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ORIGINAL ARTICLE

# Changes in correlations between cervical and distal spinal sagittal alignments in asymptomatic population with aging

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ABSTRACT

**Background:** In recent years, the correlations between spinal sequences and aging have been identified. However, the trends in correlations between cervical and distal spinal alignments with aging in asymptomatic populations remain underexplored.
**Aim:** This study aimed to compare the correlations between cervical and distal spinal sagittal alignments in different age groups as well as investigate their trends during the aging process in an asymptomatic population.
**Methods:** A total of 128 asymptomatic healthy volunteers were enrolled and stratified into four groups according to age (Group A: ≤20 years; Group B: 21 – 40 years; Group C: 41 – 60 years; Group D: >61 years), with 32 subjects in each group. Then, sagittal spinal parameters including C0-1 Cobb angle (C0-1 CA), C1-2 Cobb angle (C1-2 CA), C0-2 Cobb angle (C0-2 CA), C2-7 Cobb angle (C2-7 CA), C2-7 sagittal vertical axis (C2-7 SVA), neck tilt, thoracic inlet angle (TIA), T1 slope (TS), thoracic kyphosis (TK), lumbar lordosis, pelvic tilt, sacral slope, pelvic incidence, and C7-S1 sagittal vertical axis (C7-S1 SVA) were measured, and differences in parameters among the four groups were analyzed. Finally, the trends in correlations between the cervical and distal spinal sagittal parameters were investigated in the different age groups.
**Results:** No significant correlations were detected between upper cervical sagittal parameters (C0-1 CA, C1-2 CA, and C0-2 CA) and distal spinal sagittal parameters in the four groups. An increasing trend with aging was discovered in the correlations between subaxial cervical sagittal parameters and distal spinal sagittal parameters. Finally, significant correlations were observed between TS and TK, as well as between TIA and TK in the four groups.
**Conclusions:** Subaxial cervical alignments exhibit a close correlation with distal spinal alignments during the aging process in the asymptomatic population. An increasing trend was observed with age in the correlations between C2-7 CA, C2-7 SVA, and distal spinal sagittal parameters.
**Relevance for Patients:** Given the correlations between the cervical and distal spinal alignments, which tend to increase with age, it is crucial to pay special attention to the influence of C2-7 CA and C2-7 SVA on distal spinal alignments before spinal surgery for patients.

## 1. Introduction

The sagittal balance of the spine has recently garnered increasing attention from spinal surgeons [1,2]. Indeed, sagittal alignment of the spine provides key information about spinal function and largely influences spinal biomechanics. Thus, maintaining the sagittal balance of the spine plays a vital role in maintaining the normal posture of the body [3].

As is well documented, the spine is composed of cervical and distal segments. As an essential component of the spine, the cervical spine plays an instrumental role in maintaining the

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sagittal balance of the spine and the head position [4]. Meanwhile, a compensatory interaction has been reported between cervical alignment and distal thoracic, lumbar, and pelvic alignment to maintain the sagittal balance of the spine [5,6]. There is evidently a close relationship between cervical and distal spinal alignments.

Moreover, our previous study revealed fluctuations in cervical alignment parameters with aging in asymptomatic populations [7]. Nevertheless, the correlation between cervical alignment and distal spinal alignment with aging remains elusive. Therefore, the purpose of this study was to investigate trends in the correlations between cervical and distal spinal sagittal alignments in the asymptomatic population with aging.

## 2. Materials and Methods

### *2.1. Selection of subjects*

This study was approved by the Institutional Review Board of the institute. A total of 206 volunteers consented to participate in the study from September 2020 to December 2021, and written informed consent was obtained from each volunteer. The inclusion criteria of the asymptomatic population were as follows: (1) no past history of chronic neck, low back, and back pain; (2) no history of spinal disease; (3) no history of hip, pelvic, or lower limb disease. The subjects were divided into 4 groups according to their age (Group A: ≤20 years old; Group B: 21 – 40 years old; Group C: 41 – 60 years old; Group D: ≥61 years old). Each group comprised 32 subjects. The age and body mass index of subjects were recorded.

