Trunk muscle activity with different sitting postures and pelvic inclination

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Abstract

Background and objective: Sitting posture may often place large burden on trunk muscles, while trunk muscle activities in the sitting posture have not been well clarified. In this study, a difference in trunk muscle activity between two kinds of sitting postures was evaluated, focusing on low back pain induced by posture holding.

Material and methods: An experiment was conducted on the subjects sitting on a stable-seat and on an unstable-seat, with the pelvis inclined forward, backward, rightward, and leftward.

Results: With the pelvis inclined forward, rightward and leftward, muscle activities were significantly increased in a stable-seat sitting posture. In contrast, no significant increase in muscle activity was observed with the pelvis inclined in every direction in an unstable-seat sitting posture.

Conclusions: With the pelvis inclined in the stable-seat sitting posture, muscle activities were imbalanced, while with the pelvis inclined in the unstable-seat sitting posture, muscle activities were not imbalanced. Thus, it is suggested that with the pelvis inclined to the maximum extent in the stable-seat sitting posture, low back pain may be induced by imbalanced muscle activities.

Keywords: Low back pain, trunk muscle, electromyography, posture, pelvis incline, stable seat, unstable seat

1. INTRODUCTION

Low back pain can develop due to many causes ranging from physical or biological injury to psychosocial factors. For this reason, low back pain is a pathological condition for which standardized evaluation and treatment protocols have not yet been established.

Low back pain is an increasingly common complaint. Today’s lifestyle means that most people sit for hours at work, at home, or when traveling; accordingly, the trunk muscles are adversely affected by maintaining a sitting posture for long periods of time. Unfortunately, the effect on the trunk muscles has hardly been examined; and in the few studies covering this topic, any experiments were limited to maintaining the posture, for example, with the trunk muscles inclined forward [1,2]. Furthermore, no study has reported the effects of the pelvic inclination, which strongly influences the sitting posture, on the musculoskeletal system of the spine; hence, the effects of the pelvic inclination on trunk muscle activity in the sitting posture have not been clarified.

Pelvic inclination induces a variance in spinal and postural alignment. This approach has been used for the treatment of low back pain as well as for alignment repositioning and preventive exercise as seen in, for example, the McKenzie method [3] and the Williams method [4]. The use of a balance disk for an unstable seat is a convenient method for easily inclining the pelvis. Muscle over-contraction [5], an event specific to patients with low back pain, has been reported. The balance disk, which enables the alignment of the spine to vary without muscle over-contraction, is suitable for treatment of low back pain. However, details on the mechanism of trunk muscle activity in the balance-disk sitting posture have not been elucidated.

Therefore, we investigated the trunk muscle activity for stabilizing the lumbar vertebra with the pelvis inclined to the maximum extent and compared the results between the chair (stable-seat) sitting posture and the balance disk (unstable-seat) sitting posture.

2. SUBJECTS AND METHODS

The study included 19 healthy male subjects (average age 23.8±1.4 years, average body height 172.8±5.6 cm, average body weight 64.3±6.1 kg) with no history of low back pain. We explained the study content to the subjects and obtained their written informed consent after confirming that the explanation was sufficiently understood. This study was approved by the Ethics Committee of the Graduate School of Comprehensive Human Sciences, University of Tsukuba.

The subjects were asked to perform the following movement tasks in the experiment:

1) Incline the pelvis to the maximum extent possible while sitting in the chair with the

