Influence of Different Spinal Alignments in Sitting on Trunk Muscle Activity

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Abstract. [Purpose] To clarify the relationship between spinal alignment and trunk muscle activities in upright sitting without manual intervention. [Subjects] Twenty-three healthy male volunteers with no history of lumbar disorders participated in this study. [Methods] Trunk alignment and surface electromyographic activities of 6 trunk muscles were measured synchronously during the motion from slump to upright sitting position. The amplitude of the muscle activities were normalized to maximal voluntary contraction. Subjects were classified into 3 spinal alignment groups: long lordosis (LL), short lordosis (SL), and kyphosis (K). [Results] The LL group consisted of 9 subjects (39%), the SL group of 9 subjects (39%), and the K group of 5 subjects (22%). The K group had significantly lower muscle activity of the back and abdominal muscles. The SL group had significantly greater muscle activity of the lumbar paraspinals than the LL group, and greater activity of the lumbar multifidus was observed in the SL group than in the other groups. The LL group showed significantly greater muscle activity of the internal oblique muscle than the other groups. [Conclusion] Upright sitting without manual correction leads to various kinds of spinal alignment. Judging from trunk muscle activities, we suggest that the desirable spinal alignment in upright sitting is a neutral lumbar position with no thoracolumbar kyphosis.

Key words: Electromyography, Trunk muscles, Sitting posture

INTRODUCTION

In modern lifestyle, people spend much time sitting. People whose occupation involves a lot of desk work often remain seated for a long time, since the burden on the legs and energy consumption can be reduced compared to if they were standing. Epidemiological research suggests that occupations which involve prolonged sitting lead to a higher rate of low back trouble¹, ², and it is believed that sitting is an aggravating factor of low back pain³. When sitting, people often assume a kyphotic posture which seems to be the most comfortable position¹, ⁴, but the problems associated with kyphosis have been highlighted⁵. For example, increasing pressure load on intervertebral disks⁶⁻⁸, and increasing stress on posterior passive tissues such as ligaments⁹, ¹⁰. Therefore, from an ergonomic viewpoint, it is said that kyphotic postures should be avoided¹¹⁻¹₃. However, there is no agreement on what kind of spinal alignment in upright sitting is desirable in order to minimize stress on intervertebral disks and ligaments¹⁴⁻¹⁶.

Recently, some studies have been carried out on spinal alignment in upright sitting¹⁷⁻¹⁸. The data from these studies have become a reference point when considering the desirable spinal alignment of sitting, and the positions they have reported are meaningful for preventing low back pain related to sitting. However, there are some issues with the studies mentioned above. First, these studies compared trunk muscle activities of the same subject adopting different sitting postures, and secondly, posture was positioned by manual correction. Between these studies, a big difference was observed in the level of trunk muscle activities in the same classification of upright sitting postures. We believe the reason for this difference is because subjects’ postures were positioned manually, resulting in superfluous muscle activity because the subjects were unaccustomed to the forced sitting postures.

In this study, to clarify the relationship between spinal alignment and trunk muscle activity, the spinal alignment and the activity of the trunk muscles were examined in different upright sitting postures without manual correction.

SUBJECTS AND METHODS

Twenty-three healthy male volunteers participated in this study (Table 1). The subjects had no history of lumbar disorders. The purpose and methods of this study were explained to all the participants who read and signed an informed consent revealing all the details of the study protocol, which had been approved by the ethics committee of the Graduate School of Health and Sports Science, Juntendo University.

The subjects were asked to sit on a stool, with their feet positioned shoulder width apart, and with their arms crossed on their chest. The knee joint was set to 90 degrees,
with the thighs parallel to the floor, by adjusting the height of the stool. Then, the subjects were asked to change their posture from slumped to upright sitting by extending the spine and tilting the pelvis forward. During the motion, subjects fixed their gaze on a mark (black dot) 2 m ahead at eye level. The motion was repeated 3 times. Subjects maintained the slump sitting posture for 5 seconds, and then changed to the upright posture within 3 seconds, finally keeping the upright posture for 5 seconds. The speed of the motion was timed with a metronome at 60 beats per minute.

