



# Impact of cervical sagittal balance and cervical spine alignment on craniocervical junction motion: an analysis using upright multi-positional MRI

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## Abstract

**Purpose** To evaluate the effect of cervical sagittal alignment on craniocervical junction kinematic.

**Methods** We retrospectively reviewed 359 patients (119 cervical lordosis, 38 cervical sagittal imbalances, 111 cervical straight, and 91 cervical kyphosis) who underwent cervical spine multi-positional magnetic resonance imaging (mMRI). The C2-7 angle, disc degeneration grading and cSVA were analyzed in neutral position. The C3-5 OCI, O-C2 angle, and OCD were analyzed in neutral, flexion, and extension position. The Kruskal–Wallis test was used to detect difference among four groups. The post hoc analysis was performed by Mann–Whitney *U* test.

**Results** The cervical sagittal imbalance, cervical straight, and cervical kyphosis groups had significantly more lordosis angle in C3 and C4 OCI and O-C2 angle than the cervical lordosis group ( $p < 0.0125$ ). Head motion in relation to C2, C3, and C4 (O-C2 angle, C3-4 OCI) in the kyphosis group was significantly greater than in the cervical lordosis group ( $p < 0.0125$ ). The cervical sagittal imbalance group showed significantly increased O-C2 angle than the cervical lordosis group ( $p = 0.008$ ). Regression analysis showed that an increase in O-C2 angle by one unit had a relative risk of 4.3% and 3.5% for a patient to be in the cervical sagittal imbalance and cervical kyphosis groups, respectively.

**Conclusions** Cervical sagittal alignment affected craniocervical junction motion with the head exhibiting greater extension and motion in the cervical sagittal imbalance and cervical kyphosis groups. Motion of the head in relation to C2 can be used to predict the cervical sagittal alignment.

**Keywords** Cervical sagittal alignment · Multi-positional MRI · Craniocervical junction · Head motion

## Introduction

The craniocervical junction consists of the occiput, atlas (C1), and axis (C2) and acts as a transitional zone between the skull and subaxial cervical spine [1]. About one-third of flexion/extension, axial rotation, and lateral flexion motion is attributed to the craniocervical junction [2, 3]. The motion at the craniocervical junction is also known to be affected by motion of the subaxial cervical spine and degeneration

[4]. On the other hand, subaxial cervical spine malalignment might develop when the occiput is fused in inappropriate or non-functional position because of the loss of mobility at the occipitocervical junction [5]. At the same time, craniocervical junction mobility (positional head changes) also influences the cervical spine curvature (C2-7 angle)[6–9].

Cervical spine sagittal alignment might play an important role in subaxial cervical spine motion. Sagittal malalignment can significantly alter the subaxial cervical spine motion [10, 11]. Furthermore, failure to compensate in cervical kyphosis malalignment results in forward head posture relative to the shoulder [12]. High cervical sagittal vertical axis (cSVA) is another cervical sagittal malalignment which alters cervical curvature and head position [13]. The effect of cervical sagittal balance on movement at the craniocervical region is still not clearly understood.

The aim of this study was to evaluate the effect of various types of cervical sagittal alignments on the craniocervical

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junction using multi-positional magnetic resonance imaging (MRI).

## Materials and methods

Patients who received a cervical multi-positional MRI at the MRI center regardless of the presenting symptoms from November 2010 to August 2017 were evaluated. The inclusion criteria included good and clear image quality in neutral, flexion, and extension positions. Patients with de novo coronal and axial deformity, congenital anomaly, cervical trauma, infection, tumor, inflammatory disease of cervical spine, and/or previous cervical spine surgery were excluded from the study.

### Multi-positional magnetic resonance imaging

Multi-positional MRI of the cervical spine was performed using a 0.6 T MRI scanner (Upright Multi-Position, Fornar Corp., New York, NY, USA). The MR unit uses a horizontal orientation of two opposing magnetic poles, allowing patients to be scanned in the weight-bearing position. The image protocol included T1- and T2-weighted sagittal fast spin-echo images that were obtained using a flexible surface coil with the patient seated in upright weight-bearing neutral (0°), flexion (40°), and extension (−20°) positions.

