Dynamic Intervertebral Body Angle of the Lower Cervical Spine during Protracted Head Extension Using Measured by Fluoroscopy

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Abstract. [Purpose] To analyze dynamic lower cervical spine kinematics under neutral head extension (Ex) and protracted head extension (Pro-Ex) using fluoroscopy. [Method] The intervertebral body angle of the lower cervical spine of 8 healthy individual was analyzed using fluoroscopy during cervical extension with the head in the neutral (Ex) and protracted (Pro-Ex) positions. [Results] At maximum cervical extension position, we noted a significantly smaller value in the Pro-Ex position than in Ex position. During extension, the intervertebral body angle was significantly greater at C3-4 and less at C6-7 level in the Pro-Ex position compared to the Ex position in the initial phase. However, there was no significant difference in the intervertebral body angle between the two positions in final phase of extension. This shows greater extension movement C6-7 level in Pro-Ex. [Conclusion] The pro-Ex result showed less range of motion of extension. This suggests exaggerated hypermobility in the lower segments of the cervical spine, which might be implicated in early degenerative disease of the cervical spine.

Key words: Cervical dynamic kinematics, Fluoroscopy, Lower cervical spine

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INTRODUCTION

There is a growing incidence of neck and shoulder pain, owing to prolonged malalignment posture with head protraction^{1, 2)}. It is usually caused by sedentary lifestyle, such as using a computer, watching TV or driving^{1, 2)}. Repetitive extension with head protraction can also alter the biomechanics of the cervical spine. These changes can induce severe neck pain or limitation of range of motion (ROM), which can result in a vicious cycle of cervical disease³⁻⁵⁾.

The evaluation of the cervical spine mobility of neck and shoulder pain patients is crucial for providing diagnostic and treatment information⁵⁻⁷⁾. Hypermobility and hypomobility are associated with degenerative change, pain, and dysfunctions such as reduced grip strength⁵⁻⁷⁾. Thus, segment motion analysis of the cervical spine is observed in a variety of fields. However, few studies have been conducted of dynamic motion of vertebral segments due to the complex movement of the spine⁸⁾ and the current limitations of dynamic analytical equipment in evaluation of each segment.

Motion capture systems and magnetic tracking devices are frequently used for dynamic motion analysis, but the

markers attached to the skin can be significantly affected by skin movement resulting in high error rates⁹⁾. Recently, fluoroscopy has been employed to analyze the dynamic kinematics of the spine^{10, 11)}. A fluoroscopy can be used to obtain high-quality dynamic motion images at low doses of radiation. However, cervical extension with the head in a protracted position has not yet been clearly elucidated.

In this study, we conducted fluoroscopic analysis of the cervical intervertebral body angle and lordosis of the lower cervical spine during cervical extension performed by healthy individuals with the head in the neutral extension (Ex) and protracted extension (Pro-Ex) positions. This is fundamental information for the evaluation and management of cervical disorders.

SUBJECTS AND METHODS

Eight subjects (8 females, mean age: 21.33±0.51years) with no history of neurologic or musculoskeletal disease involving the neck region participated in this experiment. The inclusion criteria were: age between 20–25 years, no subjective complaint of pain in the upper back, head, cheeks and upper limbs, no history of medical management for any

spinal problem during the last year, and full ability to sit and stand without difficulty.

The exclusion criteria were: history of previous trauma to the cervical spine, currently undergoing medical treatment for neck pain, a diagnosis of systemic disease involving the cervical spine (e.g. rheumatoid arthritis), or pregnancy.

The subjects understood the principal objective of this study and provided their written informed consent before participating in the study. This protocol was approved by the Institutional Review Board of Yeungnam University Hospital, and was conducted in accordance with the ethical standards of the Declaration of Helsinki.

