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Original Article

Effects of movement from a postural maintenance position on lumbar hemodynamic changes

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Abstract. [Purpose] To investigate the effects of movement from a postural maintenance position on lumbar hemodynamic changes, in order to prevent lower back pain and develop exercise therapy. [Subjects and Methods] Twenty-five healthy adults (mean age: 23.2 years) participated in the study. During flexion-extension exercise, the subjects moved their trunks gradually to a flexed position from an upright posture while sitting and standing, and then returned to and maintained an upright (re-upright) position. In the extension–flexion exercise, the subjects moved their trunks gradually from an upright posture to an extended position, and back while maintaining an upright (re-upright) position. Lumbar spinal muscle activity and hemodynamic changes were evaluated during both exercises. [Results] During the flexion and extension exercises, increased trunk-flexion angle caused increased muscle activity, decreased oxygenated hemoglobin in the multifidus muscle, and increased deoxygenated hemoglobin in the multifidus and lumbar erector spinae muscles. Moreover, the muscle activities were nearly the same in the re-upright and upright positions, and total hemoglobin also increased. [Conclusion] In both standing and sitting positions, holding the trunk in a flexed position causes ischemic hemodynamic changes in the multifidus muscle; however, the hyperemic response when returning the trunk to an extended position may improve circulation.
Key words: Lower back pain, Muscle activity, Near-infrared spectroscopy

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INTRODUCTION

Lower back pain represents a serious social challenge. In the current super-aging society, work-related lower back pain is common in caregivers who are frequently required to adopt a flexed posture with the trunk tilted forward. In previous studies, we examined lower back muscle activity and tissue stiffness during trunk flexion while standing and sitting and found more constant muscle activity and increased tissue stiffness at shallower flexion angles among participants in seated positions compared to those of participants in standing positions[1, 2)]. Excessive increase in tissue stiffness leads to impaired blood flow, and the resultant lumbar ischemia is associated with lower back pain. Recent reports have recommended trunk extension exercises for lower back pain caused by continuous flexion[3)]. Displacement of the intervertebral disc nucleus pulposus is one outcome of this exercise; however, the mechanism for the hemodynamic changes with respect to lumbar ischemia in this exercise remains unclear.

The objective of the present study was to elucidate the effects of movement from a postural maintenance position on lumbar hemodynamic changes in order to provide data that could serve as the basis for development of strategies for lower back pain prevention and exercise therapy.

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SUBJECTS AND METHODS

Twenty-five healthy adults (mean age: 23.2 years, mean finger-floor distance: 2.3 cm, and mean modified Schober test: flexion +5.4 cm) participated in the present study. The study was conducted with the approval of the Institutional Review Board of Saitama Prefectural University (no: 27048) after the subjects provided written informed consent.

In accordance with earlier studies[1, 2], the first exercise task (flexion-extension exercise) involved the subject gradually moving the trunk, 10° at a time, from an upright, resting trunk position of 0° flexion, as measured by an electric goniometer (NorAngle, Noraxon, Scottsdale, AZ, USA), to a position of maximum flexion, and then returning to a position of 0° flexion (re-upright) by extending the trunk. The second task (extension-flexion exercise) involved the subject gradually moving the trunk, 10° at a time, from an upright position to a position of maximum trunk extension, and then returning to a position of 0° flexion (re-upright) by flexing the trunk. Both tasks were performed in sitting and standing positions, and each angle (degree of flexion and/or extension) was maintained for 10 s.

The lumbar erector spinae (LES) and multifidus (MF) muscles were set as the measurement points. The muscle activity and the hemodynamic changes were measured with a surface electromyogram (TeleMyo G2, EM-601, Noraxon) and near-infrared spectroscopy (NIRS) tissue oxygenation monitor (Pocket NIRS Duo, DynaSense, Hamamatsu, Japan), respectively. Muscle activity on the left side and hemodynamic changes on the right side were synchronously measured. Measurements were taken at the level of the third lumbar vertebra for the LES and at the levels of the fifth lumbar and first sacral vertebrae for the MF. The integrated electromyogram (iEMG) value during the maintenance of each trunk flexion angle was calculated as %iEMG, which was normalized to the myoelectric value during maximal isometric contraction. Hemodynamic changes were evaluated using relative changes in oxygenated, deoxygenated (deOxy-Hb), and total hemoglobin (Oxy-Hb, deOxy-Hb, and total-Hb respectively), with the upright values as the reference values. The examination items were trunk angle and measurement point. Each of these factors underwent statistical processing for both the standing and sitting positions using repeated measures analysis of variance (ANOVA). Corrected p-values were calculated using Schaffer's multiple comparison procedure. Statistical analyses were performed using the statistical software R with a significance level of 5%.