## Occipitocervical parameters

Occipitocervical inclination (OCI) is the angle formed by the line connecting the posterior border of the cervical vertebral body and the McGregor's line (Fig. 1a). The McGregor's line is drawn from the postero-superior aspect of the hard palate and the caudal-most point of the midline occipital curve. We measured OCI at C3, C4, and C5 levels in neutral, flexion, and extension positions.

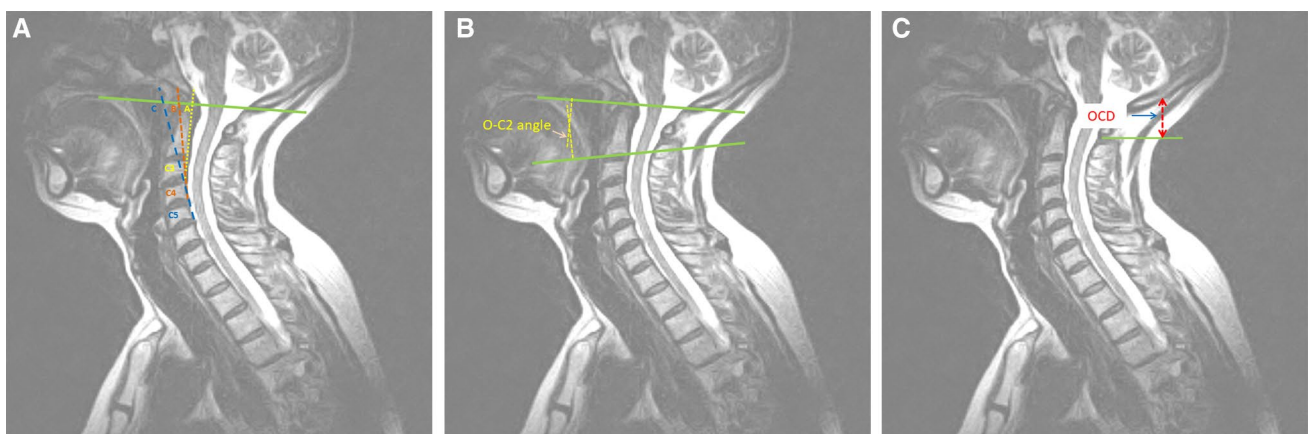
Occiput-C2 angle (O-C2 angle) is the angle formed by the McGregor's line and the line drawn parallel to the inferior endplate of C2 (Fig. 1b).

Occipitocervical distance (OCD) is the shortest distance of the vertical line between the occipital protuberance and the uppermost part of the spinous process of the axis (Fig. 1c).

## Cervical spine sagittal alignment parameters

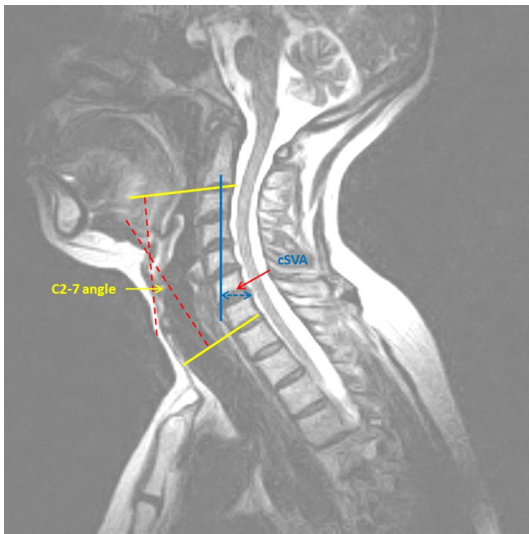
The C2-7 angle (cervical lordotic measurement) was measured as the angle between the tangent lines of the lower endplates of the axis and C7 (Fig. 2). The positive value was the kyphotic alignment, and the negative value was the lordotic alignment.

