sitting on an unstable surface. Tanemoto et al.[17) stated that deep trunk muscles are more involved in somatosensory functions such as intrinsic receptor sensations. They stated that the activation of the deep trunk muscles may trigger a feedback system that provides information regarding intersegmental motions and positional changes of the spine, which may facilitate postural control and reduce COG sway.

In summary, the local muscles may be involved in improving spinal stability owing to their muscle contractile activity and may also contribute to the reduction of COG sway by acting as intrinsic receptors.

On the basis of these considerations, we have discussed the differences in exercise effectiveness between CSE and MCE. Ito et al.[18) described the lumbar spine stabilization system as being, composed of the following three subsystems: (1) a passive lumbar stabilization system (PS) that focuses on the vertebral body, intervertebral disks, intervertebral joints, and ligaments; (2) an active subsystem (AS) that focuses on a group of flexors such as the abdominal muscles and a group of extensor muscles such as the erector spinae, which stabilizes the lumbar spine; and (3) a neural subsystem (NS), which efficiently coordinates the activities of these systems. The transverse abdominis and internal oblique muscles are essential for lumbar spinal stability. According to Yoon et al.[19), CSE involving raising the limbs from a four-crawl position, which was used in this study, activates the medial obliques, external abdominal obliques, multifidus, and erector thoracic spinal muscles. The dorsal and trunk muscles showed greater activity when the unilateral lower limb was raised than when only the unilateral upper limb was raised. In this study, while raising the unilateral lower limb or the unilateral and contralateral upper limbs, the CSE may have increased the muscle activity of the back and trunk muscles, especially the medial and external abdominal obliques, lumbar multifidus, and thoracic erector spinae, which resulted in lumbar spinal stability. On the other hand, MCE is performed to coordinate, control, and restore the ability of the trunk muscles, but as Hodge et al.[16] stated, a coordinated response of the trunk is required to maintain unstable sitting; thus, MCE may affect the reduction of COG sway in terms of improving trunk coordination.

Both CSE and MCE were effective in improving LBP and reducing COG sway, but the differences in their effects were small. In the present study, we found no significant difference in the effect of the exercises in the patients with mild LBP because of the small difference in COG sway between them, and healthy subjects. In addition, the intervention period was only 6 weeks, and the effect of muscle strengthening was not significant. To investigate the difference in exercise effectiveness in the future, it is necessary to conduct a similar study with a longer intervention period in subjects with more severe LBP.

Conclusion

The effects of both CSE and MCE improved spinal stability and subjective LBP in 3 weeks. CSE and MCE showed approximately the same degree of efficacy in reducing LBP and COG sway while sitting on an unstable surface, indicating that spinal stability and trunk muscle coordination were involved in the reduction of LBP and COG sway. The results showed that CSE improved spinal stability and trunk muscle coordination in the subjects with LBP and reduced COG sway in the subjects with and without LBP. To further investigate the differences in exercise effectiveness in the future, studies must include subjects with severe LBP and longer intervention periods.

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