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The effects of aging on the profile of the cervical spine

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Abstract

The study aims to investigate the effects of aging on the cervical spine.

Outpatients in the study were grouped by age. The cervical spine image in the sagittal plane from participants in the supine position was acquired with MRI. Thoracic inlet angle (TIA), T1 slope (T1S), neck tilt (NT), and cervical angle (CC2–7) were measured.

NT and TIA measured 41.84 ± 9.26 and 64.15 ± 10.72 in participants younger than 40, and 53.02 ± 9.52 and 72.09 ± 10.49 in participants older than 40 ($P < .01$). CC2–7 measured 6.11 ± 9.88 in participants younger than 40, significantly lower compared with participants older than 40, which measured 10.89 ± 11.02 ($P = .003$). TIS did not differ significantly between the 2 groups ($P = .087$). No significant difference was found in all measurements between the female and male participants. Age was moderately correlated with NT ($r = 0.466$, $P < .01$) and TIA ($r = 0.512$, $P < .01$), but weakly correlated with CC2–7 ($r = 0.315$, $P < .01$) and TIS ($r = 0.210$, $P = .005$). TIA showed a strong correlation with NT ($r = 0.748$, $P < .01$) and a moderate correlation with T1S ($r = 0.458$, $P < .01$). Lastly, T1S was strongly correlated with CC2–7 ($r = 0.701$, $P < .01$).

The result showed that NT, CC2–7, and TIA, but not T1S, increased with age.

Abbreviations: CC2–7 = cervical angle, ICC = interclass correlation coefficient, NT = neck tilt, T1S = T1 slope, TIA = thoracic inlet angle.

Keywords: age, cervical spine, correlation, sagittal alignment, sex

1. Introduction

The sagittal curvature of the spine changes during aging, which may be associated with pathological conditions. The changes in the parameters in thoracic and lumbar spines are well defined and documented,[1,2] however, findings from studies of the changes in the cervical spine are inconsistent.

The cervical spine supports the head and has the widest range of motion compared with the rest of the spine. This complex nature of the cervical region makes it susceptible to malalignment.[3] A misaligned cervical spine has been shown to increase the pressure on adjacent segments of the intervertebral disc.[4] The increasing pressure can cause the adjacent cervical spine motion segments to change rapidly, leading to degeneration and diseases in these segments.[5,6] Cervical degenerative disease is one of the most common diseases of the nervous system, and it has become a common health issue in the elderly population,[7] with a neck pain incidence rate of 2.3 per 100 person years.[8] A change in cervical spine curvature has been found to be associated with neck pain.[9] Furthermore, the cervical spine affects the prognosis[10] and influences the subjacent and the overall spine sequence as compensatory changes occur to maintain the horizontal line of sight.[11]

However, as the change in curvature occurs naturally during aging and is often not associated with pathological consequences such as neck pain, it is important to understand the natural progression of the curvature parameter and develop guidelines so as to distinguish changes that are associated with clinical presentations from those that are asymptomatic. This understanding of normal spine physiology can aid in the diagnosis of spinal diseases and guide surgical corrections. Therefore, studies of the sagittal balance parameters of the cervical spine have generated much interest.

Despite a wealth of available studies, a consensus has not been reached regarding the change in cervical spine curvature. Park et al reported that cervical lordosis in the neutral position increased with age, while T1S decreased gradually.[12] In contrast, Boyle et al reported that cervical lordosis flattened during aging.[13] Further confounding the issue, previous studies evaluated images acquired from X-rays, which may not yield accurate measurements of the parameters as it is difficult to gauge the T1 accurately on an upright cervical X-ray because of the anatomical disturbance of the contour density of the shoulder joint, particularly in obese people with thick thoraces.

The present retrospective study aims to investigate the correlation between the age and the sagittal curvature of the cervical spine by using MRI images of patients in the supine position.

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The authors declare that they have no conflict of interest.