Spinal alignment and surface electromyographic (EMG) activities of 6 trunk muscles were collected synchronously during the motion from slumped to upright sitting over 3 trials. Spinal alignment was measured using a digital high-speed video camera (PHI-1416C; Frame-DIAS II motion analysis system, DKH, Tokyo, Japan). Data were sampled at a frequency of 100 Hz. Reflective markers were placed on the spinous processes of T7, L1, L3, and L5 vertebræ, to allow calculation of spinal alignment. Data were transformed to two-dimensional coordinates by two-dimensional movement analysis software (Frame-DIAS II; DKH, Tokyo, Japan). Three angular values were then defined for the following spinal regions: thoracolumbar and lumbar. The thoracolumbar angle was defined as the angle between the line which linked T7 and L1 and the line which linked L1 and L3, and the lumbar angle, as the angle between the line which linked L1 and L3 and the line which linked L3 and L5 (Fig. 1). Thoracic or lumbar angle was considered lordotic when it was more than 180 degrees and kyphotic when less than 180 degrees. Subjects were classified into 3 groups based on their spinal postures in upright sitting. Long lordosis (LL) was defined as lordotic thoracolumbar and lumbar regions; short lordosis (SL), kyphotic thoracolumbar with lordotic lumbar regions; and kyphosis (K), kyphotic lumbar regions (Fig. 1).

EMG activities of 6 spinal extensor and abdominal muscles were recorded with surface electrodes. Before EMG measurement, the skin was shaved and abraded with fine sandpaper to reduce skin impedance to below 5 kΩ. Pairs of self-adhesive disposable Ag/AgCl disc surface electrodes (Blue Sensor, N-00-S; Ambu, Denmark) were placed at an inter-electrode distance of 20 mm, parallel to the following muscles on the left side: thoracic paraspinals (2–3 cm lateral to the 8th rib); rectus abdominis (2–3 cm lateral to the umbilicus); internal oblique (2 cm below and 1 cm medial to the anterior superior iliac spine); The placement of the electrodes varied slightly according to the shape of the subjects’ bodies. A ground electrode was placed over the left iliac crest. The electrodes were taped securely to avoid excessive movement of the leads.

Surface EMG signals were recorded at a sampling frequency of 1000 Hz using a Noraxon MyoSystem 1200 (Noraxon USA Inc., Scottsdale, AZ, USA). The EMG system bandwidth was 10–500 Hz, the common mode rejection ratio was greater than 100 dB at 60 Hz, and the differential input impedance was greater than 10 MΩ. All raw myoelectric signals were amplified with a gain of 1000. Data were collected and processed using MyoResearch XP Ver.1.07 computer software (Noraxon USA Inc., Scottsdale, AZ, USA). The raw surface EMG data were first visually checked for electrocardiac artifacts. When artifacts were observed, they were removed by using a program in MyoResearch. The raw data were full wave rectified, bandpass filtered (20 Hz to 500 Hz), and the average amplitude of the EMG signals was calculated using a computer program. Then, the maximal EMG data, determined from maximal voluntary contraction (MVC), were used to normalize the EMG signals acquired and the values were expressed as a percentage of MVC (%MVC).

Three standardized tests were used to generate MVC for the abdominal muscles. The subjects were asked to lie supine with the legs straight and strapped in position with a belt. Subjects flexed the trunk to recruit the rectus abdominis, rotated the trunk to the left to recruit the external oblique and rotated the trunk to the right to recruit the internal oblique. One normalization technique test was used for all back muscles. The subject was asked to lie prone with the legs straight and strapped in position with a belt. Subjects lifted the sternum off the examination table with their hands resting on the back of the neck. There were 2 trials of 5 seconds duration each, with a 3-minute rest period given between trials to avoid the effects of fatigue. The highest 1 second contraction in 5 seconds was calculated and the mean MVC value from 2 trials was used as the measurement for each subject.

Statistical analysis was performed using Dr. SPSS II for Windows (version 11.0.1 J; SPSS, Inc., Chicago, IL). One-way analysis of variance with repeated measures was used to compare the differences in the spinal alignment and trunk muscle activities among the 3 upright sitting postures (long lordosis, short lordosis, kyphosis) and the slump sitting posture. Tukey-Kramer’s multiple comparisons and