cSVA C2-C7 is the horizontal distance between the center of C2 and the posterior edge of the C7 upper endplate (Fig. 2). The center of C2 was determined as the point of intersection of crossing diagonals within the C2 vertebral body on the central sagittal MRI picture [14, 15]. Positive value meant that the center of C2 was anterior to the posterior edge of the C7 upper endplate, and negative



**Fig. 1** The occipitocervical parameters measurement on MRI images. **a** The occipitocervical inclination (OCI) at C3-5 cervical spine level. The angle formed by the McGregor's line (line that draw from postero-superior aspect of the hard palate and the most caudal point of midline occipital curve) and the line draw from posterior border of the C3-5 vertebral body. Angle A is C3 OCI, angle B is C4 OCI,

angle C is C5 OCI. **b** The occiput-C2 angle (O-C2) is the angle formed by the McGregor's line and lower endplate of C2 vertebra. **c** The occipitocervical distance (OCD) is the shortest distance of the vertical line between occipital protuberance and the upper most part of spinous process of the axis



**Fig. 2** Cervical parameters. C2-7 angle is the angle formed by the inferior endplate of the C2 vertebra line and the inferior endplate line of C7 vertebra. Cervical sagittal vertical axis (cSVA) is the horizontal distance between the center of C2 and the posterior edge of the C7 upper end plate

value meant that the center of C2 was posterior to the posterior edge of the C7 upper endplate.

Given that different types of cervical sagittal alignment have an impact on the movement of subaxial cervical spine and occipitocervical junction [16], we subdivided patients according to their cervical sagittal alignment into four groups: (a) lordosis, (b) straight, (c) global kyphosis, and (d) cervical sagittal imbalance. C2-7 angle and cSVA were used as a cervical sagittal alignment parameter. C2-7 angle of less than  $-10^\circ$  was classified as the lordosis group, more than  $-10^\circ$  and less  $10^\circ$  as the straight group, and more than  $10^\circ$  as the kyphosis group. Patients with cSVA more than 40 mm, regardless of C2-7 angle, were classified as the cervical sagittal imbalance group [15].

The difference between flexion and extension for O-C2 angle was considered as the angular motion of the head relative to C2 (O-C2 angle F-E), and the difference of OCD between flexion and extension position was considered as linear motion relative to C2 (OCD F-E). The difference between flexion and extension of C3-5 OCI (C3 OCI F-E, C4 OCI F-E, C5 OCI F-E) was considered motion of the occiput relative to C3-5.

### Intervertebral disc degeneration evaluation

T2-weighted mid-sagittal images in the neutral position were used to grade disc degeneration. Disc degeneration was classified into 5 grades according to Suzuki et al. [17].

All multi-positional MRI images were evaluated using mid-sagittal images on eRAD PACS system software (version 7.2.38.0, South Carolina, USA).

### Statistical analysis

All multi-positional MRI images were carefully evaluated independently by three evaluators. The intraclass correlation coefficients (ICCs) were used to analyze intra- and inter-observer reliability. The ICCs value was assessed as follows: 0–0.2 indicated slight agreement, 0.21–0.4 fair agreement, 0.41–0.6 moderate agreement, 0.61–0.8 substantial agreement, and 0.81–1 excellent agreement [18].

All parameters were reported with descriptive statistics, including mean and standard deviation. The Kolmogorov–Smirnov test was used to test the normality of the data, and the nonparametric statistic was used for analysis. The Kruskal–Wallis test was used to analyze the differences in C3-5 OCI, O-C2 angle, OCD, and the mean value of disc degeneration from C2-3 to C6-7 level among 4 cervical alignment groups, with a  $p$  value of  $<0.05$  being statistically significant. The Mann–Whitney  $U$  test was used for post hoc analysis of the significant parameters from the Kruskal–Wallis test with a Bonferroni correction; a  $p$  value of 0.0125 was used as the statistically significant. Multinomial regression analysis was used to analyze the predictive model of the cervical sagittal alignment group (dependent variable) by using angular motion of the head relative to C2-C5 vertebrae (independent variable).

All statistical analyses were performed in SPSS (Version 23.0, International Business Machines, Chicago, IL, USA).