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2. Materials and methods

2.1. Patients

We coded and randomly selected outpatients who visited the China–Japan Union Hospital of Jilin University from October 2013 to October 2015 for this study. One hundred eighty patients between 15 and 70 years of age with clear and available cervical MRI images were included in the study.

Patients were excluded from the study if any of the following conditions were present: coronal deformity (Cobb angle is greater than or equal to 10), symptomatic osteoporotic fractures (severe vertebral wedge of grade 3 by semi quantitative grading),[14] orthopedic diseases (e.g., Scheuermann kyphosis, metastatic tumor, infection of adjacent vertebral bodies), history of hip or knee arthroplasty or any other surgery of the lower extremities (e.g., osteotomy, amputation), and a history of prior spine surgery. None of these patients had any neck-related disease.

Written consents were obtained from all outpatients who participated in the study, and the research protocol was approved by the Ethics Committee of China-Japan Union Hospital of Jilin University. As we were not able to identify an appropriate database to deposit the data in this study, we will make the full data set available upon request through inter-personal communications.

2.2. Study design and measurements

The study was a retrospective observational study. We designated 6 groups based on age (less than 20, 21–30, 31–40, 41–50, 51–60, and 61–70) and sought to enroll 30 patients in each group. Each subgroup included 15 female and 15 male outpatients. Next we divided the 180 individuals into 2 groups by age: A, younger than 40 years, and B, older than 40 years.

Cervical spine MRI images of the patients in a supine position (facing upward without a pillow) were acquired with the same imaging system (Siemens 3.0T; Siemens AG, Munich, Germany). Cervical spine curvature parameters, including neck tilt (NT), T1 slope (T1S), thoracic inlet angle (TIA), and cervical angle (CC2–7), were measured on the T2-weighted mid-sagittal slice.

NT was defined as the angle between a vertical line drawn on the tip of the sternum and a line connecting the center of upper endplate of T1 to the tip of the sternum (Fig. 1). T1 is the angle between the upper end plate of the T1 and the horizontal line (Fig. 1). TIA is defined as the angle formed between a perpendicular line of the upper endplate of T1 and a line connecting the center of the upper endplate of the T1 to the sternum tip (Fig. 1). Thus, TIA is the sum of T1S and NT.[14] CC2–7 was measured as the angle between the horizontal line on the lower endplate of C2 and a horizontal line on the lower endplate of C7 (Fig. 1).

Two spine surgeons made the measurements independently. For all measurements, lordosis was considered positive and kyphosis negative.

2.3. Statistical analysis

Statistical analyses were performed with SPSS statistical software (version 19; IBM-SPSS, Inc., Chicago, IL). All data are presented as mean ± standard deviation unless otherwise noted. The linear dependence between age and cervical spine curvature parameters was assessed by calculation of the Pearson product-moment correlation coefficient. The differences between genders (male vs female) in the same age group were analyzed with *t* test. One-way analysis of variance (one-way ANOVA) followed by post hoc Tukey test was used to detect differences among age groups. Interobserver reliability was assessed using intraclass correlation coefficient (ICC). A probability (*P*) value < .05 was considered statistically significant.