### *2.2. Radiographic parameters*

The subjects were placed in the upright position with a clenched fist resting on the supraclavicular fossa. Next, standard full-length anteroposterior and lateral radiographs of the spine were taken. The sagittal parameters of the global spine consisted of C0-1 Cobb angle (C0-1 CA), C1-2 Cobb angle (C1-2 CA), C0-2 Cobb angle (C0-2 CA), C2-7 Cobb angle (C2-7 CA), C2-7 sagittal vertical axis (C2-7 SVA), neck tilt (NT), T1 slope (TS), thoracic inlet angle (TIA), thoracic kyphosis (TK), lumbar lordosis (LL), sacral slope (SS), pelvic tilt angle (PT), pelvic incidence angle (PI), and C7-S1 SVA.

The aforementioned parameters were measured as follows: C0-1 Cobb angle was defined as the angle between McGregor's line (A) and the line (B) linking the anteroinferior and posteroinferior arch of atlas; C1-2 Cobb angle represented the angle between the line (B) linking the anteroinferior and posteroinferior arch of atlas and the parallel line (C) of the C2 lower end plate; C0-2 Cobb angle was the angle between the McGregor line (A) and the parallel line (C) of the C2 lower end plate; C2-7 Cobb angle was defined as the angle between the parallel line (C) of the C2 lower end plate and the parallel line (D) of the C7 lower end plate; C2-7 SVA characterized the distance between the vertical line from the center of C2 and the posterior superior corner of C7; NT symbolized the angle between two lines both originating from the upper end of the sternum, one of them being a vertical line, while the other one was connected to the center of the T1 upper end plate; TS was the angle between the horizontal plane and the parallel line of the T1 upper end plate; TIA was the angle between the line perpendicular to the T1 upper end plate and a straight line from the center of the T1 upper end plate to the upper end of the sternum; TK denoted the angle between the T1 upper end plate and the T12 lower end plate; LL represented the angle between the L1 upper end plate and the S1 upper end plate; SS was the angle between the sacral end plate and the horizontal plane; PT was the angle formed by the vertical line and the line passing through the midpoint of the sacral end plate to the center of the femoral head; PI was the angle between the line perpendicular to the midpoint of the sacral end plate and the line connecting the midpoint of the sacral end plate to the center of the femoral head; C7-S1 SVA was the distance between a vertical line from the center of C7 and the posterior corner of the sacrum. Examples of the above parameters are illustrated in Figure 1.

### *2.3. Statistical analysis*

SPSS 22.0 statistical software (SPSS, Inc., Chicago, IL, USA) was employed for statistical analysis. One-way ANOVA statistical method was used for intergroup comparisons, and Pearson correlation analysis was used to analyze the correlation between cervical alignment and distal spinal alignment. All values were expressed as mean ± standard deviation, and a $P < 0.05$ was considered as statistically significant.

## 3. Results

### *3.1. Demographic characteristics of asymptomatic volunteers*

The study included 128 subjects, ranging in age from 16 to 81 years old and comprising 65 males and 63 females. The mean age of the subjects was 40.8 ± 20.0 years. The demographic data of volunteers are detailed in Table 1.

### *3.2. Parameters analysis*

One-way ANOVA was utilized to analyze differences in global spinal sagittal parameters among the groups. The results revealed no significant differences in C0-1 CA ($P = 0.096$) and PI ($P = 0.502$) in the four groups. Meanwhile, there were significant differences in C1-2 CA ($P = 0.025$), C0-2 CA ($P = 0.050$), C2-7 CA ($P = 0.000$), C2-7 SVA ($P = 0.018$), NT ($P = 0.000$), TS ($P = 0.000$), TIA ($P = 0.000$), TK ($P = 0.000$), LL ($P = 0.007$), SS ($P = 0.019$), PT ($P = 0.000$), and C7-S1 SVA ($P = 0.000$) in the four groups. Details are summarized in Table 2.