soles of their feet not touching the floor (chair sitting posture with pelvis maximally inclined); and 2) incline the pelvis while sitting on the balance disk with the soles of their feet not touching the floor (balance-disk sitting posture with pelvis maximally inclined). The pelvis was inclined in four directions: forward, backward, rightward, and leftward. During pelvic inclination, the subjects were asked to hold their heads at a 90° angle to the floor with their upper limbs folded in front of their chest, and their hip joints and knee joints at a 90° angle for as long as possible (Fig. 1). Only the movements that were successfully and stably maintained for three seconds were used for analysis. Images of the individual movements were recorded using a video camera and each inclination of the pelvis was verified on an electromyograph synchronously with the camera. The balance disks used in this study were 34 cm in diameter and 9 cm in height. Before the movement tasks were performed, the myogenic potential for maximum voluntary contraction (MVC) was measured to obtain an index for MVC standardization. The test positions were consistent with those demonstrated in manual muscle testing books commonly used by physical therapists, except that additional manual resistance was applied in some cases. Manual resistance was applied gradually, with the maximum level held for three seconds. Correct electrode placement was further confirmed by observing the amplitude of the EMG signal during the manual muscle tests. For the rectus abdominis muscles, MVC was measured in a partial sitting-up posture with the knees flexed, hands behind the head and trunk flexed, while counter-resistance was applied to the shoulders in the direction of the trunk extension. For the external oblique muscles on the right side, the participants were in a supine position with their knees flexed and hands behind the head, while the trunk was flexed and rotated to the left. Counter-resistance was applied to the shoulders in the direction of the trunk extension and right rotation. For the external oblique muscles on the left side, the trunk was flexed and rotated to the right, with counter-resistance applied to the shoulders in the direction of the trunk extension and left rotation. The activity of the lumbar multifidus muscles and the erector spinae muscles with the trunk muscles extended was measured under the maximally forced condition through a series of movements: starting from the posture in the prone position with the fingers of both hands attached to the occipital region of the head, doing manual resistive exercise around both shoulder girdles. The contraction retention time for each measurement was set to three seconds. The manual-resistive exercise approach, as well as the verbal-command approach was used during MVC measurement, and it was verified whether the muscles had reached their maximum voluntary contraction level while the muscle potential was being checked.

Electromyography (EMG) using a pair of surface electrodes was carried out on four types of muscles: bilateral rectus abdominis muscles (3 cm lateral to the umbilicus), external oblique muscles (midway between the costal margin of the ribs), erector spinae muscles (3 cm lateral to the L3 spinous process), and lumbar multifidus muscles (approximately 3 cm lateral to the L5 spinous process [6,7]), a total of eight muscles. Although it has been indicated that crosstalk may influence the deep lumbar multifidus muscles [8], the use of a pair of surface electrodes for measurement on these muscles has been demonstrated to be acceptable [9]. Accordingly, a pair of minimally invasive surface electrodes was also used in lumbar multifidus muscle measurement instead of a pair of wire electrodes.

Vitrode F disposable electrodes (Nihon Kohden), a pair of skin surface electrodes, were used as surface electrodes and protective earth electrodes. The separation between electrodes was set to 10 mm. The areas where the disposable electrodes were to be attached were prepared by using skinPure gel (Nihon Kohden) to sufficiently remove the cornified layer. The gel was then cleaned off with alcohol-soaked cotton and the electrodes were attached and fixed to the appropriate points. The protective earth electrodes were fixed to the skin covering the costa. The impedance of the attached electrodes was set to a value of ≤ 2 kΩ for all subjects.

The measured values for muscle potential were amplified by a factor of 1000 using an amplifier (MEG-6116, JB-640J, Nihon Kohden) and analog-to-digital (A/D)-converted at a sampling frequency of 2000 Hz. Vital Recorder 2 (Kissei Comtec) was used for surface electromyography and analysis. The A/D-converted muscle potential values were processed through a bandpass filter (20–500 Hz) to remove motion artifacts for full-wave rectification (BIMUTAS-Video, Kissei Comtec).

The root mean square (RMS) of muscle potentials obtained for one second, during which the posture was stable, was divided by the RMS value for one second including the measurement point at which the maximum muscle potential for MVC was obtained, to calculate the percentage of muscle activity (%MVC). A monitor was used to check for the presence of noise such as artifacts generated by other devices and then the %MVC values were recorded.