RESULTS

The muscle activity and hemodynamic changes are shown in Tables 1 and 2.

In the flexion–extension exercise, a significant increase in both LES and MF muscle activity associated with increased trunk flexion angle was observed in both the sitting and standing positions. At maximum flexion, this activity significantly decreased, and muscle activity did not differ significantly between sitting upright and re-upright. A statistically significant difference was observed between standing re-upright and upright muscle activity; however, this difference was small and the values were nearly the same. As for hemodynamic changes, decreased Oxy-Hb was observed in the MF in association with increased trunk flexion angle, and increased deOxy-Hb was observed in both MF and LES. However, deOxy-Hb decreased in the MF and LES in the re-upright position, and there were significantly greater increases in Oxy-Hb and total-Hb in the re-upright position than in the upright position.

In the extension-flexion exercise, some statistically significant differences were observed in the muscle activity and hemodynamic changes. In any cases, these differences were small values.

DISCUSSION

Some researchers have reported using NIRS for examination of muscle tissue[4, 5]. A previous NIRS study on muscle tissue reported that muscle blood flow markedly decreases when internal muscle pressure increases[6]. The decrease and increase in Oxy-Hb during muscle contraction and muscle relaxation, respectively, reflects increased blood flow in that area[7]. Furthermore, deoxygenation during muscle contraction decreases Oxy-Hb, increases deOxy-Hb, and increases total-Hb as a result of hyperemia in the rest recovery phase following muscle contraction[8]. In our study, the muscle activity in the sitting condition was more constant at shallower flexion angles than that in the standing condition during the flexion–extension exercise. These results are consistent with our earlier study[1] and are most likely due to greater increases in muscle extension and activity in MF compared to that of LES, with an increased trunk flexion angle while standing. There was, therefore, increased internal muscle pressure in the MF, which resulted in decreased muscle blood flow, increased muscle oxygen demand due to ischemia, and decreased Oxy-Hb due to oxygen consumption. Returning to an upright position (re-upright) after maintaining a flexed position may have a hyperemic effect on ischemia in the MF by improving circulation. Thus, the extension-flexion exercise cannot be expected to induce greater improvement in hemodynamics than the flexion-extension exercise. As initially assumed[3], the extension–flexion exercise may have more potential as a method of relieving back pain through anterior displacement of the intervertebral disc nucleus pulposus than through improved hemodynamics. However, the fact that the extension–flexion exercise in our study started from a trunk position of 0° flexion may explain why ischemia was not induced. Further study on this extension–flexion exercise following loading with trunk flexion maintenance; i.e., starting from a state of induced ischemia, might be necessary. A limitation of the present study was that it was conducted in

Table 1. Changes in muscle activity and hemodynamics in the sitting position (mean ± SD, n=25)