### Results

A total of 359 patients (196 females, mean age of  $44.6 \pm 11.89$  years) were included in this study. 119 patients were classified as lordosis, 38 as cervical sagittal imbalance, 111 as straight, and 91 as kyphosis group.

The ICCs for C3-5 OCI, OCD, C2-7 angle, and cSVA had an excellent agreement in all positions (0.821–0.946), while the O-C2 angle showed substantial agreement in all position (0.611–0.724).

Table 1 shows overall data of age, C2-7 angle, C3-5 OCI, O-C2 angle, and OCN for all groups. In general, all occipitocervical parameters in the cervical imbalance, straight, and kyphosis groups were larger than in the cervical lordosis group in all three positions. In the neutral position, the cervical sagittal imbalance group showed the largest angle in all occipitocervical angular parameters (C3-5 OCI and O-C2 angle), while the cervical lordosis alignment group showed the lowest angular value. In the flexion and extension positions, the cervical sagittal imbalance, straight, and

**Table 1** Patient characteristics—age, C2-7 angle, cSVA, C3-5 OCI, O-C2 angle, and OCD

Parameters	Position	Lordosis ( <i>n</i> = 119)	Cervical sagittal imbalance ( <i>n</i> = 38)	Straight ( <i>n</i> = 111)	Kyphosis ( <i>n</i> = 91)
Age (year)	Neutral	45.76 ± 11.71	45.16 ± 12.14	43.74 ± 11.21	43.89 ± 12.84
C2-7 angle (°)	Neutral	− 18.67 ± 10.75	5.85 ± 13.13	− 0.31 ± 6.56	19.10 ± 5.26
cSVA (mm)	Neutral	20.1 ± 10.07	44.24 ± 3.38	30.58 ± 5.98	35.20 ± 3.26
C3 OCI (°)	Neutral	92.02 ± 7.56	105.48 ± 7.07	101.09 ± 6.73	102.55 ± 6.9
	Flexion	83.73 ± 7.55	92.49 ± 9.48	91.81 ± 5.1	91.71 ± 4.38
	Extension	104.81 ± 12.01	117.68 ± 6.95	115.67 ± 8.98	117.16 ± 8.37
C4 OCI (°)	Neutral	96.07 ± 9.01	106.5 ± 6.27	102.72 ± 6.76	104.3 ± 6.14
	Flexion	84.99 ± 9.96	93.6 ± 9.22	92.18 ± 5.93	92.1 ± 4.19
	Extension	114.05 ± 11.82	123.33 ± 7.63	121.14 ± 11.02	123.3 ± 7.23
C5 OCI (°)	Neutral	103.69 ± 10.2	109.17 ± 11.97	103.92 ± 6.06	105.62 ± 5.15
	Flexion	85.05 ± 10.52	92.2 ± 10.7	90.85 ± 6.61	90.78 ± 4.51
	Extension	123.64 ± 11.63	129.44 ± 10.26	128.18 ± 7.75	129.27 ± 6.87
O-C2 angle (°)	Neutral	23.62 ± 8.9	31.61 ± 7.12	27.79 ± 9.43	29.35 ± 10.04
	Flexion	18.91 ± 9.88	20.44 ± 7.8	13.88 ± 11.53	21.5 ± 10.13
	Extension	34.94 ± 10.75	41.65 ± 6.8	40.36 ± 9.86	41.87 ± 9.75
OCD (mm)	Neutral	16.02 ± 5.04	17.46 ± 4.03	17.69 ± 2.95	17.28 ± 2.63
	Flexion	21.45 ± 6.57	23.4 ± 5.63	21.15 ± 4.59	21.96 ± 3.65
	Extension	8.57 ± 3.44	10.61 ± 2.92	9.65 ± 1.57	9.62 ± 1.31

cSVA cervical sagittal vertical axis, OCI is occipitocervical inclination, O-C2 angle is occiput-C2 angle, OCD is occipitocervical distance