The Pearson correlation coefficients of C0-1 CA, C1-2 CA, and C0-2 CA and distal spinal parameters were all lower than 0.3, and no apparent trend in correlation was observed with aging. In the four groups, the Pearson correlation coefficients between C2-7 CA and TK were -0.236 ($P = 0.193$), −0.362 ($P = 0.042$), −0.502 ($P = 0.003$), and −0.655 ($P = 0.000$), the coefficients between C2-7 SVA and SS were 0.045 ($P = 0.808$), 0.265 ($P = 0.143$), 0.362 ($P = 0.042$), and 0.628 ($P = 0.000$), while the Pearson correlation coefficients between C2-7 SVA and C7-S1 SVA were 0.213 ($P = 0.242$), 0.322 ($P = 0.072$), 0.460 ($P = 0.008$), and

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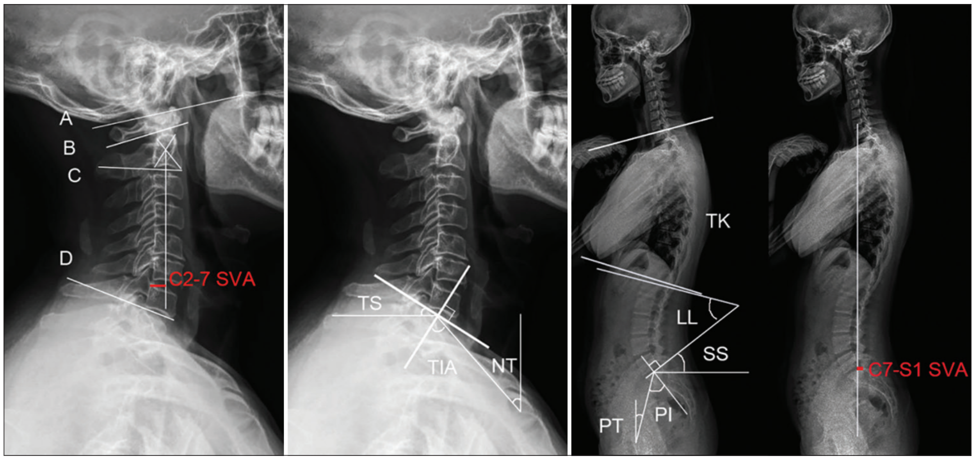


**Figure 1.** Illustrative schematic displaying cervical and distal spinal sagittal parameters: C0-1 CA, C1-2 CA, C0-2 CA, C2-7 CA, and C2-7 SVA, NT, TS, TIA, TK, LL, SS, PT, PI, and C7-S1 SVA.
Abbreviations: C0-1 CA: C0-1 Cobb angle; C1-2 CA: C1-2 Cobb angle; C0-2 CA: C0-2 Cobb angle; C2-7 CA: C2-7 Cobb angle; C2-7 SVA: C2-7 sagittal vertical axis; NT: Neck tilt; TS: T1 slope; TIA: Thoracic inlet angle; TK: Thoracic kyphosis; LL: Lumbar lordosis; SS: Sacral slope; PT: Pelvic tilt; PI: Pelvic incidence; C7-S1 SVA: C7-S1 sagittal vertical axis.

