

Comparison of Muscle Performance of the Lumbar Region and Head Alignment According to the Length of Sitting Time

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Purpose: This study aimed to verify the impact of the time that the sitting posture is maintained on changes in muscle performance and head alignment.

Methods: The subjects of this study were healthy adults aged between 20 and 30 years. Ninety-three subjects participated in this study (male: 57, female: 36). The subjects were divided into a one-hour group, a two-hour group, and a three-hour group. All the subjects adjusted the height of their chair to a comfortable position and then sat for one, two, or over three hours. Both prior to and after the experiment, the muscle performance (muscle strength, endurance, and flexibility) of the subjects was measured.

Results: In the 2-hours and 3-hour group, muscle strength, flexibility and endurance reduced significantly before and after the study, and the head alignment significantly changed.

Conclusion: These findings showed that sitting continuously for longer than two hours decreases muscle strength, endurance, and flexibility. A flexed posture affects the muscle performance of the lumbar region and may result in problematic postures, such as a forward head position.

Key Words: Sitting time, Muscle performance, Head alignment, Posture

1. Introduction

Standing and sitting postures are frequent functional daily activities. Today, people spend more time in sitting than in standing postures due to the development of science and technology and automation. Dependence on automobiles, even for traveling a short distance, together with long periods spent on the computer, contributes to today's sedentary lifestyles.¹ Sitting for a long time is associated

with a decrease in metabolic energy expenditure, which may be a cause of overweight and obesity. It may also trigger decreased resistance against all kinds of diseases and an increase in adult diseases.² Sitting may increase the load on the lumbar vertebrae, and the resulting stress may have an adverse effect on the vertebrae, restricting movement.³ It may also give rise to musculoskeletal diseases.⁴ Sitting for a long time decreases utilization of the lower extremity muscles mobilized in standing and movement, and stress resulting from the continuous load on the muscles around the vertebrae may be increased, possibly bringing about changes in the performance of the muscles around the vertebrae.

Muscle performance includes muscle strength, endurance, and flexibility.⁵ Weakened muscle strength around the

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vertebrae and instability of the vertebrae resulting from damage to the soft tissues may result in musculoskeletal system lesions and lumbar pain.⁶ Muscle strength refers to the work performance of the muscles when they contract or extend. Evaluating the strength of the lumbar vertebrae muscles plays an important role in maintaining appropriate locations of the trunk and the pelvis.⁵ The endurance of the trunk muscles may be a predictive factor for lumbar pain symptoms.⁷ Endurance refers to the ability of the muscles to maintain low-intensity exercise for a long time.⁵ For normal activities of daily living, the soft tissues should be flexible, and joint mobility should be normal.

Sedentary postures impose considerably greater load on the lumbar region than standing postures.⁸ The increased load on the muscles around the vertebrae and on the vertebrae increases muscle fatigue, possibly reducing muscle performance. Reduced physical activity may also weaken the strength of the muscles and lead to a decrease in flexibility, an imbalance in body composition, and a decline in physical strength, such as cardiovascular and respiratory endurance.

Many studies have adopted dynamic approaches to evaluate sitting postures compared to other postures. However, research concerning the length of time to maintain sitting postures has been lacking. Accordingly, this study aimed to verify the impact of the time that the sitting posture is maintained on changes in muscle performance (muscle strength, endurance, and flexibility) and head alignment and to present a guideline for continuously sitting postures.

II . Methods

1. Subjects

The subjects of this study were healthy adults aged between 20 and 30 years. The inclusion criteria of selection of the subjects were: those who did not have musculoskeletal or neuromuscular system problems or disabilities; those who did not have pain in the lumbar or cervical area or restriction in range of motion; those who did not have injury in the lumbar region or undergo a surgical operation of the

region in the previous six months; and those who had a no problem with sitting for a long time. All subjects understood the purpose of this study and agreed to participate in this research. All participants signed an informed consent approved by the Institutional Review Board.

