Variation of Spinal Alignment in Standing and Automotive Seated Postures

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I. INTRODUCTION

Quantitative data regarding spinal alignment (curvature) is required in developing and positioning a human model, as well as in investigating spine injury mechanism due to an accident. In the previous study [1], the authors analysed x-ray images, obtained from a hospital database of the cervical spine of 51 male patients with minor neck disorders. It was found that cervical spine alignment varied widely, showing five different types of alignment (lordotic, kyphotic, straight, s-shaped and inverse s-shaped). However, this alignment distribution might be different in the healthy male population. Furthermore, spinal alignments in automotive seated posture, as well as variations of thoracic and lumbar spine alignment have also not yet been investigated.

In this study, lateral x-ray imaging of 18 healthy male volunteers in standing and automotive seated postures was conducted in order to investigate variations in spinal alignment among individuals, age groups, as well as between standing and automotive seated postures.

II. METHODS

Volunteers

Eighteen Japanese male volunteers without any spinal disorders were recruited for the experiment. The volunteers were divided into three age groups: twenties, forties and sixties, with six men in each age group. Average height and weight of the volunteers were 171.2±3.8 cm and 63.3±9.4 kg respectively. The research protocol was approved by the Ethical Committee of Niigata Rinko Hospital (Niigata, Japan).

Experimental Method

Lateral x-ray imaging was conducted at the Niigata Rinko Hospital. Volunteers were asked to perform two types of posture: standing and automotive seated postures (Fig.1). The imaging area covered dens of C1 to the inferior end of sacrum. In a standing posture, volunteers were asked to stand in a relax position with the head facing forward and both hands grasping a horizontal bar placed almost at the same height as the volunteer shoulder. In seated posture, volunteers were asked to simulate a relaxed driving position with the head and both hands in a similar position to the standing posture. To minimise the effect of seat properties, a rigid seat without a head restraint made of wooden board was used. The seat had a seatback angle of 22° and seat cushion angle of 6°.

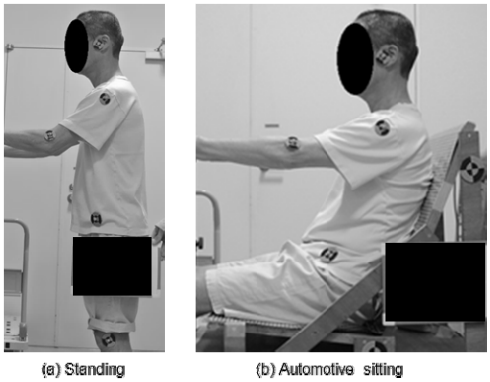

Fig. 1. Body postures during x-ray imaging.

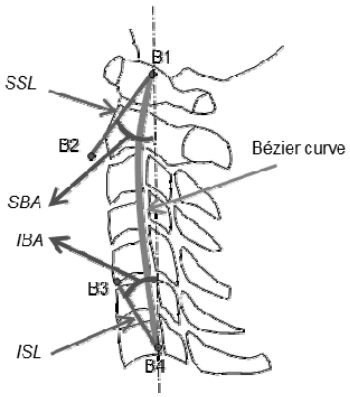

Fig. 2. Bézier curve fitting and the related parameters.

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Analysis Method

Quantitative evaluation of spinal alignment was carried out by fitting Bézier curves [2] to the posterior edges of vertebral bodies (Fig.2). To improve the fitting accuracy, spinal alignment were preliminary divided into cervical (C1-C7), thoracic (T1-T12), and lumbar spine alignment (L1-L5). The posterior edges of the vertebral bodies seen on the x-ray images were digitised using ImageJ (NIH, USA). A Bézier curve with four control points (B1-B4) was then fitted to the digitised points by minimising the residual sum of squares. The fitting process was performed using the solver tool in MS Excel 2010 (Microsoft Corp., USA). Angles between B1-B2 and B1-B4 (*SBA*) and between B3-B4 and B1-B4 (*IBA*) were used to create a 2D distribution map of the spinal alignment.

