Analysis of global spine sagittal parameters in cervical spondylocic patients and asymptomatic subjects

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Liang Zhu
Shanghai Jiaotong University First People's Hospital Department of Orthopaedics

Xiaojun Ma
Shanghai Jiaotong University First People's Hospital Department of Orthopaedics

Qiang Shen
Shanghai Jiaotong University First People's Hospital Department of Orthopaedics

Bao Sun
Shanghai Jiaotong University First People's Hospital Department of Orthopaedics

Qiang Fu
shanghaispine@hotmail.comCorresponding Author

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Abstract
Background: Degenerative changes associated with cervical spondylotic can result in a change of normal sagittal alignment, and this may be the initial change of kyphosis and sagittal imbalance. Few studies have analyzed the correlations between the cervical spine lordosis and global spine balance in patients with cervical spondylotic. This study is applied to investigate the characteristics and relationships of cervical and global sagittal parameters in normal adults and cervical spondylotic patients. Methods: We reviewed 46 asymptomatic control subjects (normal group, NG) and 48 cervical spondylotic patients (cervical spondylotic group, CSG), who had both cervical MRI and global radiographs obtained together, between January 2016 and September 2018. Data includes C1-2 angle, C2–7 lordosis (CL), T1 slope (T1S), thoracic inlet angle (TIA), C2–7 sagittal vertical axis (CSVA), sagittal vertical axis(SVA), thoracic-kyphosis(TK), thoracic-lumbar lordosis(TL), lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS). The values were presented as the mean ± standard deviation. Student t-test and Pearson’s correlation coefficient were used for statistical analysis. Probability values less than 0.05 were considered statistically significant. Results:
1. Comparison of global sagittal parameters between the normal group and cervical spondylosis group. A total of 48 cervical spondylotic patients with an average age of 57.91±9.58 and 46 healthy people with an average age of 28.00±8.09 were recruited in our study. CL in the NG was significantly lower than CSG (P<0.05), while TK and TL were significantly lower than in the CSG(P< 0.01). However, a comparison of the NG and CSG yielded no significant differences in C1-2, TIA, TIS, LL, PT, PI, SS, CSVA, and SVA. 2. The relationship between cervical and global sagittal alignment. CL positively correlated with T1S (r=0.433) and TK (r=0.335) while negatively correlated with CSVA (r=-0.309) in cervical spondylosis group. TIA has positively correlated with T1S (r=0.376 in NG and r=0.416 in CSG) and no correlated with other parameters in both groups. Conclusions: Cervical spondylosis causes changes in sagittal parameters of the cervical and thoracic spine but does not affect on lumbar and pelvic parameters. TIA is a relative constant parameter, not affected by cervical spondylotic.

