Original Article

Spinal kyphotic alignment changes spinal movement strategy during lateral reaching motion while in a sitting position

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Abstract. [Purpose] This study investigated spine kinematics during normal sitting and flexion sitting with lateral reaching using a three-dimensional motion analysis system. [Participants and Methods] Nineteen healthy young adult males participated in this study. While seated, each participant was asked to reach toward the right using his right hand. Spine angles were defined as T1, T4, T8, L1, and L5 segments. Kinematic data were calculated using the Euler angle and compared to normal sitting and flexion sitting. During flexion sitting, each participant wore a trunk flexion brace. [Results] In the frontal plane, the angle of the T8 segment during flexion sitting was significantly less than during normal sitting. In the axial plane, there were significant differences among the T4, L1, and L5 segments. [Conclusion] Changes in spinal alignment decrease spinal movement and change the movement strategy during lateral reaching while seated.

Key words: Three-dimensional analysis, Kinematics, Lateral reaching

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INTRODUCTION

The rate of population aged over 65 in Japan is increasing, reaching 27.7% in 20181). The most common change in posture in the elderly is kyphosis. It limits activities of daily living (ADL)2-4), decreases balance, and limits reaching distance upon lateral reaching in a sitting position3, 5). Kyphosis in older patients may limit life-space because they face difficulty in reaching in sitting position. Therefore, we intervene reaching in sitting position. However, the approach for improving reaching ability was unclear. Reaching in a sitting position requires head stabilization upon trunk and pelvic movement5). Therefore, trunk stabilization is important during reaching in a sitting position. Kyphosis limits spinal movement6). However, no studies have been performed to determine whether it affects the movement of the spine. The aim of this study was to investigate the difference of kinematic characteristic of the spine between normal sitting and flexion sitting upon lateral reaching by using a three-dimensional motion analysis system.

PARTICIPANTS AND METHODS

This study included 19 healthy young adult males at Kyushu University of Nursing and Social Welfare [mean ± standard deviation (SD): age 26.5 ± 6.7 years, height 170.9 ± 4.5 cm, weight 67.8 ± 9.5 kg]. Those with previous neurological or musculoskeletal abnormalities were excluded. The study received ethical approval from the Kyushu University of Nursing and Social Welfare (28-038). We explained the purpose of the study to all participants who gave their informed consent before participation.
In the starting position, the participants’ upper extremities were beside the body, 55% of the length of the thigh was located at the front edge of the chair, hip abduction angle was 0°, and hip and knee flexion were 90°. Each joint angle was measured with a goniometer. Reaching distance was defined as 80% of the maximum lateral reaching distance.

They reached to the right using the right upper extremity in two different sitting positions. One was normal, in which the spine was normally aligned in the sagittal plane (Fig. 1). The other was flexion, in which the spine was in flexion alignment in the sagittal plane (Fig. 2a). In the flexion position, the subjects wore a trunk flexion brace (Fig. 2b). Measurement in flexion position was conducted after normal position. Measurement interval was approximately 15 minutes. They watched a monitor to check that there was equal weight loading on both ischial tuberosities and that the plantar pressure was approximate 5–10% of the full weight bilaterally; they also focused on a landmark located at 1 m height and 10 m ahead before performing the reaching task. The reaching distance was defined as 80% of their maximum lateral reaching distance (Fig. 1). This measurement conducted before normal position and flexion position start respectively. They started to maintain the starting position at the starting-cue signal for 3 s. After 3 s, they started to reach for 1 s. They were instructed to abduct their right shoulder while reaching for the landmark and not to push to the force plate using their feet, abduct their left shoulder or grasp the chair (Fig. 3). They practiced this task several times with a metronome set at 1 Hz before measurement. In this study, measurement was performed using a three-dimensional motion analysis system (VICON MX-T, VICON NEXUS) with ten infrared cameras and four force plates (AMTI) with a sampling rate of 100 Hz. Fifteen reflective markers were placed on specific anatomic landmarks. Three reflective markers on each thoracic (first, fourth, and twelfth) and lumbar (first and fifth) spinous process modeled the thoracic segment (first, fourth, eighth, and twelfth) and lumbar segment (first and fifth) (Fig. 4).

The center of a joint was defined as being located between each segment. The angle of each segment was calculated using the Euler angle (turn X-Y-Z) to a global system coordinate. The definitions of the starting and finishing points in this task were set using the integrated center of pressure (COP) from two force plates (force plate 1, force plate 2) (Fig. 1). The negative side was left and the positive side was right in the direction of COP. Regarding the definition of the starting point in the reaching task, the average value and standard deviation (SD) were calculated from the COP for 3 s at a resting sitting position. The reaching task started at the moment when average value was exceeded by 2 SD. Regarding the definition of the finishing point in the reaching task, the average value and SD were calculated from the COP for 1 s upon holding a reaching position. The reaching task finished at the moment when the value dropped below the average value +2 SD. For the reaching data, these were defined using the Euler angle characterized as the difference between the starting point and the finishing point in the reaching task. The relative Euler angles for each adjacent segment were calculated from the Euler angle to a global system coordinate. Each relative Euler angle described anterior–posterior tilt, right–left tilt, and right–left rotation about each

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**Fig. 1.** In the starting position, their upper extremities were beside the body, 55% of thigh located at the front edge of the chair, hip abduction angle was 0°, and hip and knee flexion were 90°. Each joint angle was measured with a goniometer. Reaching distance was defined as 80% of the maximum lateral reaching distance.

