



Original Article

A newly developed floor chair placed on an office chair reduces lumbar muscle fatigue by cyclically changing its lumbar supporting shape

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Abstract. [Purpose] This study investigated lumbar muscle fatigue before and after maintaining a seated position for one hour, lumbar and pelvic inclination angle change, in subjects with and without active lumbar support. [Subjects and Methods] Fourteen healthy subjects randomized into two groups sat on a floor chair, placed on an office chair, that cyclically changed its lumbar supporting shape to provide active lumbar support (ALS) or no ALS for one hour. Before and after, we measured the frequency of muscle waveforms of the trunk extensor muscles when the subjects lifted an object weighing 10% of their body weight, using both hands while seated. In addition, ROMt (Range of motion test) of trunk rotation, degree of fatigue and muscle stiffness were analyzed. [Results] Muscle frequency while lifting the weight decreased significantly without ALS compared to with ALS. Mean muscle stiffness increased, ROMt decreased in desk work task significantly without ALS compared to with ALS. [Conclusion] These results suggest that the lumbar muscles became fatigued, because low frequencies, increased muscle stiffness, and decreased ROMt without ALS. We suggest lumbar muscle fatigue was maintained low for subjects seated in a chair with ALS.

Key words: Muscle fatigue, Active lumbar support, Low back pain

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INTRODUCTION

Recent studies have shown an association between prolonged and low back pain (LBP)^{1,2)}. Occupational LBP has become a major problem in industrial health³⁾. The major causes of LBP include handling heavy objects, standing up for long periods of time, and performing tasks while seated, with further investigation of the latter finding that fatigue in the lumbar muscles caused by maintaining a seated position for a long period of time can lead to LBP^{4,5)}. One representative bad sitting posture is a head forward position⁶⁾, involving bending of the waist. In this position, the head is located more anteriorly than in control subjects, leading to acute LBP⁷⁾. An increased bending posture increases the shearing force on the lumbar vertebrae and the compressive force on the vertebral duct, reducing tissue tolerance⁸⁾. It has been estimated that 50–80% of the population experiences LBP, which negatively affects daily life and task performance⁹⁾. Chronic low back pain (CLBP), defined as LBP sustained for >12 weeks¹⁰⁾, has been associated with various motor control problems, including damage to postural adjustment¹¹⁾ and delay in muscular response¹²⁾.

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Table 1. Demographic characteristics of study subjects

	ALS activated (n=7)	ALS not activated (n=7)
Age (years)	21.4 ± 0.8	21.4 ± 0.8
Height (cm)	167.1 ± 5.6	169.5 ± 10.9
Weight (kg)	54.7 ± 8.5	57.6 ± 9.9

All results are reported as mean ± standard deviation.

Table 2. Parameters measured before and after maintaining ALS activated and ALS not activated for 1 hour

	ALS not activated		ALS activated	
	pre	post	pre	post
FFD (cm)	0	0.4 ± 1.1	3.4 ± 4.7	2.6 ± 5.5
ROM[Rt] (°)	30.0 ± 9.6	27.1 ± 8.1	27.9 ± 4.9	27.9 ± 6.4
ROM[Lt] (°)	29.3 ± 9.3	24.3 ± 6.7*	27.1 ± 4.9	27.9 ± 5.7
Stiffness (Rt)	47.9 ± 8.4	54.5 ± 10.9*	53.4 ± 9.7	54.8 ± 11.6
Stiffness (Lt)	50.9 ± 10.0	61.5 ± 8.3*	53.0 ± 10.7	52.9 ± 12.5
VAS	2.5 ± 2.0		1.3 ± 0.9	

All results are reported as mean ± standard deviation

*p<0.05. Rt: right; Lt: left

Lumbar support devices, which support the lordosis of the back side of the lumbar region, have been commercialized and used frequently. Pelvic anteversion has been reported significantly higher in the presence than in the absence of lumbar support¹³). General lumbar support can maintain lordotic lordosis and anteversion of the pelvis, resulting in a posture in the sitting position close to the ideal physiological lordosis. However, even with general lumbar support, maintaining the same posture for a long period of time may reduce tissue tolerance of the lumbar loading structure, accompanied by sustained stress and increased tissue viscosity. Although the application of sustained stress to viscoelastic tissue leads to a creep phenomenon that causes tissue deformation, a creep phenomenon, even in the lumbar region, has also been observed after sustaining a bending posture for 20 minutes¹⁴). Tissue tolerance may decrease while viscous friction increases after maintaining the same posture for a long time, and may also occur after maintaining an intermediate waist posture. Furthermore, deformation caused by the creep phenomenon has been associated with microscopic damage to the tissue¹⁴). Moving one's waist while in a sitting position may prevent the deleterious effects on posture of maintaining the same position for a long period of time.