Background
Disc degeneration has been recognized as the initiating event of spondylotic changes, which can lead
to abnormal cervical spine biomechanics and loss of normal sagittal alignment. Abnormalities of the
cervical sagittal alignment, in return, could contribute to spinal cord dysfunction [1]. On the other
hand, neck pain and functional disability could be caused by loss of cervical lordosis[2].
Lee found a significant sequential relationship between C2–7 angle and T1 slope in asymptomatic
volunteers without the history of symptoms related to the whole spine[3]. In Kim’s study, nearly one-
fourth of the asymptomatic participants (26.3%) have kyphotic cervical posture and no statistically
significant correlations were found among cervical kyphosis and the global spine parameters (TK, LL,
SS, PT, and PI)[4]. One study showed that C2–7 angle was the only predictor of CSVA in patients with
cervical spondylotic myelopathy. Age combined with CSVA could predict the severity of
myelopathy[1]. In one analysis of cervical and global spine alignment in Chinese cervical spondylotic
patients and asymptomatic subjects, the authors found that the percentages of cervical lordosis were
28.3 % and 36.4 % in asymptomatic and spondylotic group and cervical angles were significantly
related to the thoracic kyphosis[5]. One study reviewed the characteristics of cervical sagittal
parameters in 50 healthy cervical spine adults and 50 patients with cervical disc degeneration. They
found that T1S was involved in the occurrence and development of cervical disc degeneration, and
TIA could be considered as a constant morphological parameter in both the normal population and
cervical disc degeneration patients[6]. Yoon Ha reported that changes in the balance of the
thoracolumbar spine caused reciprocal changes in cervical spine alignment. Cervical spine alignment
may depend on changes in regional anatomic curvatures (thoracic or lumbar) and sagittal
alignment[7]. The interaction between thoracic, lumbar spine and pelvis has been well
documented in publications during the past decade[8, 9]. However, there is little research on the
comparison of full-spine sagittal parameters between patients with cervical spondylosis and healthy
adults. Moreover, the correlation between the parameters is not clear.
Therefore, we prospectively observed the radiological characteristics of the cervical spine in 46
normal people and 48 cervical spondylotic patients, then analyzed the relationship between cervical
and global spine alignment parameters.
Materials And Methods
A retrospective analysis was performed of data from 46 normal control subjects whose cervical spine are healthy (normal group, NG) and 48 patients with cervical spondylosis (cervical spondylosis group, CSG), who visited the outpatient department or physical examination center of our hospital between January 2016 and September 2018. Each individual had both a full-length spine lateral X-ray radiographs and cervical MRI scans(Fig. 1 and Fig . 2).

**Inclusion criteria of NG** Enrolled asymptomatic volunteers whose ages are between 20 and 40 years and no history of diagnosis or treatment related to any part of the spine. No evidence of cervical spondylosis with clinical manifestations, physical examination, and MRI scan.

**Inclusion criteria of CSG** Combined with clinical manifestations, physical examination, X-ray and MRI examination, confirmed as cervical spondylotic. Patients were only suffering from the cervical disease but free from chronic back pain, deformity or other orthopedic diseases. No history of spinal surgery, trauma, deformities, or tumors.

Data including C1–C2 angle, C2–7 lordosis (CL), T1 slope (T1S), thoracic inlet angle (TIA), C2–7 sagittal vertical axis (CSVA), TL, TK, LL, PI, PT, SS and SVA on radiographs were collected and analyzed.

**Cervical sagittal parameters (Fig. 3)**

C1–C2 angle: an angle between C1 and the C2 lower endplate was measured using the Cobb method.

C2–C7 angle(CL): the Cobb angle between the lower endplates of C2 and C7.

C2–7 sagittal vertical axis (CSVA): the distance from the posterosuperior corner of C7 to a vertical line from the center of the C2 vertebra.

T1S: the angle between the horizontal and the upper endplate of T1.

TIA: an angle formed by a vertical line from the center of the T1 upper endplate, and a line connecting the center of the T1 upper endplate and the upper end of the sternum.

**Global sagittal parameters (Fig. 4 and Fig. 5)**

TK: the Cobb angle between the lower endplates of T4 and T12.

TL: the Cobb angle between the lower endplates of T10 and L2.

LL: the Cobb angle between the lower endplates of L1 and S1.

SVA: the horizontal distance between the vertical line passing through the center of the seventh
cervical vertebral body and the posterior superior angle of the sacrum.

PI: the angle subtended by a line drawn from the hip axis to the midpoint of the sacral endplate and a line perpendicular to the center of the sacral endplate.

PT: the angle between the line connecting the midpoint of the upper endplate of the sacrum and the center of the bilateral femoral head and the vertical line through the upper endplate.

SS: the angle subtended by a horizontal reference line and the sacral endplate.

PACS full-spine imaging and SPSS version 17.0 were used for the statistical analyses. The values were presented as the mean ± standard deviation. Student t-test and Pearson’s correlation coefficients were used to examining the correlation between variables. The statistical significance level was set at P < 0.05.