2. Experimental Methods

1) Study procedures

To compare the muscle performance capabilities according to the time spent sitting, all the subjects adjusted the height of their chair to a comfortable position and then sat for one, two, or over three hours. During this period, they performed what they wanted to do, such as using the computer or learning. Both prior to and after the experiment, the muscle performance—muscle strength, endurance, and flexibility—of the subjects was measured.

2) Measurement tool

(1) Muscle strength evaluation

Regarding muscle strength, the subjects' extensor muscle strength and flexor muscle strength were measured using a back strength dynamometer (TKK 5102 Badk-D, Takei, Japan). The extensor muscle strength was measured while the subjects stood on the board of the dynamometer, spread their legs by about 30 cm, grabbed the grips with both hands, tilted their upper body by about 30 degrees to adjust the length of the chains, and slowly strained the extensor muscle without bending their knees. The muscle strength was measured with the subjects stretching their upper body. The flexor muscle strength was measured while the subjects stood on the board of the dynamometer, spread their legs by about 20 cm, grabbed the grips with both hands, and strained the flexor muscle to a maximal extent. The muscle strength was measured while the subjects bent their upper body. The extensor muscle strength and the flexor muscle strength were measured three times, and the values were averaged. The unit was kg.

(2) Evaluation of endurance

Endurance was measured with the side-bridge test. The

subjects adopted a preparatory position lying on their side with their knees extended, bending their elbow joint of their lower arm by 90 degrees, the opposite arm crossed from the chest to be placed on the shoulder of their lower arm. The test was initiated when they raised their hips and knees from the base of the support and maintained their body in a straight line.⁹ While the subjects maintained this posture, the measurement was taken until the subjects felt pain in their waist or their hips or knees contacted the base of the support. When the maintenance time exceeded five minutes, the measurement was finished. Their muscle endurance was measured three times, and the values were averaged. The unit was seconds.

(3) Evaluation of flexibility

Flexibility was measured using a modified Schober test,¹⁰ a certified test that identifies mobility of the lumbar vertebrae by separating the movement of the lumbar vertebrae from other movements. Marks were made on the center of the line connecting the posterior superior iliac spine and 10 cm up from the posterior superior iliac spine. A tape measure was used to measure changes in the gap between the marks, with the subjects bending their trunk to a maximal extent. The unit was cm.

(4) Evaluation of head alignment

The subject's sitting position was photographed using a digital camera prior to and after the experiment, and then their body alignment was measured and analyzed using a global posture system (Italy, 2005). The distance between the centerline of the shoulder joint to the external ear on the sagittal plane was measured. As the gravity line passes the front of the external ear and the centerline of the shoulder joint, the larger the measured value is, the more the head is protruded forward. The measurement unit was mm.

3. Statistical analysis

Statistical analyses were performed using SPSS version 14 for Windows (SPSS Institute Korea, Seoul, Korea) and the results are presented as Mean±SD. In order to analyze the changes in muscle strength, endurance,

flexibility and head alignment the pre- and post-test, the paired t-test was used for the changes. One-way ANOVA was used for comparison of difference between the value before and after of muscle strength, endurance, flexibility and head alignment on each group, and multi analyses of three groups were Turkey test. Statistical significance was accepted for values of as $P<0.05$.

III . Results

1. General characteristics of the subjects

Ninety-three subjects participated in this study (male: 57, female: 36). The subjects were divided into a one-hour group, a two-hour group, and a three-hour group. They were equally and randomly assigned to one of the three groups (with 19 males and 12 females in each group). The average age of the participants in the one-hour group, the two-hour group, and the three-hour group was 24.20 years, 23.59 years, and 22.86 years, respectively. The average height and weight of the one-hour group, the two-hour group, and the three-hour group were 168.80 cm and 62.20 kg, 170.78 cm and 68.44 kg, and 166.12 cm and 66.59 kg, respectively. There were no significant differences in the homogeneity of the three groups prior to the experiment. The general characteristics of the subjects are shown in Table 1.

2. Changes in muscle strength

The strength of the flexor and the extensor muscles decreased according to the length of the sitting time. The strength of the flexor and the extensor muscles significantly differed prior to and after the experiment only in the three-hour group. After the experiment, there were significant differences in the flexor muscle strength between the one- and two-hour groups and the three-hour group ($P<0.05$).