**Table 1.** Demographic data of the four groups

| Characteristic | Group A: ≤20 years *N*=32 | Group B: 21 – 40 years *N*=32 | Group C: 41 – 60 years *N*=32 | Group D: ≥61 years *N*=32 |
|---|---|---|---|---|
| Male | 18 | 17 | 13 | 17 |
| Female | 14 | 15 | 19 | 15 |
| BMI (kg/m$^2$) | 17.7±1.4 | 23.6±6.6 | 26.9±5.5 | 26.8±6.6 |
| Age (years) | 14.0±4.4 | 34.1±5.5 | 48.7±4.8 | 66.5±5.4 |

BMI: Body mass index

**Table 2.** Values of spinal sagittal alignment parameters in the four groups

| Radiographic parameter | Group A: ≤20 years *N*=32 | Group B: 21 – 40 years *N*=32 | Group C: 41 – 60 years *N*=32 | Group D: ≥61 years *N*=32 | *P*-value |
|---|---|---|---|---|---|
| C0-1 CA | 12.5±6.9 | 9.3±10.8 | 13.5±4.6 | 13.5±7.4 | 0.096 |
| C1-2 CA | −20.4±5.6 | −20.7±10.2 | −24.0±5.9 | −24.8±5.8 | 0.025* |
| C0-2 CA | −7.1±6.1 | −11.5±8.4 | −10.5±6.2 | −11.3±7.2 | 0.050* |
| C2-7 CA | −7.9±8.2 | −6.5±10.3 | −13.1±8.0 | −17.0±10.1 | 0.000** |
| C2-7 SVA | 20.1±9.1 | 18.2±10.6 | 20.3±8.2 | 25.7±10.9 | 0.018* |
| NT | 41.4±6.9 | 47.3±9.7 | 50.5±8.8 | 51.1±10.6 | 0.000** |
| TS | 22.1±5.1 | 20.3±5.7 | 23.8±4.9 | 27.1±8.8 | 0.000** |
| TIA | 63.5±9.8 | 67.6±9.5 | 74.2±8.3 | 78.2±11.8 | 0.000** |
| TK | 36.0±7.2 | 38.6±8.1 | 42.5±7.7 | 48.3±10.9 | 0.000** |
| LL | −50.5±10.5 | −42.0±9.8 | −44.4±9.6 | −42.1±13.4 | 0.007** |
| SS | 34.6±7.3 | 32.4±8.4 | 31.9±7.3 | 28.6±7.4 | 0.019** |
| PT | 7.9±8.5 | 12.9±8.1 | 13.7±10.7 | 18.1±7.8 | 0.000** |
| PI | 42.6±8.2 | 45.3±11.1 | 45.5±12.7 | 46.7±11.6 | 0.502 |
| C7-S1 SVA | −7.3±31.0 | 2.7±28.5 | −8.5±24.7 | 28.4±43.3 | 0.000** |

*$P<0.05$; **$P<0.01$.
Abbreviations: C0-1 CA: C0-1 Cobb angle; C1-2 CA: C1-2 Cobb angle; C0-2 CA: C0-2 Cobb angle; C2-7 CA: C2-7 Cobb angle; C2-7 SVA: C2-7 sagittal vertical axis; NT: Neck tilt; TS: T1 slope; TIA: Thoracic inlet angle; TK: Thoracic kyphosis; LL: Lumbar lordosis; SS: Sacral slope; PT: Pelvic tilt; PI: Pelvic incidence; C7-S1 SVA: C7-S1 sagittal vertical axis

0.581 ($P$ = 0.000), and finally, the coefficients between TS and TK were 0.443 ($P$ = 0.011), 0.664 ($P$ = 0.000), 0.529 ($P$ = 0.002), and 0.757 ($P$ = 0.000). The correlations between the above-mentioned cervical parameters and distal spinal parameters showed an increasing trend with age (Figure 2). In addition, the Pearson correlation coefficient between TIA and TK was 0.448 ($P$ = 0.010), 0.486 ($P$ = 0.005), 0.382 ($P$ = 0.031), and 0.479 ($P$ = 0.006), exposing significant differences among groups, but no trend was noted. The correlations between cervical and distal spinal parameters in the four groups are displayed in Table 3.