**Fig. 2.** a. In the flexion sitting position, the spine is in flexion alignment in the sagittal plane. b. The trunk flexion brace.

**Fig. 3.** The subjects were instructed to abduct their right shoulder while reaching for a landmark and not pushing on a force plate using their feet, abducting their left shoulder, or grasping the chair.
segment’s X-, Y-, and Z-axes. Each positive direction of relative Euler angle described as X is anterior tilt, Y is left tilt, and Z is right rotation. The amount of change of each segment was calculated from the relative Euler angle. IBM SPSS Statistics for Windows version 23.0 (IBM Corp.) was used for statistical analysis for comparing the data between normal reaching and flexion reaching. The paired t-test and Wilcoxon’s signed-rank test were used to determine the difference in the movement of each segment in both groups. P-values <0.05 were considered significant.

RESULTS

There was no significant difference between groups in X-axis of all segments. In the Y-axis, there was a significant difference between groups for the T8 segment. The T8 segment tilted significantly more to the left side in normal reaching than in flexion reaching (p<0.01). In the Z-axis, there were significant differences between groups for the T4 segment, L1 segment, and L5 segment. The T4 segment rotated to the right side significantly more in normal reaching than in flexion reaching (p<0.01). The L1 segment rotated to the left side in normal reaching and to the right side in flexion reaching (p<0.01). The L5 segment rotated to the left side significantly less in normal reaching than in flexion reaching (p<0.01) (Table 1).

Table 1. Comparison of angle change in each segment

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T4</th>
<th>T8</th>
<th>p value</th>
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</thead>
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<tr>
<td></td>
<td>normal</td>
<td>flexion</td>
<td>normal</td>
<td>flexion</td>
</tr>
<tr>
<td>X</td>
<td>2.08±4.46</td>
<td>2.91±5.19</td>
<td>0.07±3.78</td>
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<td>−0.68±1.68</td>
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<tr>
<td>Z</td>
<td>−0.62±7.68</td>
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<td>3.89±5.47</td>
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<tr>
<td></td>
<td>L1</td>
<td>L5</td>
<td>p value</td>
<td></td>
</tr>
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<td>X</td>
<td>3.66±3.89</td>
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<td>Y</td>
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<tr>
<td>Z</td>
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<td>4.09±3.98</td>
<td>−0.39±1.62</td>
<td>−2.85±1.58</td>
</tr>
</tbody>
</table>

Mean ± standard deviation, *p<0.01.


DISCUSSION

This study indicated that a change in spinal alignment decreased spinal movement and changed the movement strategy upon lateral reaching in a sitting position (Fig. 5). In the results for the X-axis, there was no significant difference between groups for all segments. For this reason, lateral reaching involved greater movement in the frontal plane than in the sagittal plane and motor control was dominantly involved as the kinematic characteristic to perform the reaching task.

In the result for the Y-axis, there was a significant difference between groups for the T8 segment. Normal reaching was significantly more than flexion reaching. The angle of thoracic kyphosis increases significantly with age, and the range of thoracic spine movement decreases significantly with age in lateral bending. However, it was not indicated which part of the thoracic spine exhibits decreased movement. In this study, the results suggested that motion around the T8 segment decreases. The spine has been observed to undergo lateral bending and rotation at the same time; considering that flexion of the spine decreases the rotation angle, the thoracic spine may decrease lateral bending movement in the flexion position. However, there is the study that flexion posture increases in the range of thoracic coupled lateral flexion compared with that in the neutral posture. There has been no consensus on the patterns of coupled motion of the thoracic spine.

In the Z-axis, there was a significant difference between groups for the T4, L1, and L5 segments. This study supported the conclusion that flexion posture decreases in the range of thoracic rotation. Regarding the L1 segment, normal reaching and flexion reaching showed the opposite movement. To maintain balance, there is a need for the center of gravity to stay over the base of support. Regarding the movement of the thoracic region, all of the segments showed the same direction of movement. Therefore, in the L1 segment, the opposite movement to that in the thoracic segments occurred to maintain balance. However, in flexion reaching, right rotation was exhibited. The reason for this is that the L1 segment in flexion reaching showed right rotation to contribute to extending the reaching distance because in the flexion posture the reaching distance is decreased. Regarding the L5 segment, it needed to rotate to the left side more because the L1 segment showed right rotation in flexion reaching. However, as thoracic coupled motion, no consensus has been reached on the patterns of coupled motion of the lumbar spine. Further research is needed on this issue.

This study demonstrated that a flexion posture changed limitation of spine movement and altered movement strategy upon lateral reaching in a sitting posture. However, the participants in this study were healthy young adult men. Therefore, the present study could not address the effect of age and gender on the results. Further study assessing the characteristics of movement in older people with kyphosis is required.

Conflict of interest

None.

REFERENCES