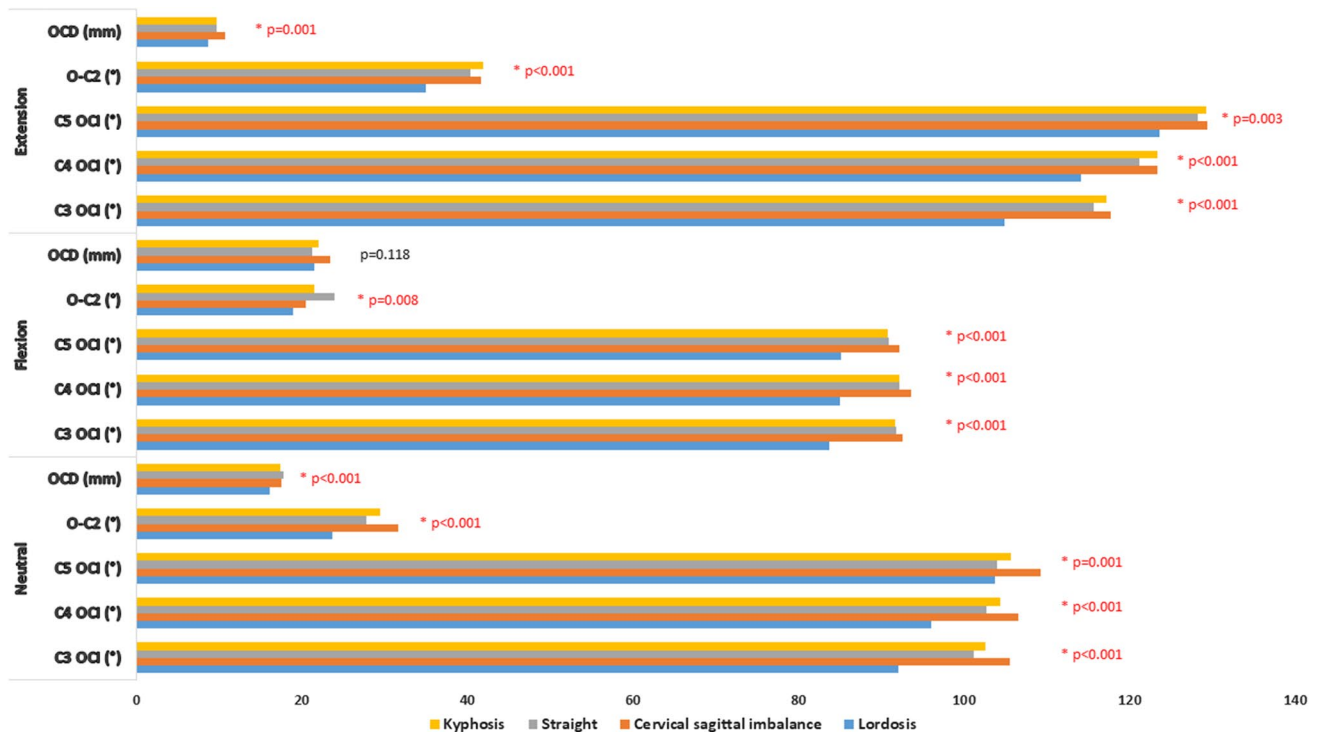
kyphosis alignment groups showed higher angular values in all occipitocervical angular parameters. There were statistically significant differences in all five occipitocervical parameters among the four cervical alignments groups in all three positions, except OCD in the flexion position ( $p$  value < 0.01, Fig. 3).

Post hoc analysis confirmed that the cervical sagittal imbalance group showed significantly larger C3-5 OCI and O-C2 angle than the cervical lordosis group in three positions ( $p$  < 0.01), except in extension (C5 OCI) and flexion (O-C2, Table 2). Only C3-5 OCI in neutral position showed a statistically significant difference between the cervical sagittal imbalance and straight alignment groups ( $p$  < 0.01). There was no statistically significant difference in occipitocervical parameters between the straight and kyphosis groups or the cervical sagittal imbalance and kyphosis groups (Table 2).