Results
1. Comparison of parameters between the normal group and cervical spondylotic group.
A total of 48 CSM patients with an average age of 57.91 ± 9.58 and 46 healthy people with an average age of 28.00 ± 8.09 were recruited in our study. The mean of CL(8.18 ± 9.06), TK(18.45 ± 7.67) and TL (5.38 ± 11.44) in NG which was significant lower than CSG (CL11.87 ± 6.99,TK23.25 ± 8.40, TL12.04 ± 9.79 respectively). However, a comparison of the NG and CSMG yielded no significant differences in C1-2, TIA, TIS, LL, PT, PI, SS, CSVA and SVA. Radiographic parameters in the current study were listed in Table 1.

|                  | NG        | CSG       | P       |
|------------------|-----------|-----------|---------|
| NO. Subjects     | 46        | 48        |         |
| Age (years)      | 28.00 ± 8.09 | 57.91 ± 9.58 | 0.000*  |
| C1-2             | 26.47 ± 5.64 | 25.82 ± 6.30 | 0.603   |
| TIA              | 67.32 ± 7.81 | 68.18 ± 7.45 | 0.584   |
| TIS              | 23.11 ± 6.61 | 25.88 ± 9.26 | 0.101   |
| CL               | 8.18 ± 9.06  | 11.87 ± 6.99 | 0.029*  |
| TK               | 18.45 ± 7.67 | 23.25 ± 8.40 | 0.005*  |
| TL               | 5.38 ± 11.44 | 12.04 ± 9.79 | 0.003*  |
| LL               | -35.13 ± 23.80 | -42.87 ± 12.24 | 0.049   |
| PT               | 9.91 ± 7.52  | 12.07 ± 8.58 | 0.200   |
| PI               | 41.39 ± 9.85 | 44.63 ± 8.75 | 0.094   |
| SS               | 31.46 ± 9.80 | 32.56 ± 9.34 | 0.580   |
| CSVA(mm)         | 21.89 ± 11.44 | 21.81 ± 12.70 | 0.978   |
| SVA(mm)          | 7.17 ± 39.73 | 16.15 ± 38.08 | 0.266   |

2. The relationship between cervical and global sagittal alignment.
When examining the correlations among the parameters in NG, we found statistically significant
correlations among the following variables (Table 2): age with TL ($r = 0.339$, $P < 0.01$), age with PT ($r = -0.306$, $P < 0.05$), C1-2 with LL ($r = -0.291$, $P < 0.05$), CL with T1S ($r = 0.382$, $P < 0.01$), CL with T1S ($r = 0.48$, $P < 0.05$), T1S with CSVA ($r = 0.322$, $P < 0.05$), TIA with T1S ($r = 0.376$, $P < 0.05$), T1S with PT ($r = 0.387$, $P < 0.01$), PT with SS ($r = -0.378$, $P < 0.01$), PL with SS ($r = 0.708$, $P < 0.01$), CSVA with SVA ($r = 0.305$, $P < 0.05$).

| Parameters | C1-2 | CL | TIA | T1S | TK | TL | LL | PT | PI | SS | CSVA | SVA |
|------------|------|----|-----|-----|----|----|----|----|----|----|------|-----|
| Age        | -0.27 | -0.134 | 0.032 | -0.073 | 0.146 | 0.339$^*$ | 0.270 | -0.136 | -0.306$^*$ | -0.202 | 0.005 | 0.200 |
| C1-2       | 0.228 | -0.193 | 0.112 | 0.382$^{**}$ | 0.119 | 0.153 | -0.169 | 0.333 | -0.110 | 0.145 | -0.062$^{*}$ | 0.435 |
| CL         | 0.176 | -0.072 | -0.079 | 0.376$^*$ | 0.217 | 0.329 | 0.166 | 0.146 | 0.417 | 0.322$^*$ | 0.124 |
| TIA        | 0.480$^{**}$ | -0.013 | -0.165 | -0.133 | -0.283 | -0.271 | -0.054 | 0.282 | 0.037 | 0.272 | 0.124 |
| T1S        | 0.620$^{**}$ | -0.063 | -0.276 | -0.195 | 0.256 | 0.276 | 0.195 | 0.008 | 0.195 | 0.195 | 0.256 |
| TK         | 0.276 | -0.016 | -0.341$^*$ | -0.331$^*$ | -0.224 | -0.093 | -0.114 | 0.008 | 0.008 | 0.008 | 0.008 |
| TL         | 0.387$^{**}$ | -0.378$^*$ | 0.093 | 0.177 | 0.028 | 0.090 | 0.305$^*$ | 0.093 | 0.177 | 0.028 | 0.090 |
| LL         | 0.708$^{**}$ | -0.098 | -0.177 | -0.028 | -0.090 | 0.305$^*$ | 0.093 | 0.177 | 0.028 | 0.090 | 0.305$^*$ |
| PT         | 0.453 | 0.349 | 0.364 | 0.430 | 0.363 | 0.394 | 0.363 | 0.394 | 0.363 | 0.394 | 0.363 |
| CSVA       | 0.430 | 0.430 | 0.430 | 0.430 | 0.430 | 0.430 | 0.430 | 0.430 | 0.430 | 0.430 | 0.430 |
| SVA        | 0.362 | 0.362 | 0.362 | 0.362 | 0.362 | 0.362 | 0.362 | 0.362 | 0.362 | 0.362 | 0.362 |