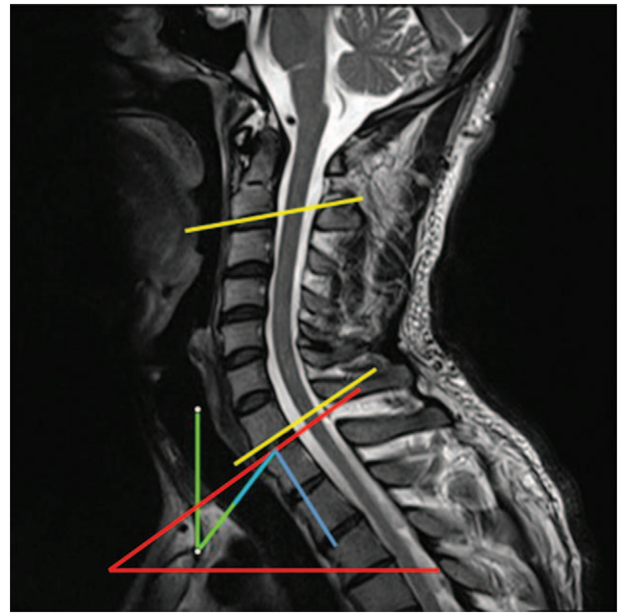

Figure 1. Neck tilt (NT) is defined as the angle between a vertical line drawn on the tip of the sternum and a line connecting the center of upper endplate of T1 to the tip of the sternum. T1 slope (T1S) is the angle between the upper end plate of the T1 and the horizontal line. Thoracic inlet angle (TIA) is defined as the angle formed between a perpendicular line of the upper endplate of T1 and a line connecting the center of the upper endplate of the T1 to the sternum tip. Cervical angle (CC2-7) is measured as the angle between the horizontal line on the lower endplate of C2 and a horizontal line on the lower endplate of C7.

3. Results

3.1. Demographic information of the patients

A total of 180 outpatients were included in the study. The average age was 40.48 years (range 15 to 70 years). Clinical baseline characteristics data such as body mass index were not collected as the participants of the study were not hospitalized. Interobserver reliability was assessed, and the overall interclass correlation coefficient (ICC) was greater than 0.6, which was within the fair to moderate range (interobserver reliability was considered excellent for ICC in the 0.9 to 1.0 range, good for 0.7 to 0.89, fair/moderate for 0.50 to 0.69, low for 0.25 to 0.49, and poor for 0.0 to 0.24.).

3.2. Measurements of the sagittal curvature of the cervical spine

The patients were grouped into 6 groups by age: younger than 20, 20–30, 30–40, 40–50, 50–60, and 60–70 years. Initial analyses revealed that CC2–7, T1S, NT, and TIA increased significantly with age, but no significant differences in these parameters were detected between female and male patients within the same age

Table 1

Female vs male comparison of sagittal alignment among different age groups.

Parameters	Sex	<20 y	21–30 y	31–40 y	41–50 y	51–60 y	60–70 y	P	P (LSD, between age groups)
TIA	Male	63.87±11.00	64.47±10.52	65.43±10.59	71.27±10.16	77.49±8.42	79.07±8.04		***c, d, e, h, l, j, k, L, n
	Female	61.93±9.02	55.86±10.58	62.88±11.05	72.90±11.10	71.29±11.09	75.92±11.23		**c, *d, **e, ***g, h, i, *j, k, **l
	P (male vs female)	.603	*.034	.525	.676	.096	.384		
	Total	62.90±9.93	60.17±11.26	64.15±10.72	72.09±10.49	74.39±10.17	77.50±9.73		***c, d, e, g, h, l, j, k, L
T1S	Male	19.07±9.10	20.97±6.93	21.20±7.41	20.83±6.69	21.62±7.80	24.34±6.28	.555	
	Female	16.38±5.79	20.82±6.78	21.96±8,51	19.10±7.38	23.06±6.57	22.56±6.56	.093	
	P (male vs female)	.343	.22	.333	.376	.135	.666		
	Total	17.72±7.62	20.90±6.74	19.97±6.98	21.58±7.85	22.34±7.12	23.45±6.38	.043	*b, d, **e
NT	Male	44±13.86	40.87±9.15	44.31±8.26	51,47±9.07	55.47±11.68	54.39±7.47		*c, ***d, e, g, h, l, k, L
	Female	43.07±8.17	37.53±4.78	41.24±8.80	54.37±8.61	49.48±9.56	52.94±10.46		**c, *d, **e, ***g, h, i, ***j, **k, ***l
	P (male vs female)	.825	.952	.796	.506	.589	.454		
	Total	43.54±11.19	39.20±7.37	42.78±8.53	52.92±8.81	52.48±10.92	53.66±8.96		***c, d, e, g, h, l, j, k, L
CC2–7	Male	4.87±10.37	7.01±11.15	9.51±9.50	10.10±6.96	12.77±8.66	17.08±12.93	.025	*d, **e, **l, *L
	Female	1.87±7.85	5.91±9.19	7.50±10.80	3.69±10.02	8.20±1253	13.49±10.42	.048	**e, *l, **n
	P (male vs female)	.38	.77	.593	.052	.255	.41		
	Total	3.37±9.16	6.46±10.05	6.90±9.08	8.51±10.05	10.48±10.83	15.29±11.68		**d, e, **l, *L, **n

Thoracic inlet angle (TIA); T1 slope (T1S); Neck tilt (NT); Cervical angle (CC2–7).