III. INITIAL FINDINGS

Since the thoracic spine alignment shows a kyphotic trend, and remains unaltered with postural change, this paper focuses on cervical and lumbar spine alignment. Distribution maps of cervical and lumbar spine alignment in standing and automotive seated postures are shown in Fig.3. If *SBA* and *IBA* are positive, the alignment tends to be lordotic. If *SBA* and *IBA* are negative, the alignment tends to be kyphotic. If *SBA* is positive and *IBA* is negative, the alignment tends to be s-shaped. If *SBA* is negative and *IBA* is positive, the alignment tends to be inverse s-shaped. If *SBA* and *IBA* are close to zero, the alignment tends to be straight. According to Fig.3, alignments were found to vary among individuals. Moreover, postural change alters the alignment distribution. On the cervical spine alignment, a seated posture has a tendency to shift the lordotic alignment in a standing posture to the s-shaped alignment. On the lumbar spine alignment, a seated posture has a tendency to shift the lordotic alignment in a standing posture to the straight or kyphotic alignments. In addition, the degree of lordotic alignment of the cervical spine is becomes more pronounced with the increase of age in a standing posture.

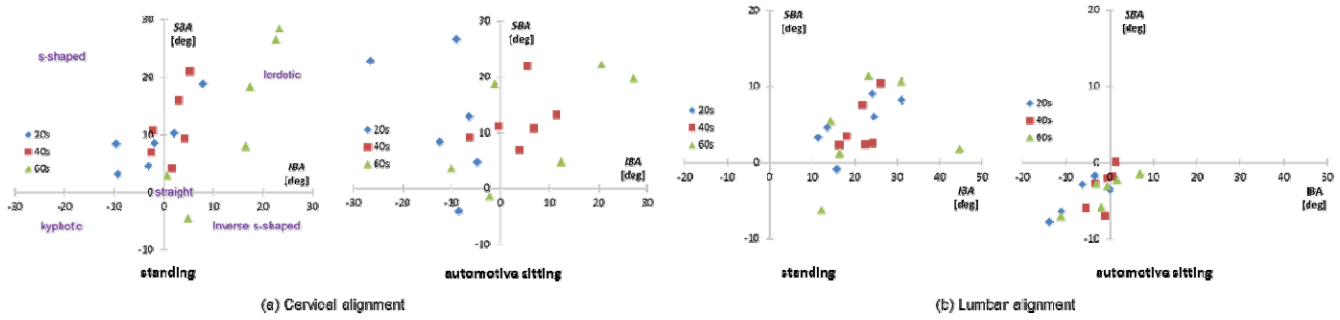

Fig. 3. Distribution map of spinal alignment in cervical and lumbar spine.

IV. DISCUSSION

Lordotic alignment seems to cover the majority of cervical alignment. However, the presence of s-shaped, straight and inverse s-shaped alignments can also be confirmed from the healthy male population. Considering the authors' previous study [1], it can be said that there is no clear relationship between cervical alignment and the existence of minor neck disorders. This finding is also coincident with the literature [3]. In the automotive seated posture, head flexion increases due to seatback inclination, causing kyphosis of lower cervical spine. This was considered to be the cause of an alignment shift to s-shaped alignment on the cervical spine. Furthermore, an alignment shift was also definitely found on the lumbar spine. Lower extremities extension in a seated posture which invokes kyphosis of the whole lumbar spine was considered to cause the alignment shift. However, a vehicle seat with lumbar support may provide a different result from the current result. Another interesting finding is that the degree of lordotic alignment on the cervical spine tends to increase with the increase of age in a standing posture, which is also in good agreement with the literature [4].

V. REFERENCES

[1] Pramudita, J.A., et al., *ICRASH*, 2014.
[2] Klinich, K.D., et al., *J Biomech Eng*, 2012.
[3] Grob, D., et al., *Eur Spine J*, 2007.
[4] Kim, H.J., et al., *Spine Deform*, 2014.