** Significant correlation at the 0.01 level
* Significant correlation at the 0.05 level

When examining the correlations among the parameters in CSG, we found statistically significant correlations among the following variables (Table 3): age with TIA ($r = 0.345$, $P < 0.05$), age with TK ($r = 0.321$, $P < 0.05$), age with PT ($r = 0.364$, $P < 0.05$), age with CSVA ($r = 0.366$, $P < 0.05$), age with SVA ($r = 0.349$, $P < 0.05$), C1-2 with CL ($r = -0.312$, $P < 0.05$), C1-2 with CSVA ($r = 0.430$, $P < 0.05$), CL with T1S ($r = 0.433$, $P < 0.01$), CL with CSVA ($r = -0.309$, $P < 0.05$), TIA with T1S ($r = 0.416$, $P < 0.01$), T1S with TK ($r = 0.638$, $P < 0.05$), T1S with CSVA ($r = 0.388$, $P < 0.01$), T1S with SVA ($r = 0.404$, $P < 0.01$), TK with TL ($r = 0.398$, $P < 0.01$), TK with LL ($r = -0.363$, $P < 0.05$), TL with LL ($r = 0.438$, $P < 0.01$), TL with PT ($r = 0.501$, $P < 0.01$), LL with PL ($r = -0.398$, $P < 0.01$), LL with SS ($r = -0.6539$, $P < 0.01$), LL with PT ($r = 0.419$, $P < 0.01$), PT with SS ($r = -0.525$, $P < 0.01$), PT with SVA ($r = 0.299$, $P < 0.05$), PL with SS ($r = 0.553$, $P < 0.01$), PL with SVA ($r = 0.362$, $P < 0.05$), CSVA with SVA ($r = 0.416$, $P < 0.05$).
CL lordosis positively correlated with T1S and TK while negatively correlated with CSVA in the cervical spondylosis group. TIA has positively correlated with T1S and no correlated with other parameters in both groups.

Discussion
The global spine lateral radiograph is a key image to evaluate global spinal sagittal alignment.

Previous studies have attempted to find out the relationship between the cervical spine sagittal parameters and global spine sagittal parameters, but do not form a unified opinion[1, 10, 11].