**Table 1. Characteristics of the subjects**

<table>
<thead>
<tr>
<th>Number</th>
<th>whole</th>
<th>long lordosis</th>
<th>short lordosis</th>
<th>kyphosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>21.0 ± 3.0</td>
<td>20.3 ± 1.9</td>
<td>22.0 ± 4.1</td>
<td>20.6 ± 1.9</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.3 ± 6.7</td>
<td>174.4 ± 6.7</td>
<td>175.8 ± 6.2</td>
<td>166.8 ± 3.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>62.6 ± 8.1</td>
<td>62.2 ± 9.6</td>
<td>65.4 ± 7.3</td>
<td>58.4 ± 5.7</td>
</tr>
<tr>
<td>BMI</td>
<td>20.8 ± 1.7</td>
<td>20.3 ± 1.9</td>
<td>21.1 ± 1.5</td>
<td>21.0 ± 1.7</td>
</tr>
</tbody>
</table>

mean ±SD

BMI : Body Mass Index
analyses were conducted as post hoc tests. P values less than 0.05 were considered significant.

**RESULTS**

All 23 subjects were classified into three groups. The LL group consisted of 9 subjects (39%), the SL group consisted of 9 subjects (39%), and the K group consisted of 5 subjects (22%). Spinal alignment (thoracolumbar angle, lumbar angle) is summarized in Table 2. There were no significant differences among the 3 groups at the starting slump sitting posture, on the other hand, there were significant differences among the upright sitting postures (p<0.01). In other words, there were significant differences among the 3 upright spinal alignments. There were no significant differences among the 3 groups in height, body weight, or BMI (Table 1).

The mean and SD of normalized trunk muscle activities (as percentages of MVC) were compared across the 3 spinal alignments and the results are shown in Table 3. The levels of trunk muscle activity were 1–11%MVC. Comparing the trunk muscle activities of the 3 groups (LL, SL, K) revealed the back muscles of the 3 upright sitting groups had significantly higher activities than those of slump sitting (p<0.05). As for abdominal muscles, the LL group showed significantly higher activities in upright than in slump sitting (p<0.01). There were significant differences (p<0.05) among the 3 upright sitting postures in the activities of lumbar paraspinals, lumbar multifidus and internal oblique muscles. There were no significant differences in thoracic paraspinals, external oblique, rectus abdominis among the three groups.

The K group had significantly lower muscle activities in the back and abdominal muscles than the other groups.
(p<0.05). The SL group had significantly greater muscle activity in the lumbar paraspinals than the LL group (p<0.05), and greater activity of the lumbar multifidus was observed in the SL group than in the other groups (p<0.05). The LL group had significantly greater muscle activity of the internal oblique than the SL (p<0.01) and K (p<0.05) groups. There were no significant differences in thoracic paraspinals, external oblique, and rectus abdominis among the 3 groups.

**DISCUSSION**

In this study, the spinal alignment and the activities of trunk muscles were examined in different upright sitting postures without manual correction. Subjects were classified into 3 groups as described in previous studies\(^17,18\). The LL group was 39% of the whole, the SL group 39%, and the K group 22%. The level of trunk muscle activity was 1–11%MVC. Comparing the trunk muscle activities of the 3 upright sitting groups (LL, SL, K) to slump sitting, which was the starting posture, the activities of all back muscles in the 3 upright sitting groups were significantly greater than those of slump sitting. Regarding abdominal muscles, only the activities of the LL group were significantly greater than those of slump sitting. Moreover, comparing the trunk muscle activities among the 3 upright sitting postures, the activities of the K group were generally low, whereas activities of the internal oblique in the LL group and the lumbar multifidus in the SL group were significantly greater than in the other groups.

It is said that the slump sitting posture (spinal kyphosis) is a posture which should be avoided because of the increased stress it puts on lumbar intervertebral disks and the posterior ligamentum. This leads to the question of what kind of postures are desirable in order to minimize stress on intervertebral disks and ligaments. In previous studies\(^17,18\), trunk muscle activities of different spinal alignments in upright sitting postures were investigated to answer this question. In these studies the ideal spinal alignment was defined as the alignment which results in minimum stress and maximum efficiency\(^20,21\). From this viewpoint, O’Sullivan et al.\(^18\) presented the lumbopelvic alignment (lumbar lordosis and thoracolumbar kyphosis), as the ideal spinal alignment in upright sitting. They suggested that in this spinal alignment, the lumbar multifidus, internal oblique and transversus abdominis (deep trunk muscles) contract greater, and the erector spinae muscles (superficial trunk muscles) do not contract too much\(^22\). On the other hand, Claus et al.\(^17\) reported that the flat spinal alignment, in which the lumbar and thoracolumbar curve was in neither lordosis nor kyphosis, was the most efficient and least stressful, because trunk muscle activities were generally low in this alignment. The conclusions of these studies are different. The reason for this difference in conclusions seems to be the difference in the methods of the two studies. In both studies, subjects’ spinal alignment was manually corrected. This adjustment might have led to a variation in the activity of muscles, which would have affected judgement of what is a desirable alignment.