			Upright (a1)	10° flexion (a2)	20° flexion (a3)	Maximum flexion (a4)	Re-upright (a5)		Upright (a1)	10° extension (a2)	Maximum extension (a3)	Re-upright (a4)
NIRS	Oxy-Hb	LES	−0.4 ± 1.2	−0.5 ± 2.1	−0.8 ± 4.3	−1.8 ± 5.2	3.0 ± 2.7	LES	−0.2 ± 0.5	1.4 ± 3.0	4.4 ± 5.5	0.4 ± 4.7
		MF	−0.2 ± 0.9	−0.8 ± 2.5	−2.6 ± 4.4	−5.0 ± 6.2	3.2 ± 3.9	MF	0.0 ± 0.5	0.6 ± 2.7	5.1 ± 5.0	−0.2 ± 3.1
	De-Oxy-Hb	LES	−0.0 ± 0.5	2.9 ± 4.5#	7.1 ± 6.9#	9.7 ± 9.2#	1.4 ± 3.8	LES	−0.1 ± 0.5	−0.6 ± 2.9	−0.6 ± 5.6	0.1 ± 3.0
		MF	0.1 ± 0.4	−0.1 ± 3.2#	2.2 ± 4.5#	4.5 ± 7.2#	0.8 ± 3.6	MF	−0.1 ± 0.4	−1.0 ± 2.6	2.5 ± 6.7	−0.7 ± 2.5
	Total-Hb	LES	−0.5 ± 1.4	2.3 ± 5.6#	6.4 ± 9.3#	8.0 ± 11.4#	4.4 ± 4.6	LES	−0.3 ± 0.6	0.8 ± 5.4	3.9 ± 9.7	0.4 ± 5.8
		MF	−0.1 ± 0.7	−0.8 ± 4.6#	−0.4 ± 4.9#	−0.5 ± 8.0#	4.0 ± 5.9	MF	−0.1 ± 0.7	−0.4 ± 4.8	7.6 ± 11.0	−0.9 ± 4.3
%iEMG		LES	7.4 ± 4.7	15.0 ± 6.4	17.0 ± 7.3	3.4 ± 3.5	7.1 ± 4.2	LES	5.5 ± 3.7	4.7 ± 4.2	5.3 ± 3.9	5.7 ± 3.8
		MF	7.3 ± 4.8	17.6 ± 7.8	19.7 ± 9.1	3.2 ± 2.1	7.1 ± 5.0	MF	5.3 ± 4.0	5.0 ± 2.8	6.5 ± 3.6	6.0 ± 4.7
NIRS	Oxy-Hb	LES					a1,2,3,4<a5 *		a1,2<a3 *		a3>a4 *	
		MF			a1,2>a3 *	a1,2,3>a4 *	a1,2,3,4<a5 *					
	De-Oxy-Hb	LES		a1<a2 *	a1,2<a3 *	a1,2,3<a4 *	a3,4>a5 *		n.s.			
		MF	n.s.									
	Total-Hb	LES	a1<a3,4,5 *	a2<a3,4 *				LES	n.s.			
		MF	a1<a5 *					MF			a1,2<a3 *	a3>a4 *
%iEMG		LES	a1<a2,3 *		a2,3>a5 *	a1,2,3>a4 *	a4<a5 *		n.s.			
		MF	a1<a2,3 *		a2,3>a5 *	a1,2,3>a4 *	a4<a5 *					

NIRS: change of hemodynamic (au; arbitrarily unit. value/10^{-2}), %iEMG: muscle activity (%), *p<0.05 (factor of trunk angle), #p<0.05 (factor of measurement point), n.s.: not significant

Table 2. Changes in muscle activity and hemodynamics in the standing position (mean ± SD, n=25)