To compare the %MVC values of individual muscles between the chair sitting posture and the balance-disk sitting posture with the maximally inclined pelvis, the %MVC values were normalized by the MVC values by one-way ANOVA. A multiple comparison test was carried out on the test items for which a significant difference was observed, using the Dunnet method for the group of ipsilateral muscles and the Tukey method for the group of opposite muscles. Dr. SPSS II for Windows

(11.0.1J) was used for statistical processing and the significance level was set to 5%.

3. RESULTS

The percentage of trunk muscle activity (%MVC) increased significantly with the pelvis inclined forward in the chair sitting posture compared with that of the bilateral rectus abdominis muscles, external oblique muscles, erector spinae muscles, and lumbar multifidus muscles. On the other hand, no significant difference in %MVC was observed among the individual muscles with the pelvis inclined backward. With the pelvis inclined leftward, the %MVC value for the right erector spinae muscles increased significantly compared with that of the right and left rectus abdominis muscles, the left external oblique muscles, left lumbar multifidus muscles, and left spinae muscles. With the pelvis inclined rightward, the %MVC value for the left erector spinae muscles increased significantly compared with that of the right and left rectus abdominis muscles, the right external oblique muscles, right lumbar multifidus muscles, and right spinae muscles (Table 1).

No significant difference in %MVC was observed among the individual muscles in the balance-disk sitting posture when all tasks were performed with the pelvis inclined (Table 1).

With the pelvis inclined rightward and leftward, the elector spinae muscles showed significantly higher activities in the chair-sitting posture than those in the balance-disk sitting posture. Any other significant difference was not observed (Table 1).

4. DISCUSSION

In this study, we compared the trunk muscle activity between the stable-seat sitting posture and the unstable-seat sitting posture with the pelvis inclined to the maximum extent, focusing on low back pain induced by maintaining the same posture. Panjabi reported that the stabilizing system of the spine is maintained by three subsystems: a passive subsystem composed of bones and interspinal disks; an active subsystem composed of muscles and others; and a neural subsystem composed of nerves [10]. The passive subsystem contributes to the stability of joints in the terminal range of motion (ROM) and the active subsystem stabilizes the joints in the middle range of motion (neutral zone). The pelvis was inclined to the maximum extent in the sitting postures in this study. Under this condition, the stabilizing system of the spine tends to rely on the passive subsystem because the pelvis sits in the vicinity of the terminal ROM of the lumbar region. In this terminal ROM, a problem with the passive subsystem, such as an injury, may cause further damage unless the appropriate subsystem fully compensates for it [11]. Moreover, an imbalance in the activity of the trunk muscles, a component of the active subsystem, or an imbalance between the trunk muscles and the antagonistic muscles, may increase the risk of developing low back pain [12-15]. This suggests that the investigation of trunk muscle activity under the conditions set in this study may provide a key to estimating the function of the active subsystem in the sitting postures.

The trunk muscles in the lumbar region are classified into two groups, one being a local muscle group in the deep zone and the other being a global muscle group in the shallow zone [16]. Among the abdominal muscles, the musculus transversus abdominis, which is a local muscle, is strongly involved in the stabilization of the trunk muscles [17-19] and among the dorsal muscles, the lumbar multifidus muscles, which are the thickest local muscles in the lumbosacral region, are known to be 80% involved in the stabilization of the spine [20]. Moreover, for the stabilization of the lumbar vertebra, it is essential that the musculus transversus abdominis and lumbar multifidus muscles, which are classified in the local muscle group, contract together under the control of the neural subsystem（17）.

The findings of this study showed that with the pelvis inclined forward in the chair (stable-seat) sitting posture, muscle activity increased in the bilateral dorsal muscles compared with the abdominal muscle group, and with the pelvis laterally inclined, they were the largest in the erector spinae muscles, which were global muscles on the opposite side of pelvis inclination, compared with those in all the opposite muscle groups.