The angular motion of head is related to the upper cervical spine (O-C2 angle F-E and C3 OCI F-E), with the cervical sagittal imbalance, straight, and kyphosis groups having higher values than the cervical lordosis group. For OCD F-E, all groups showed nearly similar changes in distance from flexion to extension. In relation to C5 vertebrae (C5 OCI F-E), the angular motion of the head in all groups had nearly similar angles (Table 3, Fig. 4). There were statistically significant differences in O-C2 F-E ( $p$  = 0.004), C3 OCI F-E ( $p$  = 0.003), and C4 OCI F-E ( $p$  = 0.043) among the four cervical alignment groups (Fig. 4). C5 OCI F-E

and OCD F-E failed to demonstrate statistically significant difference among the four groups. Post hoc analysis showed that the cervical sagittal imbalance group had more head motion relative to C2 (O-C2 angle F-E) than the cervical lordosis group, and the cervical kyphosis group showed significantly more head motion relative to C2 (O-C2 F-E,  $p$  value = 0.004), C3 (C3 OCI F-E,  $p$  value = 0.001), and C4 (C4 OCI F-E,  $p$  value = 0.007, Table 4).

Multinomial regression analysis showed a statistically significant difference between the cervical lordosis group and the other three groups in O-C2 angle F-E and C3 OCI F-E (Table 5). The C3 OCI F-E showed a relative risk of 1.039 ( $p$  = 0.034), 1.026 ( $p$  0.044), and 1.041 ( $p$  0.003) of being in the cervical imbalance, straight, and kyphosis groups, respectively, compared to the lordosis group if C3 OCI F-E increased by one unit. The O-C2 angle F-E also showed a relative risk of 1.043 ( $p$  0.015) and 1.035 ( $p$  0.007) of being in the cervical sagittal imbalance and kyphosis group compared to the lordosis group if O-C2 angle F-E increased by one unit (Table 6). An increase in one unit of O-C2 F-E had a higher risk of being in the cervical sagittal imbalance group than the straight group (odds ratio 0.962,  $p$  value = 0.029, cervical sagittal imbalance group being the reference) and a higher risk of being in the cervical kyphosis group than straight group (odd ratio 1.03,  $p$  value = 0.019, Table 6). There was no statistically significant difference in multinomial regression analysis between the cervical sagittal imbalance group and the cervical kyphosis group.



**Fig. 3** Occipitocervical parameters data of all four cervical alignment groups in neutral, flexion, and extension positions. O-C2 angle is occiput-C2 angle, OCI is occipitocervical inclination, OCD is occip-

itocervical distance. \*is statistically significant difference between four cervical alignment group at the  $p$  value of less than 0.05 by Kruskal–Wallis test

The cervical sagittal imbalance group had the least disc degeneration, followed by the lordosis and straight groups. The cervical kyphosis group had the highest level of disc degeneration. Kruskal–Wallis analysis showed a statistically significant difference in disc degeneration among the four groups ( $p < 0.001$ ). Post hoc analysis showed that the cervical kyphosis group had a significantly higher level of disc degeneration than the straight ( $p = 0.006$ ), cervical sagittal imbalance ( $p < 0.001$ ), and cervical lordosis groups ( $p < 0.001$ ) (Fig. 5).

## Discussion

Our results showed differences in occipitocervical parameters, especially angular parameters, among four types of cervical sagittal alignment. The cervical lordosis alignment group had the lowest value for occipitocervical angular parameters. Based on the results from this study, the angular motion of the head in relation to the upper cervical spine can significantly predict cervical sagittal alignment.

Several studies demonstrated that the cervical sagittal alignment affects subaxial cervical spine segmental motion [11, 19]. For the craniocervical junction, Hayashi et al. found that the motion at the craniocervical junction increased if the subaxial cervical intervertebral had disc degeneration and

decreased motion, but the author did not evaluate the effect of cervical sagittal alignment [4]. We hypothesized that the cervical sagittal alignment might have an effect on changes in motion at the craniocervical junction and altered head motion relative to the cervical vertebrae.