Below, we will discuss 3 topics: spinal alignment in the upright posture without manual correction; comparison of trunk muscle activities in this study and previous studies; and comparison of trunk muscle activities among the 3 different spinal alignments investigated in this study.

In this study, subjects adopted an upright sitting posture without any manual correction. Spinal alignment was varied, as reported in previous studies. There were subjects without lumbar lordosis (K group), subjects with lumbar lordosis and thoracolumbar kyphosis (SL group), and subjects with lumbar and thoracolumbar lordosis (LL group). Standing postures are varied and can be classified\(^20,22\). There are also various upright sitting postures and these can be classified as in this study. When standing, lumbar curvature usually becomes lordotic\(^20,23–25\), on the other hand, in an upright sitting position, lumbar curvature does not always become lordotic. So, in order to achieve lumbar lordosis in upright sitting, it might be necessary to teach subjects how to create a lordotic lumbar curve. Also, if spinal alignment is manually corrected, forced muscle activity may occur. In this study, trunk muscle activity in upright sitting was 1–11%MVC, which was very low compared to the 9–36%MVC reported by O’Sullivan et al.\(^18\), and approximately the same level as the 1–13% reported by Claus et al.\(^17\). O’Sullivan et al.\(^18\) reported that the activity of the trunk muscles in the upright posture was 9–36%MVC. Especially, thoracic paraspinals in long lordosis showed activity of 36%MVC, and the lumbar multifidus in short lordosis showed activity of 33%MVC, which seem to be abnormally high. This high activity may have reflected the effort necessary to maintain the alignment, therefore the activity of muscles observed may not have been ‘normal’.

Sawai et al.\(^26\) investigated the activity of the erector spinae in daily living, and reported that it was less than 5%MVC during standing, one-leg standing, and walking; it was 5–10%MVC in standing up, going up a slope, and climbing upstairs. Comparing these activity levels, it would seem to be difficult to stay in the same upright sitting posture for a long time while maintaining the activity levels reported by O’Sullivan et al.\(^18\). Based on the results of Sawai et al.\(^26\) the activity levels observed in this study and in the study of Claus et al.\(^17\) seem more reasonable than the levels reported by O’Sullivan et al.\(^18\). Comparing the activity of the trunk muscles in upright sitting among the 3 groups, the results of this study differed from those of previous studies that proposed short lordosis as the desirable spinal alignment in upright sitting. The activities of the trunk muscles in the K group were generally low in upright sitting in which the lower spine was kyphotic, although the spinal alignment was not slumped. The spinal alignment of those in the K group was very similar to the flat posture reported as efficient and less stressful by Claus et al.\(^17\). So, the spinal alignment of the K group seems to be desirable in order to minimize stress on joints or ligaments. The activities of back muscles in the LL group were also low whereas that of the internal oblique muscle was significantly more active. On the other hand, the activities of the back muscles in the SL group were significantly greater than those in the other groups. Grenier et al.\(^23\) reported
that the internal oblique muscle contributes to lumbar stabilization. Sapsford et al. 28, 29) reported that increasing the activity of the internal oblique was associated with increasing activity of the pelvic floor muscles that contribute to lumbar stabilization. Gardner-Morse et al. 30) reported that excessive contraction of the back muscles increased lumbar pressure. Based on this knowledge, the spinal alignment of the LL group seems to be more appropriate than that of the SL group. In brief, the result of this study suggests that the desirable spinal alignment when sitting upright is a neutral lumbar position with no thoracolumbar kyphosis. This spinal alignment seems to minimize stress on intervertebral disks and ligaments and prevent low back pain.

The current results should be considered in light of several factors. First, all subjects were young men, second, the height of the stool was set to only one protocol, and third, spinal alignment was examined from the body surface 31). Although these limitations should be investigated further in the future, we believe the results of this study are meaningful.

In conclusion, upright sitting without manual correction leads to various kinds of spinal alignments in which trunk muscle activities are about 10%MVC. The trunk muscle activities suggest that the desirable spinal alignment for upright sitting is a neutral lumbar position with no thoracolumbar kyphosis.

REFERENCES

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