One trained physical therapist gave instructions to the subjects on the exact movements to perform. The subjects performed the cervical extension with the head in the Ex and Pro-Ex positions for 10-seconds. Neutral head extension (Ex) was a relaxed sitting posture with zero sagittal rotation and the face turned towards the ceiling. Protracted head extension (Pro-Ex), on the other hand, was the maximal forward gliding position with zero sagittal rotation and the face turned towards the ceiling as far as possible¹²⁾. A thoracolumbosacral orthosis (TLSO) was worn by the subjects to prevent compensatory movements of the lumbar and thoracic spine. The subjects practiced each position three times in preparation for the subsequent radiograph studies.

Video images were obtained with a fluoroscopy unit (ARCADIS Orbic, Siemens, USA) in the sagittal plane. Video data were acquired at 10 frames per second and subsequently converted to still images, resulting in approximately 100 images per cervical extension. However, approximately a quarter of these images were discarded because the image motion was blurred and the inferior end plate at C7 was occluded by the clavicle. Therefore, approximately only 25 images per cycle were used and these images were analyzed using LabVIEW software (National Instruments, USA).

The Cobb angle from C3 to C7 and intervertebral body angle were measured. The Cobb angle is the angle between the superior end plate of C3 and the inferior end plate of C7 and represents the lordosis of the lower cervical spine¹³⁾ (Fig. 1). The intervertebral body angle is the angle between the midplane of the adjacent vertebral spine as described by Frobin et al.^{14, 15)} (Fig 1). The angle is counted positive, if the wedge opens ventrally. We determined that the Cobb angle was a reference value for comparison among the subjects, and the measured value was resampled to calculate the exact coordinates using a linear interpolation method. The interpolation was conducted using Matlab (Mathworks, USA). Differences between Ex and Pro-Ex were analyzed using the paired t-test. PASW 18.0 for Windows was used throughout. Statistical significance was accepted for values of $p < 0.05$.

RESULTS

Eight subjects were enrolled in the study, all of who were females. They had a mean age of 21.33 ± 0.51 years, a mean weight of 51.83 ± 3.37 kg, and a mean height of 161.50 ± 4.72 cm.

In the comparison of Cobb angles between the Ex and Pro-Ex positions in the neutral cervical position, no

Fig. 1. Schematic diagram of the Cobb angle from C3 to C7 and the intervertebral body angle

significant difference was noted between the two positions ($p > 0.05$). However, at the maximum extension position, we noted a significantly smaller lordosis value in the Pro-Ex position than in the Ex position ($p < 0.05$) (Table 1).

The intervertebral body angle of each segment widened with increase in the Cobb angle (Table 2). The intervertebral body angle was less at the C3-4 level and greater at the C6-7 level in Pro-Ex than in Ex and there were a significant differences at Cobb angle of 15° and 20° ($p < 0.05$) (Table 2). However, there were no significant difference between two positions at Cobb angle of 25° and 30° (Table 2).

DISCUSSION

We analyzed the dynamic lordosis and intervertebral body angle of the lower cervical spine with fluoroscopy with the head in the neutral and protracted extension positions. We observed the kinematic changes of head position. To our knowledge, this is the first study to provide dynamic kinematic data according to head position changes during extension.

In maximal cervical extension, lordosis was less in the Pro-Ex position, which indicates that this position resulted in a smaller ROM of the lower cervical spine. Wu et al.¹¹⁾ demonstrated that C5-6 has the highest intervertebral body angle during extension. Our results demonstrate that at maximum extension with the head protracted, C5-6 had the highest value but C6-7 had the smallest value and this may result in reduction in lordosis. Another possible reason for reduced lordosis in the Pro-Ex position is that the head is posteriorly located in Ex compared to Pro-Ex. This may result in greater lordosis in Ex than in Pro-Ex, because the posterior head weight may squeeze the lower cervical spine¹⁶⁾. Kuo et al.¹⁷⁾ demonstrated that older adults generally have a forward head posture. The cervical extension range of motion was significantly reduced in this group compared to young adults. These results indicate those with chronic Visual Display Terminal syndrome or the elderly who have less lordosis of lower cervical spine may have a limited neck ROM.