			Upright (a1)	10° flexion (a2)	20° flexion (a3)	30° flexion (a4)	40° flexion (a5)	Maximum flexion (a6)	Re-upright (a7)		Upright (a1)	10° extention (a2)	20° extention (a3)	Maximum extention (a4)	Re-upright (a5)
NIRS	Oxy-Hb	LES	−0.5 ± 1.0	0.2 ± 3.2	−1.1 ± 4.9	−1.1 ± 6.2#	−1.3 ± 5.8#	0.4 ± 64#	3.5 ± 3.1	LES	0.0 ± 0.9	3.5 ± 4.4	5.0 ± 4.8	5.4 ± 5.8	0.8 ± 4.5
		MF	−0.6 ± 1.0	−0.4 ± 3.2	−2.8 ± 4.2	−6.3 ± 6.0#	−8.6 ± 6.9#	−8.1 ± 6.4#	2.7 ± 3.7	MF	−0.3 ± 1.0	1.3 ± 5.5	1.8 ± 7.3	5.3 ± 11.5	0.9 ± 4.8
	De-Oxy-Hb	LES	−0.1 ± 0.5	2.3 ± 4.1	6.4 ± 6.5#	11.7 ± 11.2#	15.6 ± 12.8#	18.6 ± 15.1#	1.6 ± 2.1	LES	0.1 ± 0.8	1.7 ± 6.1	1.9 ± 6.8	1.4 ± 7.4	0.5 ± 4.5
		MF	0.0 ± 0.5	−0.1 ± 4.3	1.1 ± 4.7#	2.7 ± 5.6#	4.8 ± 6.9#	8.3 ± 10.0#	2.4 ± 2.2	MF	−0.1 ± 0.6	0.9 ± 5.4	2.7 ± 7.8	6.9 ± 11.8	1.1 ± 4.7
	Total-Hb	LES	−0.7 ± 1.1	2.6 ± 6.9	5.3 ± 9.9#	10.7 ± 14.7#	14.2 ± 14.6#	19.0 ± 17.3#	5.0 ± 3.6	LES	0.1 ± 1.4	5.2 ± 10.2	6.9 ± 11.1	6.8 ± 12.3	1.3 ± 8.2
		MF	−0.5 ± 1.2	−0.5 ± 7.0	−1.7 ± 8.1#	−3.6 ± 9.3#	−3.8 ± 10.3#	0.2 ± 13.3#	5.1 ± 4.9	MF	−0.4 ± 1.4	2.2 ± 10.7	4.5 ± 14.7	12.2 ± 22.6	2.0 ± 9.0
%iEMG		LES	5.5 ± 4.0#	15.2 ± 5.5#	19.1 ± 5.8#	20.0 ± 6.0#	16.0 ± 7.8#	2.7 ± 1.5	7.1 ± 5.2#	LES	5.3 ± 4.1	3.1 ± 1.9	3.1 ± 1.4	3.9 ± 2.2	5.7 ± 4.1
		MF	7.2 ± 4.5#	20.6 ± 5.7#	25.8 ± 7.2#	26.6 ± 7.3#	21.4 ± 10.0#	2.9 ± 1.2	8.6 ± 5.0#	MF	6.0 ± 4.3	3.7 ± 2.9	3.1 ± 1.3	3.8 ± 2.0	7.0 ± 4.6
NIRS	Oxy-Hb	LES							a1,2,3,4,5<a7*				a1<a2,3*	a1,2,3<a4*	a2,3,4>a5*
		MF			a1,2>a3*	a1,2,3>a4*	a1,2,3,4>a5*	a1,2,3>a6*	a1,2,3,4,5,6<a7*						
	De-Oxy-Hb	LES		a1<a2,3,4,5,6,7*	a2<a3,4,5,6*	a3<a4,5,6*	a4<a5,6*	a5<a6*	a2,3,4,5,6 > a7*	LES	n.s.				
		MF		a1<a4,5,6,7*	a2<a3,4,5,6,7*	a3<a4,5,6*	a4<a5,6*	a5<a6*	a6>a7*	MF				a1,2,3<a4*	a4>a5*
	Total-Hb	LES	a1<a2,3,4,5,6,7*	a2<a3,4,5,6,7*	a3<a4,5,6*	a4<a5,6*		a5<a6*	a3,4,5,6>a7*		a1<a2,3,4*	a2<a3,4*	a3<a4*		a3,4>a5*
		MF						a5<a6*	a1,2,3,4,5<a7*						
%iEMG		LES	a1<a2,3,4,5,7*	a2<a3,4*		a4>a5*	a1,2,3,4,5>a6*	a6<a7*	a2,3,4,5>a7*	LES	a1>a2,3*	a2<a4,5*	a3<a4,5*		
		MF	a1<a2,3,4,5,7*	a2<a3,4*		a3,4>a5*	a1,2,3,4,5>a6*	a6<a7*	a2,3,4,5>a7*	MF	a1>a3*				a2,3,4<a5*

NIRS: change of hemodynamic (au; arbitrarily unit. value/10^{-2}), %iEMG:muscle activity (%), *p<0.05 (factor of trunk angle), #p<0.05 (factor of measurement point), n.s.: not significant healthy individuals without lower back pain. Future studies in individuals with lower back pain are required. Thus, the results of the present study should only be used to better understand hemodynamic changes in healthy individuals.

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