Usually, we use the C2-C7 angle to represent cervical lordosis(CL), but the relationship between cervical degeneration and cervical lordosis has been controversial. Wang observed no significant difference in the C2–7 angle between the normal group and the degenerative cervical spondylolisthesis group[12]. Generally speaking, the presence of a kyphotic cervical alignment may indicate substantial deformity and be linked to poor clinical outcomes. But in an author's report, 29% of patients without cervical complaints have kyphotic cervical alignment. Kyphotic alignment of the cervical spine cannot alone define cervical deformity[10, 13]. Kim's report showed that nearly one-fourth of asymptomatic people have kyphotic cervical posture[4]. Yoshida's study demonstrated that the pathology of the responsible lesion was related to global sagittal balance but not regional cervical
alignment, which might be due to compensation against global malalignment during aging[11]. On the other hand, the C2–7 angle increased with age in the normal population[14, 15]. In our study, the cervical lordosis in CSG is higher than NG(11.87 ± 6.99 VS 8.18 ± 9.06 P < 0.05) and the age of the CSG is also higher than NG(57.91 ± 9.58VS 28.00 ± 8.09 P < 0.01). Therefore, we speculate that age combined with cervical lordosis reflects the disease status of cervical spondylosis.

Sang-Hun Lee found that no significant relationship between CL and TK in seventy-seven asymptomatic volunteers without the history of symptoms (p=-0.154) [3]. Also, Our study suggests that CL and TK are not related in the NG(P = 0.119). Bassel found that as thoracic kyphosis increased, the amount of lower cervical lordosis increased in patients with a diverse range of thoracolumbar pathologies[13]. Jeffrey ‘s study revealed there was a significant association between the thoracic kyphosis and cervical lordosis for females (r = 0:33, P < 0.001), and for males (r = 0:27, P < 0.03) in post-mortem lateral spinal radiographs[15]. In our study, CL has positively correlated with TK(r = 0.335 P < 0.05) in CSG. It may be that cervical spondylosis changes the relationship between CL and TK. Cervical lordosis could increase as a compensatory reaction against sagittal imbalance or hyperthoracic kyphosis in with adult spinal deformity[10].

As a key vertebra, T1 joins the cervical and thoracic vertebra, fixed on both sides of the ribs not altered by position. Therefore, T1S parameter may provide a reference value for determining the correction of the sagittal balance of the cervical spine[16]. Also, T1S was involved in the occurrence and development of cervical disc degeneration[6]. In our study, CL is influenced by T1S(r = 0.382 in NG and r = 0.433 in CSG respectively P < 0.01). T1S exhibited a significant correlation with CL in previous research [3, 16–18]. Rong found that T1S positively correlated to CL patients with cervical disc degeneration. Lower T1S decreased the CL to obtain a sagittally balanced cervical spine and led to a relatively straight cervical spine[6]. T1S is the site that mainly bears the stress from the head weight. Long-term exposure to the stress could result in T1 tilting forward. To maintain a horizontal gaze, CL would increase along with the increased T1S in a compensatory manner [3]. In our study, T1S has a positive relation with TK, CSVA ,and SVA in CSG. As T1 slope is the angle between T1 and the global horizontal line, T1 slope becomes greater when thoracic kyphosis becomes greater or
positive sagittal imbalance becomes larger[10, 13].

In our study, the mean TIA of the NG and CSG were 67.32 ± 7.81 and 68.18 ± 7.45, similar to data in the previous study that the mean TIA of the NG and DG were 70.22 ± 6.8 and 71.5 ± 8.0, respectively. There were no significant differences in the TIA between the two groups in our study, indicating that TIA was not involved in the development of cervical disc degeneration, which could be considered a constant parameter of approximately 70°. TIA could be considered as a constant morphological parameter in the normal population and cervical disc degeneration patients[6]. TIA concerning cervical sagittal balance may be as important as pelvic incidence in lumbar lordosis[3]. There were positive correlations between TIA and T1S (r = 0.475) in Xing's study.[6] In our study, TIA has positively correlated with T1S in the two groups (r = 0.376 and r = 0.416). TIA is a more important parameter than TK and that it influences cervical spine sagittal balance to achieve physiologic posture with horizontal gaze in the spine without sagittal imbalance[3].