Previous studies have reported that with the pelvis inclined forward, the lordosis of the lumbar vertebra is augmented and the tips of the intervertebral joints come into contact with the adjacent vertebral arc, leading to articular capsule compression by one-sixth of the pressure force. Some reports suggest that with the pelvis inclined laterally, the opposite articular capsule is over-extended, with a dull pain likely to occur in the lumbar region [21-23]. Furthermore, even if the erector spinae muscles, which are global muscles, contract to the maximum extent, the stability of the spine deteriorates unless local muscles such as the lumbar multifidus muscles function properly [24,25]. In this study, an imbalance in muscle force tended to occur because the %MVC value for the trunk muscles increased only on the side of the pelvis inclination in the stable-seat sitting posture. It is also suggested that the passive subsystem augments the flexion of the lumbar vertebra to retain its stability due to poor contraction of local muscles, which are capable of improving the stability. Thus, an imbalance in muscle force may occur with the pelvis inclined to the maximum extent in the stable-seat sitting posture, causing an increased burden on the passive subsystem and eventually affecting the articular capsule. It was clarified that in contrast to the stable-seat sitting posture, the over-contracted muscles did not induce an imbalance in muscle force with the pelvis inclined in the balance-disk (unstable-seat) sitting posture.

Thus, it is suggested that a heavy load tends to be exerted on the articular capsule and the intervertebral disks with the pelvis inclined to the maximum extent in the stable-seat sitting posture compared with the unstable-seat sitting posture.

The pelvis inclined forward and laterally in the stable-seat sitting posture is frequently seen in people working and operating a PC at a desk for which the height has not been correctly adjusted, driving a car, or during balance training in the chair sitting posture, and so on. It was demonstrated that maintaining the posture with the pelvis inclined is likely to exert a heavy burden on the articular structure of the lumbar region, increasing the risk of developing low back pain. Our findings demonstrated that it is important to intentionally change the posture at regular intervals to avoid an uncomfortable position such as the pelvis inclined to the maximum extent for a long time in the chair sitting posture.

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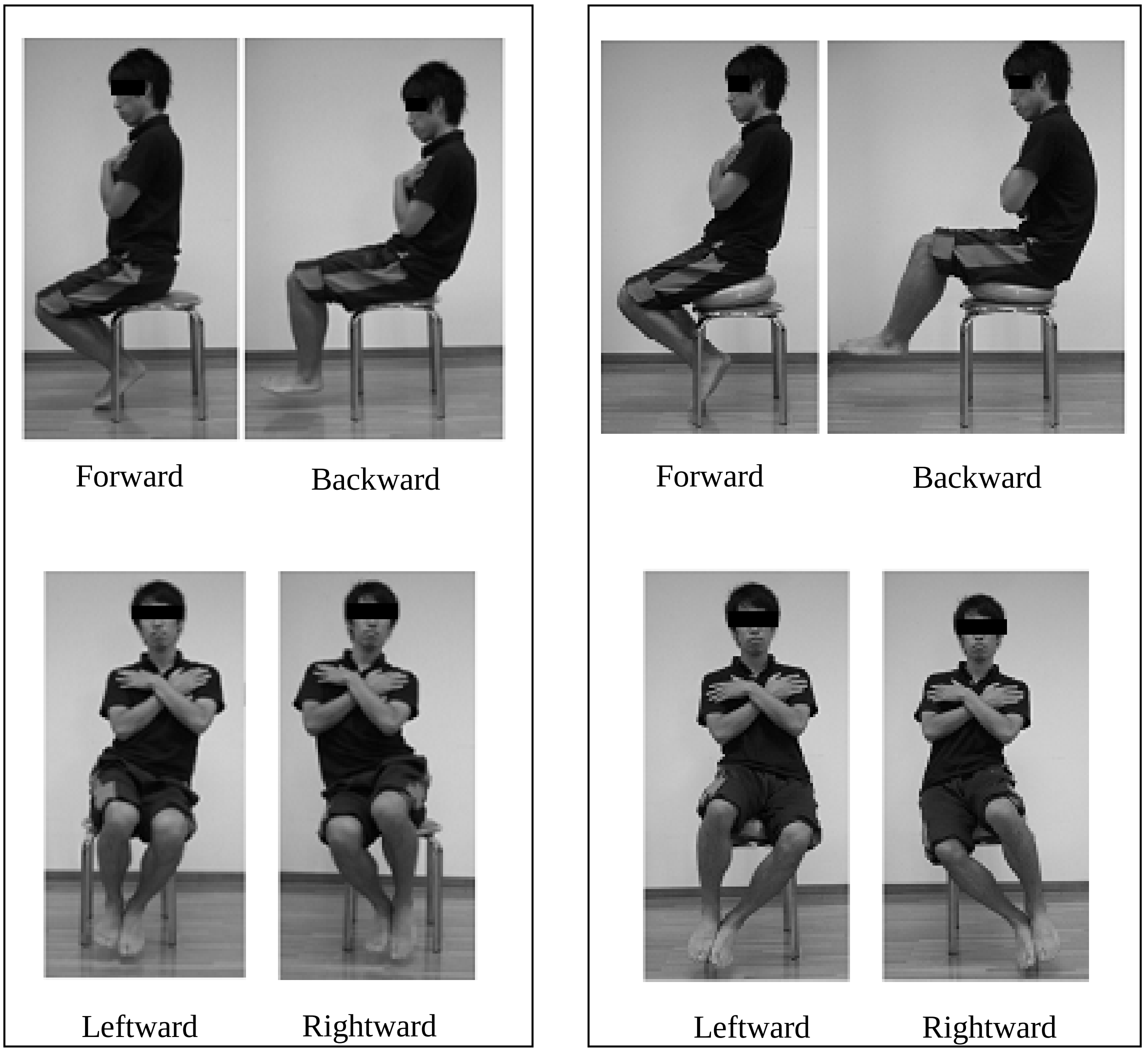
Table 1. Correlation between maximally inclined pelvis and percentage of individual muscle activity (%MVC)