3. Changes in endurance

The endurance decreased according to the length of sitting time. As the subjects' sitting time increased, the difference in endurance increased, and there was a significant change in the three-hour group ($P<0.05$). However, there were no

Table 1. General characteristics of the subject

	1-hour group	2-hour group	3-hour group	F	P-value
Age (year)	24.20 ± 4.42	23.59 ± 3.98	23.86 ± 2.21	1.789	.209
Height (cm)	168.80 ± 8.46	171.78 ± 10.57	166.12 ± 4.53	1.377	.281
Weight (kg)	62.20 ± 13.95	68.44 ± 12.70	66.59 ± 14.61	.533	.549

significant differences among the three groups.

4. Changes in flexibility

Flexibility decreased according to the length of sitting time. There were significant changes in the two-hour and three-hour groups after the experiment compared to before the experiment (P<0.05). In particular, there were significant changes between the one- and two-hour groups and the three-hour group after the experiment (P<0.05).

5. Changes in head alignment

There were changes in the subject's head alignment

according to the length of sitting time. The subject's head was protruded further forward in the two-hour group after the experiment relative to that before the experiment, but the change was not significant. The subject's head was significantly protruded further forward in the three-hour group after the experiment compared to before the experiment (P<0.05).

Table 2 shows the changes in muscle strength, endurance, flexibility, and head alignment according to the length of sitting time.

Table 2. Comparison of muscle strength, endurance, flexibility and head alignment in intra-group and inter-group between pre- and post-experimental

		Group	Pre-experiment	Post-experiment	P-value
Muscle strength (kg)	Flexor muscle	1	65.50 ± 16.26	65.29 ± 15.99	.224+
		2	68.94 ± 20.60	62.39 ± 19.81	.392+
		3	73.89 ± 22.56	57.44 ± 17.96	.012*
	Extensor muscle	1	60.47 ± 22.03	58.55 ± 15.58	.369
		2	68.68 ± 22.92	62.94 ± 24.58	.194
		3	77.93 ± 21.46	58.08 ± 23.79	.034*
Muscle endurance (sec)	1	122.22 ± 20.76	121.00 ± 23.35	.892	
	2	129.56 ± 24.45	123.33 ± 22.27	.659	
	3	136.50 ± 25.95	102.38 ± 15.70	.048*	
Flexibility (mm)	1	54.00 ± 8.47	53.20 ± 8.59	.403+	
	2	49.92 ± 14.78	47.56 ± 14.11	.046*+	
	3	56.88 ± 13.02	40.38 ± 11.68	.025*	
Head alignment (mm)	1	50.66 ± 20.52	50.27 ± 23.58	.462	
	2	58.90 ± 21.43	66.08 ± 32.06	.067	
	3	55.12 ± 26.01	72.23 ± 37.64	.044*	

1: 1-hour group; 2: 2-hour group; 3: 3-hour group
 * P<0.05 significance difference in comparison to pretest;
 +P<0.05 significance difference in compared to the 3-hour group

IV . Discussion

This study was conducted to provide a guideline for sitting postures for extended periods by examining changes in muscle performance and head alignment resulting from sedentary behaviors. Sedentary behaviors refer to too much time spent sitting rather than a lack of physical activity.¹¹ Changes in occupations (increased computer use) in today's modern world and transportation (use of automobiles) have led to prolonged sitting,¹² with most adults' daily sitting time steadily increasing. Prolonged periods sitting may greatly influence the musculoskeletal system. In particular, prolonged sitting is profoundly correlated with low back pain¹³ and may aggravate symptoms of pain.¹⁴

The activity of the lumbar muscles decreases in a sitting posture.¹⁵ Therefore, a lack of activation of the lumbar muscles may be a cause of atrophy,¹⁶ and the lumbar muscles may not function appropriately in a prolonged sitting position. As shown in the present study, the muscle strength of the subjects who sat for two hours and longer than three hours significantly decreased. This result is consistent with that of the above reports. The lumbar muscles may experience fatigue in a continuous sitting position. In particular, in the present study, there was a greater reduction in the strength of the flexor muscles compared to the extensor muscles. But this study, but strength of extensor muscle is more reduced in 3 hours group. Therefore, sitting for longer than two hours appears to increase fatigue of the extensor muscles. Low activation resulting from increased fatigue of the lumbar muscles places a load on the ligaments and on passive structures, such as the intervertebral disc, possibly causing low back pain.¹⁷ Therefore, sitting continuously for longer than two hours can be considered to adversely affect the lumbar vertebrae, as well as muscle strength.