We have therefore constructed a prototype active lumbar support (ALS) chair with an automatic shape-changing function that automatically moves the waist during sustained sitting in a poor desk work environment and everyday life. Using ALS may reduce fatigue of back muscles and lumbar soft tissue. This study investigated the effects of ALS on lumbar muscle fatigue by measuring the latter before and after maintaining a seated position for a long period of time with and without transitive pelvic angle changes.

SUBJECTS AND METHODS

The study subjects comprised 14 healthy individuals, seven men and seven women, of mean age 21 years, with no current back pain. They were randomly separated into two groups (Table 1). Written informed consent was obtained from each participant before the study. The study protocol was approved by the Tokyo Metropolitan University of Health Sciences Ethical Review Board (Authorization Number 16042). All authors declare they have no conflicts of interest.

We developed a seat with an ALS shape-changing function designed to suppress lumbar pain fatigue by transitively changing the pelvic angle when a person performs seated tasks for long periods of time. The ALS regularly pushes the lower back anteriorly to prevent prolonged sitting in the same posture. The subjects were required to maintain a desk work seated position for one hour. Subjects in the control group sat on the device without ALS activated; whereas ALS group subjects sat on the device with ALS activated. The device was a newly developed small floor chair, placed on an office chair, which could have ALS switched to on or off. (Rinnza Auto, Labonetz Inc. Japan; Fig. 1). The ALS included automatic air pressure and back support (Fig. 2) and was designed to rise in two stages, with each cycle lasting 34 sec.

Electrodes for surface electromyography were attached to the right and left sides of each subject, from 3 cm L3–4, and the frequency bandwidth was set at 1,000 Hz. Before and after sitting for one hour, the subjects had to use both hands to lift an object, weighing 10% of their body weight, while seated.

Bilateral erector spinae muscle activity was recorded by surface electromyography (DKH Inc. Japan) after filtering. Frequency analyses were performed of muscle waveforms of the trunk extensor muscle, and the mean power frequency (MPF) and median values (MDF) were calculated.



Fig. 1. Front and side views of the developed chair with active lumbar support
Right figure: Experiment environment

Before and after sitting for one hour, trunk rotation in the sitting position was assessed by performing active range of motion tests (ROMt) using a goniometer. Other parameters measured before and after sitting for one hour included finger-floor distance (FFD), muscle stiffness using a durometer (PEK-1, ImoNET Inc., Japan) and degree of fatigue using a visual analog scale (VAS) ranging from 0 (no fatigue) to 10 (highest fatigue) points.

Measurements obtained before and after sitting for one hour were compared statistically using Wilcoxon's rank-sum tests. All statistical analyses were performed using the SPSS statistical package for Windows, version 21.0, with p values < 0.05 considered statistically significant.

RESULTS

MPF and MDF decreased before and after sitting for one hour while performing desk work tasks without ALS compared to with ALS (Table 3). MDF (left side) while lifting a weight decreased significantly before and after being seated for 1 hour without ALS, but no change with ALS. Mean muscle stiffness increased, ROMt decreased in desk work task significantly without ALS compared to with ALS (Table 2).

DISCUSSION

The present results suggest that the lumbar muscles became fatigued without ALS, reducing frequencies, increasing muscle stiffness, and decreasing ROMt. Muscle stiffness was lower after sitting on a chair with ALS, suggesting a reduction in extensibility of the lumbar muscles. The ALS prototype was designed to generate sustained passive movement of the waist and pelvic region while sitting. A previous study assessing whether the waist actually moves while being seated in the ALS prototype found that inflating to the second stage of ALS resulted in an average anterior pelvic inclination angle of 1° and that the average forward motion of the waist at the third lumbar level was 8 mm (p < 0.05)¹⁵. Thus, tissue stiffness in the lumbar region was regarded as associated with reduced ROMt, due to increased muscle fatigue in the normal seated position and increased muscle stiffness. Chronic pain has been found to increase muscle fatigue¹⁶. Muscle fatigue generated by maintaining muscular contractions while being in the same fixed sitting posture has been found to cause chronic lumbar pain.