[a]less than 20VS21-30; [b]less than 20VS31-40; [c]less than 20VS41-50; [d]less than 20VS51-60, [e]less than 20VS61-70; [f]21-30VS31-40; [g]21-30VS41-50; [h]21-30VS51-60; [l]21-30VS61-70l; [j]31-40VS41-50; [k]31-40VS51-60; [L]31-40VS61-70; [m]41-50VS51-60; [n]41-50VS61-70; [o]51-60VS61-70.

* $P<.05$.

** $P<.01$.

*** $P<.000$.

group. However, while these parameters in patients that were included in the 3 below age 40 groups differed significantly from each of the 3 above age 40 groups, the 3 below age 40 groups did not differ from each other significantly. Similarly, the 3 above age 40 groups did not differ from each other significantly (Table 1). Therefore, we combined the 3 below age 40 groups into the younger than 40 group and the 3 above age 40 groups into the older than 40 group for further analyses.

Further analyses found that NT measured 41.84±9.26 in the younger than 40 group and 53.02±9.52 in the older than 40 group ($P<.01$) (Table 2). T1S measured 20.07±7.53 in the younger than 40 group, and 21.92±6.91 in the older than 40 group ($P=.087$) (Table 2). CC2–7 measured 6.11±9.88 in the younger than 40 group and 10.89±11.02 in the older than 40 group ($P=.003$, Table 2). The reliability of parameter measurements was tested with ICC. The intraobserver reliability was 0.997 for the NT measurements, 0.984 for the T1S measurements, and 0.777 for the Cobb angle. The interobserver reliability was 0.965 for the NT measurements, 0.955 for the T1S measurements, and 0.672 for the Cobb angle.

TIA increased significantly with age. Of note, in the 21 to 30 age group, TIA of male participants was significantly greater than that in female participants ($P=.034$), although no significant difference between the sexes was found in all other sub age groups (Table 1). Further subgroup analyses found TIA measured 62.41±10.66 in the younger than 40 group and 74.66±10.26 in the older than 40 group ($P<.01$, Table 2). The reliability statistics by ICC for TIA measurements were as follows: intraobserver reliability 0.991 and interobserver reliability 0.971.

Table 2

Comparison of sagittal alignment between different age groups.

Variables	TIA	T1S	NT	CC2–7
15–40	62.41±10.66	20.07±7.53	41.84±9.26	6.11±9.88
41–70	74.66±10.26	21.92±6.91	53.02±9.52	10.89±11.02
T	−7.85	−1.72	−7.99	−3.06
Sig	0	0.087	0	0.003

3.3. Correlation between age and sagittal curvature measurements

Next, we computed the Pearson correlation coefficients between age and different sagittal curvature measurements. We found that age was moderately correlated with NT ($r=0.466$, $P<.01$) and TIA ($r=0.512$, $P<.001$), but weakly correlated with CC2–7 ($r=0.315$, $P<.01$) and TIS ($r=0.210$, $P=.005$).