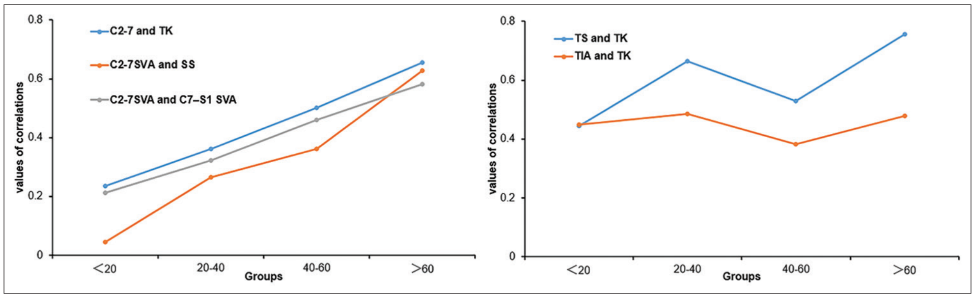


**Figure 2.** The correlations between the cervical and distal spinal parameters showed an increasing trend with aging, and TIA and TS were significantly correlated with TK, but no definite trend in correlation was detected between TIA and TK.
Abbreviations: TS: T1 slope; TIA: Thoracic inlet angle; TK: Thoracic kyphosis.

## 4. Discussion

In recent years, an increasing number of studies has reported the correlations between cervical and thoracolumbar pelvic alignments. For instance, Lee *et al.* discovered factors impacting cervical spine sagittal balance in asymptomatic adults and identified the T1 slope as a key factor [8]. At the same time, other scholars have found that C7 SVA is strongly correlated with C2-7 CA [5]; the C7 slope is a link between the occipitocervical and thoracolumbar spine [9]. These results all established the correlations between the cervical alignments and the distal spinal alignments. Our previous studies evinced that some cervical spine parameters tend to vary with aging [7]. Meanwhile, the interaction between cervical and distal spine alignments has also been reported [10,11]. Therefore, the trends of their correlations with aging, which have not been focused on so far, deserve further investigation.

Asymptomatic populations were stratified according to age, and sagittal parameters of the global spine were measured. Our study determined a gradual increase in C1-2 CA, C0-2 CA, C2-7 CA, C2-7 SVA, NT, TS, TIA, TK, PT, and C7-S1 SVA with aging. On the contrary, a gradual decrease in LL and SS was noted with aging. These results are consistent with those of Yukawa *et al.* [12]. Moreover, the results of cervical spine parameters were also comparable to those of our previous research [7], corroborating that sagittal spine parameters show a tendency to change with age. Notably, the loss of lumbar lordosis attributed to disk degeneration has been universally recognized as the initiator of the degenerative cascade, eventually leading to reciprocal changes in other regions [13]. Thoracic alignments serve as a bridge between cervical and distal spinal alignments. As individuals age, the thoracic vertebras begin to manifest adaptive changes, with a wedge-shaped which is narrow at the front and wide at the back [14,15], resulting in physiological kyphosis. Besides, earlier studies described that thoracic kyphosis was progressively aggravated during the aging process owing to the accumulation of mechanical load [14,16], especially in women and elderly osteoporotic patients [17,18]. It is worthwhile emphasizing that thoracic kyphosis steadily worsens over time, and lumbar lordosis concurrently decreases, leading to adaptive adjustments in the spine, such as increased cervical lordosis and decreased pelvic inclination. The synergistic effect of thoracic and lumbar alignments partially explains the trend observed with aging between cervical and distal spinal alignments.

Furthermore, the correlations between cervical and distal spinal parameters were compared among the different groups, and the results demonstrated that the correlations between upper cervical spine parameters (C0-1 CA, C1-2 CA, and C0-2 CA) and distal spinal parameters were all below 0.3, while the correlations between subaxial cervical parameters (C2-7 CA and C2-7 SVA) and distal spinal parameters showed an increasing trend with time. To maintain the sagittal balance of the global spine, changes in the thoracic and lumbar alignment require compensation through the involvement of the cervical spine [19]. Nonetheless, this balance maintenance is supposed to be sufficient through subaxial cervical alignment compensation and does not necessitate the involvement of upper cervical alignments. Therefore, there was a weak correlation between upper cervical spinal and distal spinal parameters.