Table 3. Muscle frequencies before and after maintaining normal and dynamic sitting positions for 1 hour

		ALS not activated		ALS activated	
		pre	post	pre	post
MDF	Rt	81.0 ± 14.2	65.6 ± 19.7	77.3 ± 17.8	91.6 ± 19.7
	Lt	78.5 ± 10.3	65.9 ± 16.6*	79.4 ± 18.0	89.6 ± 23.1
MPF	Rt	101.1 ± 16.2	96.4 ± 17.2	102.7 ± 21.4	112.7 ± 23.0
	Lt	92.4 ± 11.1	92.5 ± 17.8	101.6 ± 19.3	110.66 ± 21.9

All reports are reported as mean ± standard deviation.

*p < 0.05

Rt: right; Lt: left

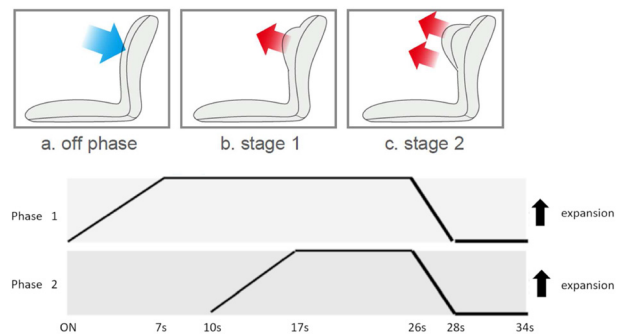


Fig. 2. Schematic diagrams showing active back rest, with each cycle requiring 34 sec

a: off phase: flow of air away from the subject through the back rest (pelvic neutral position)

b: stage 1: flow of air towards the subject through the back rest (pelvic forward tilt and lumbar lordosis)

c: stage 2: flow of air towards the subject through the back rest (more pelvic forward tilt and lumbar lordosis)

The air bag inserted in the lumbar support on the back expands in two stages (upper row), pushing the waist forward within one cycle (34 seconds). The lower row shows the timing of inflation of the air bag using an electric motor (DC 12.8 V, 1.8 A).

Although the differences were not statistically significant, even in VAS, sitting on the ALS prototype, even for 1 hour, was not associated with fatigue. These findings indicate that the ALS could maintain a sitting position with a comfortable posture.

Electromyogram frequency is dependent on type of muscle fiber, with Types I and II being in the low and high frequency regions, respectively. Suppression of activity due to fatigue of Type II fibers result in MPF and MDF gradually becoming lower. When MDF of the lumbar muscle was compared with MPF while lifting 10% of body weight for about 1 hour in the sitting position, we found that frequency was lowered only on the left side (Table 3). This may have been due to muscle fatigue in the normal seated position in the absence of ALS, resulting in the muscles having a low frequency immediately after lifting the weight. Despite the non-occurrence of lumbar muscle fatigue when performing ALS after performing the Sorensen test¹⁵, ALS was regarded as less likely to cause lumbar muscle fatigue. However, because there was a significant difference only in the left hip, further study is considered necessary. The ROMs of flexion and extension have been reported significantly increased following lumbar exercise¹⁷, suggesting that mild exercise of the lumbar region can expand ROM.

Maintaining a fixed posture, whether standing or sitting, for a long period of time is a cause of LBP^{1, 2}). The results of the present study suggest that moving the lumbar area, including the pelvis, through automatic air injection and removal while sitting, can prevent or reduce fatigue in the lumbar muscles. The major limitation of this study was that all subjects were in the same age group (mean age, 21 years). Therefore, these findings require verification in other age groups. Additional studies are also required to analyze the relationships of ALS degree of expansion and cycle time with tissue tolerance and muscle fatigue, thereby optimizing ALS parameters.

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