CSVA is an important parameter for evaluating cervical sagittal balance. According to the previous studies, the CSVA values in asymptomatic normal volunteers are maintained in a tight range within 20 mm[11, 19]. In Yuan's report, the mean CSVA value in patients with CSM was 17.2 ± 12.1 mm, within the normal value, indicating that most patients with CSM before surgery presented normal sagittal balance[1]. These are different from our findings. In our report, there is no difference in C2-7 SVA between NG and CSG(21.89 ± 11.44 mm VS 21.81 ± 12.70 mm P > 0.05). In the normal group, the value of CSVA is also higher than that reported in the previous literature. We suspect that a considerable number of people in the asymptomatic group also have a cervical sagittal imbalance, which requires further research in the future. In Rong's report, C2-7 lordosis was correlated with CSVA in the normal group(r=-0.482 P < 0.01) [6]. In Yuan's report, C2-7 lordosis was also correlated with CSVA in patients with cervical spondylotic myelopathy (r=-0.395, p = 0.001)[1]. Kwon also reported that C2-7 lordosis was significantly correlated CSVA in patients with spondylotic myelopathy and/or radiculopathy for ossification of the posterior longitudinal ligament and degenerative disc disorders. (r=-0.631, P < .001)[20]. These above studies are the same as the results of our study. In our study, C2-7 lordosis was negatively correlated with CSVA in NG and CSG (r=-.062 and r=-0.309, P < 0.05). It
means an excessively large CSVA that caused cervical spine decompensation would contribute to an imbalance in the cervical spine[1]. CSVA should be corrected by surgeons to improve the clinical outcomes when treating CSM. The restoration of C2–7 lordosis is critical to achieving a satisfactory CSVA[20].

The development of cervical spondylotic is a dynamic process. Accordingly, it is practical to assess each patient based on the individual conditions of global sagittal balance and regional alignment. [21] Now more researches reported that cervical lordosis has less related to spinopelvic parameters. Lee found no direct correlation between pelvic parameters and thoracic or cervical spine alignment[12]. Kim found no statistically significant correlations were found among cervical kyphosis and the global spine parameters[4]. Miao found that the cervical angles were related to thoracic angles, but not with the lumbar angles. They conclude that the cervical alignment is more liable to be influenced by the local parameters as an independent degenerative disease but is seldom influenced by the global spinal degeneration[5]. These results agree with our current research. In our study, CL has no relation with LL, PT, SS PT and SVA. In our opinion, cervical lordosis is mainly affected by cervical and thoracic parameters such as T1S, TIA, and TK, but not by lumbar-pelvic parameters.

There are some limitations in this study. Firstly, due to the small sample size, we are unable to further group according to the level of cervical spondylotic. Secondly, this study lacked scores like JOA and NDI. Our next work is to explore the relationship between JOA and NDI and the sagittal balance of the whole spine.

**Conclusion**

Cervical spondylosis causes changes in sagittal parameters of the cervical and thoracic spine but does not affect on lumbar and pelvic parameters. TIA could be considered as a constant morphological parameter in the normal population and cervical spondylotic.

**Abbreviations**

CL: C2–7 lordosis

T1S: T1 slope

TIA: thoracic inlet angle
CSVA: C2-7 sagittal vertical axis  
SVA: sagittal vertical axis  
TK: thoracic kyphosis  
TL: thoracic-lumbar lordosis  
LL: lumbar lordosis  
PI: pelvic incidence  
PT: pelvic tilt  
SS: sacral slope  
NG: normal group  
CSG: cervical spondylotic group  

Declarations  
Ethics approval and consent to participate  
The study design was approved by the Ethical Committee of Shanghai General Hospital, Shanghai Jiao Tong University. All of the participants provided written informed consent.  

Consent for publication  
Not applicable.  

Availability of data and materials  
All data generated or analyzed during this study are included in this published article and its additional files.  

Competing interest  
We declare that we do not have any competing interests.  

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Authors’ contributions

Liang Zhu and Xiaojun Ma contributed to interpreting the data and writing the final manuscript. Bao Sun was responsible for the original data collection. Qiang Shen contributed to reviewing the accuracy of the data. Qiang Fu was in charge and contributed to all stages of the present study. All authors read and approved the final manuscript.