At the same time, the correlations between C2-7 CA and TK, C2-7 SVA and SS, as well as C2-7 SVA and C7-S1 SVA showed an increasing trend with age in our study. This signified that in the elderly population, there is a strong correlation between cervical lordosis and thoracic kyphosis and between the forward translation of the cervical spine and the forward translation of the global spine. These phenomena occur naturally over time, which might be related to spinal degeneration and atrophy of the paravertebral extensor. Indeed, recent studies corroborated that muscle atrophy and spinal degeneration lead to corresponding alterations in spinal and pelvic alignments [20-25]. Yang [20] found a negative correlation between the atrophy of the paravertebral extensor and cervical sagittal parameters, while Okada [21] reported that changes in cervical spinal alignment contribute to the progression of disc degeneration at C7-T1. In other words, degeneration increased the correlation between cervical lordosis and thoracic kyphosis and that between cervical forward translation and global spine forward translation. We speculate that in the youth population, well-developed cervical paravertebral extensors, intervertebral discs, and intervertebral joints aid in supporting the head, thereby maintaining the horizontal gaze and keeping the head's central gravity line close to the pelvis. However, following paravertebral extensor atrophy, and intervertebral disc and intervertebral joint degeneration, the cervical spine not only becomes more lordotic to compensate for the increased thoracic kyphosis but also leans

**Table 3.** Correlations between cervical and distal spinal parameters in the four groups

| Cervical parameters | Distal spinal parameters | Group A: ≤20 years | Group B: 21 – 40 years | Group C: 41 – 60 years | Group D: ≥61 years |
|---|---|---|---|---|---|
| C0–1 CA | TK | −0.036 | 0.135 | 0.191 | 0.263 |
| | LL | 0.108 | −0.083 | −0.058 | −0.168 |
| | SS | 0.146 | 0.114 | 0.056 | −0.151 |
| | PT | −0.139 | 0.055 | 0.297 | 0.113 |
| | PI | −0.016 | 0.127 | 0.283 | −0.020 |
| | C7–S1 SVA | 0.031 | 0.019 | −0.051 | −0.190 |
| C1–2 CA | TK | 0.238 | −0.127 | −0.216 | −0.119 |
| | LL | −0.086 | -0.002 | 0.151 | 0.343 |
| | SS | −0.092 | 0.019 | 0.026 | 0.018 |
| | PT | −0.083 | −0.028 | −0.134 | −0.095 |
| | PI | −0.169 | −0.006 | −0.098 | −0.052 |
| | C7–S1 SVA | −0.129 | 0.085 | −0.121 | −0.087 |
| CO-2 CA | TK | 0.084 | 0.018 | −0.064 | 0.177 |
| | LL | 0.065 | −0.109 | 0.101 | 0.103 |
| | SS | 0.075 | 0.169 | 0.066 | -0.142 |
| | PT | −0.147 | 0.037 | 0.093 | 0.041 |
| | PI | −0.087 | 0.156 | 0.117 | −0.063 |
| | C7–S1 SVA | −0.155 | 0.127 | −0.153 | −0.268 |
| C2–7 CA | TK | −0.236 | −0.362* | −0.502** | −0.655** |
| | LL | 0.105 | 0.195 | 0.389* | 0.202 |
| | SS | 0.136 | −0.075 | 0.221 | −0.103 |
| | PT | −0.155 | −0.057 | −0.177 | 0.155 |
| | PI | −0.041 | −0.099 | −0.022 | 0.039 |
| | C7–S1 SVA | 0.022 | 0.048 | 0.201 | 0.163 |
| C2–7 SVA | TK | 0.076 | −0.141 | -0.361* | 0.105 |
| | LL | 0.116 | −0.064 | 0.134 | 0.080 |
| | SS | 0.045 | 0.265 | 0.362* | 0.628** |
| | PT | 0.240 | −0.378* | 0.045 | −0.191 |
| | PI | 0.291 | −0.075 | 0.247 | 0.273 |
| | C7–S1 SVA | 0.213 | 0.322 | 0.460** | 0.581** |
| NT | TK | 0.312 | 0.087 | 0.068 | −0.094 |
| | LL | 0.324 | −0.064 | 0.065 | −0.273 |
| | SS | −0.299 | −0.333 | −0.098 | −0.185 |
| | PT | 0.292 | 0.255 | 0.146 | −0.134 |
| | PI | 0.038 | −0.067 | 0.067 | −0.209 |
| | C7–S1 SVA | −0.328 | −0.193 | −0.161 | 0.021 |
| TS | TK | 0.443* | 0.664** | 0.529** | 0.757** |
| | LL | 0.131 | −0.284 | −0.213 | −0.155 |
| | SS | −0.024 | 0.243 | −0.198 | 0.331 |
| | PT | 0.319 | −0.153 | −0.068 | −0.151 |
| | PI | 0.312 | 0.073 | −0.171 | 0.110 |
| | C7–S1 SVA | −0.003 | −0.047 | −0.285 | 0.180 |
| TIA | TK | 0.448* | 0.486** | 0.382* | 0.479** |
| | LL | 0.296 | −0.235 | −0.056 | −0.360* |
| | SS | −0.223 | −0.193 | −0.220 | 0.081 |
| | PT | 0.370* | 0.168 | 0.115 | −0.233 |
| | PI | 0.187 | −0.024 | −0.030 | −0.106 |
| | C7–S1 SVA | −0.233 | −0.225 | −0.338 | 0.153 |