With regards to intervertebral body angle, the upper segments, C3-4 and C4-5, demonstrated greater extension

Table 1. Comparison of the Cobb angle from C3 to C7 between the Ex and Pro-Ex positions with neck upright and in maximum extension

Cobb angle from C3 to C7	Ex (Mean $\pm$ SD)	Pro-Ex (Mean $\pm$ SD)
Upright Position	7.12 $\pm$ 4.52	-0.06 $\pm$ 7.9
Maximum Extension*	39.34 $\pm$ 5.5	35.48 $\pm$ 3.84

(unit: deg) The asterisk indicates the results of the paired t-test between Ex and Pro-Ex were significant $p < 0.05$. The abbreviations used are as follows. Ex=Neutral Extension position, Pro-Ex=Protracted Extension position

in the initial and middle phase in the Pro-Ex position and decreased ROM. The lower segment conversely appeared to show a compensatory motion in relation to this movement. Generally, degenerative changes frequently occur in the lower segment¹⁸⁾. The results of our study support the idea that the Pro-Ex position creates a higher ROM of intervertebral body angle at the C5-6 and C6-7 levels, possibly causing degenerative change in these segments during extension.

Finally, the trend in the intervertebral body angle demonstrated that extension of the upper segment was higher than that of the lower segment in the initial and middle phases during protraction. However, this trend changed in the final phase, at the Cobb angle of 30°. These findings suggest static or functional X-rays cannot represent dynamic kinematics, and dynamic kinematic analysis is needed to determine the exact causes of neck pain.

The limitations of this study were a small sample size and the lack of analysis of upper cervical motion due to the limited field of view available. The interpolation was used to identify trends of segmental motion.

In conclusion, the results suggest protraction is ineffective at increasing ROM and could exaggerate hypermobility of the lower cervical spine, which might be implicated in degeneration of the lower cervical spine. This should be helpful for the establishment and assessment of treatment strategies for patients with cervical impairment.

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Table 2. Comparison of the intervertebral body angles between the Ex and Pro-Ex positions at Cobb angle from 15° to 30°

Cobb angle	Segment	Ex (Mean $\pm$ SE)	Pro-Ex (Mean $\pm$ SE)
15°	C3-4*	2.13 $\pm$ 1.38	7.44 $\pm$ 0.75
	C4-5	4.36 $\pm$ 1.06	5.98 $\pm$ 1.57
	C5-6	5.50 $\pm$ 1.40	3.14 $\pm$ 1.45
	C6-7*	6.19 $\pm$ 1.33	0.93 $\pm$ 0.99
20°	C3-4*	3.13 $\pm$ 1.39	7.84 $\pm$ 1.53
	C4-5	6.07 $\pm$ 1.3	7.45 $\pm$ 1.16
	C5-6	6.96 $\pm$ 1.45	4.99 $\pm$ 1.69
	C6-7*	6.74 $\pm$ 1.08	2.08 $\pm$ 1.48
25°	C3-4	4.78 $\pm$ 1.07	7.99 $\pm$ 1.41
	C4-5	7.43 $\pm$ 1.00	7.93 $\pm$ 1.24
	C5-6	7.70 $\pm$ 1.13	7.77 $\pm$ 1.23
	C6-7	7.55 $\pm$ 1.18	4.43 $\pm$ 1.59
30°	C3-4	6.16 $\pm$ 0.75	8.28 $\pm$ 1.06
	C4-5	8.41 $\pm$ 0.92	8.68 $\pm$ 0.99
	C5-6	10.55 $\pm$ 1.04	10.09 $\pm$ 1.05
	C6-7	7.52 $\pm$ 1.36	5.89 $\pm$ 1.33

(unit: deg) The asterisk indicates the results of the paired t-test between Ex and Pro-Ex were significant $p < 0.05$. The abbreviations used are as follows. Ex=Neutral Extension position, Pro-Ex=Protracted Extension position

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