			forward	backward	leftward	rightward
Chair	Right	RA	7.4±3.8	6.0±3.5	5.5±2.2	4.8±1.7
		EO	5.2±2.0	6.3±3.6	12.3±9.4	7.3±5.8
		MF	31.2±15.3†	7.4±2.3	14.7±9.1	6.9±2.4
		ES	24.2±10.1†	6.6±2.8	21.1±7.6*∫♯	6.4±2.7
	Left	RA	5.9±1.6	6.7±4.8	5.5±3.6	5.7±3.1
		EO	6.1±3.2	8.1±5.7	6.9±6.1	19.9±15.3
		MF	24.1±7.9†	5.0±2.4	4.8±1.5	13.3±4.0
		ES	23.2±5.6†	6.6±4.1	5.6±1.9	27.2±16.7*∫♯
Balance disk	Right	RA	12.0±6.0	13.9±12.4	11.4±7.1	10.5±8.6
		EO	17.7±13.1	16.2±15.0	11.3±6.2	15.4±11.8
		MF	12.5±9.6	5.9±3.1	10.3±5.3	11.2±7.7
		ES	13.1±11.4	6.3±5.5	8.0±4.4	9.0±6.6
	Left	RA	12.2±8.0	13.7±13.2	12.6±9.0	7.6±4.5
		EO	23.8±16.4	20.0±19.5	16.8±10.6	17.1±13.7
		MF	10.2±7.7	7.8±12.1	11.7±7.1	7.0±4.2
		ES	9.9±8.0	4.5±2.9	7.3±5.2	7.6±5.2

Abbreviations: RA; rectus abdominis, EO; external oblique, MF; lumbar multifidus, ES; erector spinae.
† Indicates a significant difference in the group (vs. bilateral RA, EO; P<0.05).
* Indicates a significant difference in the group (vs. ipsilateral RA; P<0.05).
∫ Indicates a significant difference in the group (vs. the muscles on the opposite side; P<0.05).
♯ Significantly higher than that of the lateral erector spinae (P＜0.05).



Chair-sitting

(Stable-seat sitting)

Balance-disk sitting

(Unstable-seat sitting)

Fig. 1 Task: Inclining pelvis in four directions