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References

1. Yuan W, Zhu Y, Zhu H, Cui C, Pei L, Huang Z: Preoperative cervical sagittal alignment parameters and their impacts on myelopathy in patients with cervical spondylotic myelopathy: a retrospective study. *PeerJ* 2017, 5:e4027.

2. Tang JA, Scheer JK, Smith JS, Deviren V, Bess S, Hart RA, Lafage V, Shaffrey CI, Schwab F, Ames CP et al: The impact of standing regional cervical sagittal alignment on outcomes in posterior cervical fusion surgery. *Neurosurgery* 2015, 76 Suppl 1:S14-21; discussion S21.

3. Lee SH, Son ES, Seo EM, Suk KS, Kim KT: Factors determining cervical spine sagittal balance in asymptomatic adults: correlation with spinopelvic balance and thoracic inlet alignment. *Spine J* 2015, 15(4):705-712.

4. Kim SW, Kim TH, Bok DH, Jang C, Yang MH, Lee S, Yoo JH, Kwak YH, Oh JK: Analysis of cervical spine alignment in currently asymptomatic individuals: prevalence of kyphotic posture and its relationship with other spinopelvic parameters. *Spine J* 2018, 18(5):797-810.

5. Yu M, Zhao WK, Li M, Wang SB, Sun Y, Jiang L, Wei F, Liu XG, Zeng L, Liu ZJ: Analysis of cervical and global spine alignment under Roussouly sagittal
classification in Chinese cervical spondylotic patients and asymptomatic subjects. *Eur Spine J* 2015, **24**(6):1265-1273.

6. Xing R, Liu W, Li X, Jiang L, Yishakea M, Dong J: **Characteristics of cervical sagittal parameters in healthy cervical spine adults and patients with cervical disc degeneration.** *BMC Musculoskelet Disord* 2018, **19**(1):37.

7. Ha Y, Schwab F, Lafage V, Mundis G, Shaffrey C, Smith J, Bess S, Ames C: **Reciprocal changes in cervical spine alignment after corrective thoracolumbar deformity surgery.** *Eur Spine J* 2014, **23**(3):552-559.

8. Mac-Thiong JM, Labelle H, Charlebois M, Huot MP, de Guise JA: **Sagittal plane analysis of the spine and pelvis in adolescent idiopathic scoliosis according to the coronal curve type.** *Spine (Phila Pa 1976)* 2003, **28**(13):1404-1409.

9. Roussouly P, Gollogly S, Berthonnaud E, Dimnet J: **Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position.** *Spine (Phila Pa 1976)* 2005, **30**(3):346-353.

10. Fujimori T, Le H, Schairer W, Inoue S, Iwasaki M, Oda T, Hu SS: **The Relationship Between Cervical Degeneration and Global Spinal Alignment in Patients With Adult Spinal Deformity.** *Clin Spine Surg* 2017, **30**(4):E423-E429.

11. Yoshida G, Alzakri A, Pointillart V, Boissiere L, Obeid I, Matsuyama Y, Vital JM, Gille O: **Global Spinal Alignment in Patients With Cervical Spondylotic Myelopathy.** *Spine (Phila Pa 1976)* 2018, **43**(3):E154-E162.

12. Wang Q, Wang XT, Zhu L, Wei YX: **Thoracic Inlet Parameters for Degenerative Cervical Spondylolisthesis Imaging Measurement.** *Med Sci Monit* 2018, **24**:2025-2030.

13. Diebo BG, Challier V, Henry JK, Oren JH, Spiegel MA, Vira S, Tanzi EM, Liabaud B, Lafage R, Protopsaltis TS et al: **Predicting Cervical Alignment Required to**
Maintain Horizontal Gaze Based on Global Spinal Alignment. *Spine (Phila Pa 1976)* 2016, 41(23):1795-1800.

14. Park MS, Moon SH, Lee HM, Kim SW, Kim TH, Lee SY, Riew KD: The effect of age on cervical sagittal alignment: normative data on 100 asymptomatic subjects. *Spine (Phila Pa 1976)* 2013, 38(8):E458-463.