We further analyzed the correlation between sagittal curvature measurements and found that TIA showed a strong correlation with NT ($r=0.748$, $P<.01$) and a moderate correlation with T1S ($r=0.458$, $P<.01$). Furthermore, T1S was strongly correlated with CC2–7 ($r=0.701$, $P<.01$)

4. Discussion

Because of the associated neurological consequences such as pain, numbness, and muscle weakness, cervical degenerative disease is one of the most common diseases of the nervous system and is becoming a common health issue in the elderly population.[7] Therefore, understanding the changes in sagittal curvature of the cervical spine during aging is crucial in differentiating normal and diseased states. To our knowledge, very few previous studies have evaluated the sagittal profile of the cervical spine with magnetic resonance imaging (MRI) stratified by age.[19]

We did not find any significant difference in cervical sagittal alignment between males and females. However, NT, T1S, TIA, and CC2–7 increased with age. Consistent with previous studies, we also found a correlation among sagittal curvature parameters of the cervical spine.[15,16]

A study by Lee et al reported a mean CC2–7 of 9.3 degrees, TIA of 69.5 degrees, TS of 25.7 degrees, and NT of 43.7 degrees.[17] In our study, the average CC2–7 measured 8.50 degrees, TIA measured 68.53 degrees, T1S measured 20.99 degrees, and NT measured 47.43 degrees. The causes of the differences could be because the previous study used PA and lateral view X-ray images, while in this study, participants were in a supine position when images of their cervical spine were acquired. The differences could also be caused by the methods used when measuring CL: Cobb method and Harrison method can yield slightly different results. Moreover, in the supine position, the physiological curvature of the spine is smaller than in the erect position. Thus, our findings are consistent with physiological characteristics.

In this study, we found that the CC2–7, NT, and TIA increased significantly with age, which is inconsistent with previous findings. Boyle showed that CC2–7 decreased with age.[13] Park et al reported that in the neutral position, cervical lordosis increased, whereas T1S decreased with age.[12]

Although observations vary in different studies, it is highly likely that changes in PI, lumbar lordosis, thoracic kyphosis, and cervical lordosis are inter-related.[13] Compared with the whole spine, cervical curvature can be considered as an adaptive segment of the spinal, similar to thoracic kyphosis and lumbar lordosis. Moreover, thoracic kyphosis increases with age regardless of gender.[13] Therefore, for horizontal gaze, CC2–7 and NT would increase. The changes in TIA may also reflect changes in pulmonary function with age as the chest cavity expands.

This study found a significant difference in the sagittal curvature in the cervical spine between the under and over 40 year olds. The change in cervical curvature may be because of age-related decrease in back muscle strength. The back muscles support and are pulled to maintain the normal physiological structure of the spine. As the strength of back muscles decreases with age, the back muscles provide progressively less support to the spine. As a result, the curvature of the spine changes, which may cause some health issues.

Previous studies on the correlation between the changes of sagittal balance parameters and gender were not consistent.[14,18] Our study is consistent with the findings by Gore et al, who reported in their study of a asymptomatic population (200 subjects) that the cervical lordosis increased with age in both men and women.[14] In contrast, Cote et al reported that the changes in cervical lordosis with age differed in men and women. Specifically, in middle age, the cervical curve tends to flatten out in men before it does in women.[18] It is possible that factors other than age and gender, for example, BMI, may affect these parameters; however, the effects of these factors are beyond the scope of this study.

There were several limitations in our study. First, out of consideration of the cost, we did not acquire thoracic and lumbar images from the participants and thus the study lacked data on these parameters. However, the measurements that we acquired from the cervical spine are sufficient to support our findings. Second, due to radiation concerns, we did not obtain X-rays from the patients, and therefore were not able to compare the curvature parameters obtained using MRI measurements with X-ray measurements in the same patients. In addition, the images were taken when the participants were in the supine position, which is not a natural position of the spine. Furthermore, as this study only included a Han Chinese population, whether the trend changes apply in other ethnic groups needs further examination. Lastly, the recorded clinical symptoms of a patient were not correlated with the images of the same patient in our database. Nevertheless, this study of the correlation between age and cervical curvature is unique and valuable as it provides initial information of the change in spine curvature during aging. Further studies will explore these problems more closely.

5. Conclusions

We found a correlation between the increase of TIA, NT, and CC2–7 with age, especially in the population of older than 40 years. However, we did not find significant difference in sagittal alignment parameters of the cervical spine between the genders. Sagittal parameters of the cervical spine are closely correlated with each other.

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