*$P<0.05$; **$P<0.01$.

Abbreviations: C0-1 CA: C0-1 Cobb angle; C1-2 CA: C1-2 Cobb angle; C0-2 CA: C0-2 Cobb angle; C2-7 CA: C2-7 Cobb angle; C2-7 SVA: C2-7 sagittal vertical axis; NT: Neck tilt; TS: T1 slope; TIA: Thoracic inlet angle; TK: Thoracic kyphosis; LL: Lumbar lordosis; SS: Sacral slope; PT: Pelvic tilt; PI: Pelvic incidence; C7-S1 SVA: C7-S1 sagittal vertical axis

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forward to support the head, thereby increasing C2-7 CA and C2-7 SVA, meanwhile, the more kyphotic the thoracic spine, the lower the degree of lordosis in the lumbar spine. Moreover, the retroverted pelvis, which manifests over time, pushes the trunk forward and thus elevates the C7-S1 SVA. This mechanism may explain the upward trend of correlations between cervical and distal spinal alignment with aging.

In addition, the correlations between TIA and TK in the four groups were significant, but no trends were observed with aging. This result revealed that the correlation between TIA and TK was consistent and not influenced by aging. Correspondingly, the correlation between TS and TK showed an increasing trend with aging, which implied that the impact of TK on TS was more pronounced than TIA during the aging process.

Finally, there were some limitations in this study that needs to be taken into consideration. To begin, the sample size of this study was relatively small, and more subjects need to be enrolled in future studies to reach credible conclusions. Second, the patients were enrolled from South China, and hence, our findings may not be generalizable to the global population. Therefore, future studies should enroll participants from different regions and ethnicities.

## 5. Conclusion

The alignments of the subaxial cervical spine are closely correlated with distal spinal sagittal alignment during the aging process in the asymptomatic population. In addition, an increasing trend with aging was observed in the correlations between C2-7 CA and TK, C2-7 SVA and SS, and C2-7 SVA and C7-S1 SVA.

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## Conflicts of Interest

The authors declare no conflicts of interest in this research.

## Ethics Approval and Consent to Participate

This study was approved by Institutional Review Board of The First Affiliated Hospital of Nanchang University, and informed consent was obtained from the patients by the authors.

## Consent for Publication

Consent was given by the patients to publish their data and images in this paper.

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