Muscle endurance and continuous contraction ability influence the passive stability of the vertebrae.¹⁸ As reported earlier, evaluation of muscle strength in a sitting position results in a decrease in the muscle strength of lumbar pain patients.¹⁵ A reduction in the muscle endurance of the trunk is closely associated with the prediction of new lumbar pain symptoms.^{16,19} Muscle endurance of the trunk also plays

an important part in performing activities of daily living in a proper posture while maintaining appropriate support of the trunk.^{20,21} In the present study, the muscle endurance significantly declined in the subjects who sat for longer than three hours. Thus, sitting for longer than three hours may have a negative effect on muscle endurance. Among other factors, the continuous load on the vertebral body may bring about creep of the ligament and the intervertebral disc, non-contractible structures around the vertebrae that provide passive stability.²²

Low activation of the lumbar vertebrae muscles in a sitting posture and the resulting load delivered to the passive structures may lead to de-conditioning of the lumbar spine.^{22,23} In particular, low or no activation of the lumbar muscles may be a factor in the trunk becoming kyphosis or flexed.¹⁴ A flexed trunk may affect the maintenance of proper support of the trunk and the position of the head in a sitting posture.²³ The head should be located at the center, connecting the external ear, passing the gravity line and the center of the shoulder joint. A forward head position may be triggered when the lumbar curve increases.²⁴ Such posture is caused by compensation action, such as continuous and abnormal muscle contraction, occiput, the neck, and the shoulders.²⁵ According to the results of the present study, the flexor and the extensor muscle strength of the subjects in the three-hour group were significantly decreased and their heads were aligned significantly further forward, consistent with the results of the above reports. The neck posture is dependent on appropriate motor responses to mechanoreceptive input from joint and muscle spindle.²⁶ An impairment of kinaesthetic sense has been found to reduce the accuracy of postural repositioning.²⁷ The maintenance of incorrect posture may be an impairment of kinesthetic sensibility. Therefore Sitting for longer than three hours influenced the trunk posture, the position of the head, and the muscles around the head and the shoulders, as well as the muscle strength of the trunk

Flexibility refers to the ability to maintain all joints' range of motion to enable the musculoskeletal system to perform normal functions. It is closely related to posture. Flexibility also refers to the ability of a single joint or multiple joints

to maintain a range of movements without restriction and pain. It depends on the extensibility of the muscles.²⁸ A decrease in flexibility may affect proper posture maintenance.^{29,30} In the present study, the flexibility of the subjects who sat for two and three hours significantly decreased. This finding is similar to previous work, which found that sitting for a long time reduces flexibility. The lumbar spine has the least flexibility of all the joints in the human body. Therefore, any decrease in its flexibility resulting from muscular imbalance influences posture and may lead to disability in the musculoskeletal system.³¹

In conclusion, sitting continuously for longer than two hours decreases muscle strength, endurance, and flexibility. A flexed posture affects the muscle performance of the lumbar region and may result in problematic postures, such as a forward head position. Thus habitual posture may be cause the postural pain in low back and neck. This study provides information useful to those who maintain a sitting posture for a long time. However, this research did not take account of the different muscle strength of men and women. Therefore, based on the present findings, it is difficult to draw a definitive conclusion about the impact of sitting for a long time on the body. Further, the subjects were young adults aged between 20 and 30 years, and the results may not be applicable to other age ranges. Accordingly, further studies are warranted with different age ranges and genders and different lumbar postures using kinematic approaches.

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