15. Boyle JJ, Milne N, Singer KP: Influence of age on cervicothoracic spinal curvature: an ex vivo radiographic survey. *Clin Biomech (Bristol, Avon)* 2002, 17(5):361-367.

16. Huang Y, Lan Z, Xu W: Analysis of sagittal alignment parameters following anterior cervical hybrid decompression and fusion of multilevel cervical Spondylotic myelopathy. *BMC Musculoskelet Disord* 2019, 20(1):1.

17. Patwardhan AG, Khayatzadeh S, Havey RM, Voronov LI, Smith ZA, Kalmanson O, Ghanayem AJ, Sears W: Cervical sagittal balance: a biomechanical perspective can help clinical practice. *Eur Spine J* 2018, 27(Suppl 1):25-38.

18. Li XY, Kong C, Sun XY, Guo MC, Ding JZ, Yang YM, Lu SB: Influence of the Ratio of C2-C7 Cobb Angle to T1 Slope on Cervical Alignment After Laminoplasty. *World Neurosurg* 2019.

19. Iyer S, Lenke LG, Nemani VM, Fu M, Shifflett GD, Albert TJ, Sides BA, Metz LN, Cunningham ME, Kim HJ: Variations in Occipitocervical and Cervicothoracic Alignment Parameters Based on Age: A Prospective Study of Asymptomatic Volunteers Using Full-Body Radiographs. *Spine (Phila Pa 1976)* 2016, 41(23):1837-1844.

20. Kwon WK, Kim PS, Ahn SY, Song JY, Kim JH, Park YK, Kwon TH, Moon HJ: Analysis of Associating Factors With C2-7 Sagittal Vertical Axis After Two-level Anterior Cervical Fusion: Comparison Between Plate Augmentation and Stand-alone
Cages. *Spine (Phila Pa 1976)* 2017, *42*(5):318-325.

21. Lin BJ, Hong KT, Lin C, Chung TT, Tang CT, Hueng DY, Hsia CC, Ju DT, Ma HI, Liu MY et al: Impact of global spine balance and cervical regional alignment on determination of postoperative cervical alignment after laminoplasty. *Medicine (Baltimore)* 2018, *97*(45):e13111.

Figures
Figure 1

Full-length spine lateral X-ray

Figure 2

MRI scan of the cervical spine
Cervical lateral X-ray C1–C2 angle: an angle between C1 and the C2 lower endplate was measured using the Cobb method (by line a and line b); C2–7 lordosis (CL): the Cobb angle between the lower endplates of C2 (line b) and C7 (line c); Cervical sagittal vertical axis (CSVA): the distance from the posterosuperior corner of C7 to a vertical line from the center of the C2 vertebra (the length of line e); T1S: the angle between the horizontal and the upper endplate of T1 (line d); T1A: an angle formed by a vertical line from the center of the T1 upper endplate, and a line connecting the center of the T1 upper endplate and the upper end of the sternum (by line f and line g);
Thoraco-lumbar lateral X-ray TK: the Cobb angle between the lower endplates of T4 (line b) and T12 (line c); TL: Thoracolumbar kyphosis (T10–L2) was defined by the angle between the cranial endplate of T10 (line b) and the caudal endplate of L2 (line d); LL: defined as the
angle subtended by a line drawn along the superior endplate of L1(line c) and S1(line e);
SVA: The horizontal distance between the vertical line passing through the center of the seventh cervical vertebral body and the posterior superior angle of the sacrum (the length of line f);

Pelvic lateral X-ray SS: The angle subtended by a horizontal reference line and the sacral endplate; PI: The angle subtended by a line drawn from the hip axis to the midpoint of the sacral endplate and a line perpendicular to the center of the sacral endplate; PT: The angle between the line connecting the midpoint of the upper endplate of the sacrum and the center of the bilateral femoral head and the vertical line through the upper endplate.
Supplementary Files
This is a list of supplementary files associated with this preprint. Click to download.

rawdataNG.xlsx
rawdataCSG.xlsx