In general, our results showed that the cervical sagittal imbalance, straight, and kyphosis groups had higher value of almost occipitocervical parameters than the cervical lordosis group. These results can be explained by the hypothesis that the head usually maintains its functional position in order to maintain horizontal gaze and to keep the vestibular organ in the proper position [20, 21]. In order to maintain functional position of the head, the cervical spine sagittal alignment and the cervical paravertebral muscles, especially at the occiput, are two important factors [13, 21]. For the cervical sagittal imbalance group, although some patients had cervical lordosis alignment, the functional head position compensation mechanism was created by the forward bending of the head from sagittal imbalanced alignment.

Head angular motion relative to the upper cervical spine, especially C2, was higher in the cervical kyphosis alignment and cervical sagittal imbalance group than in the cervical lordosis group, whereas the linear motion (OCD) and head motion relative to C5 did not show a difference among the four alignment groups. We hypothesized that with kyphotic alignment, the subaxial cervical

**Table 2** Post hoc analysis by Mann–Whitney *U* test between 4 groups of cervical sagittal alignment

Alignment group comparison	C3 OCI			C4 OCI			C5 OCI			O-C2			OCD			
	N	F	E	N	F	E	N	F	E	N	F	E	N	F	E	
Lordosis vs Cervical sagittal imbalance	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.009*	0.001*	0.013	<0.001*	0.379	<0.001*	0.045	0.213	<0.001*
Lordosis vs Straight	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.747	<0.001*	0.007*	0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.278	<0.001*
Lordosis vs kyphosis	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.043	<0.001*	0.001*	<0.001*	<0.001*	0.047	<0.001*	0.003*	0.851	<0.001*
Cervical sagittal imbalance vs Straight	0.002*	0.6	0.195	0.006*	0.732	0.418	0.004*	0.967	0.409	0.028	0.080	0.483	0.769	0.016	0.173	
Cervical sagittal imbalance vs kyphosis	0.057	0.523	0.840	0.098	0.605	0.743	0.026	0.881	0.926	0.356	0.411	0.510	0.679	0.130	0.173	
Straight vs kyphosis	0.092	0.712	0.131	0.069	0.591	0.138	0.013	0.635	0.215	0.194	0.225	0.158	0.253	0.131	0.694	

*OCI* occipitocervical inclination, *O-C2 angle* occiput-C2 angle, *OCD* is occipitocervical distance  
 \*Statistically significant difference at *p* value of less than 0.0125 by Mann–Whitney *U* test

spine had more degeneration which caused decreases in angular mobility at the subaxial cervical spine and led to increased mobility at the craniocervical junction [4, 10, 11, 22]. Cervical sagittal imbalance had the least disc degeneration, which did not affect subaxial angular mobility. We hypothesized that the functional head position compensation mechanism may play a role in increasing head motion because head motion increased only in relation to C2 vertebra (O-C2 angle F–E). Regarding the compensatory mechanism of the head and motion, we hypothesized that the main compensation mechanism occurred predominantly at the upper cervical spine (C2 to C4), according to our results. Among the four different alignment groups, head motion relative to C5 vertebrae was similar and did not show any statistically significant difference. We think that the compensatory mechanism may end at the level of C5 vertebra.

Furthermore, our study also demonstrated the prediction model of four cervical sagittal alignments based on the occipitocervical angular and linear parameters. O-C2 angle F–E and C3 OCI F–E are the parameters that can predict cervical sagittal alignment. When cervical lordosis is the reference, if O-C2 F–E increases by one unit, there will be 4.3%, 0.3%, and 3.5% more risk to be in the cervical sagittal imbalance, straight, and cervical kyphosis groups, respectively. A similar trend was observed for C3 OCI F–E. If C3 OCI F–E increased by one degree, the risk of being in the cervical sagittal imbalance, straight, and cervical kyphosis groups was 3.9%, 2.6%, and 4.1%, respectively. When cervical sagittal imbalance was set as a reference, if O-C2 angle increases by one degree, the chance of being in cervical straight group was 3.8% less. When the cervical straight group was set as a reference, if O-C2 angle increases by one unit, the chance of being cervical kyphosis increased by 3%.

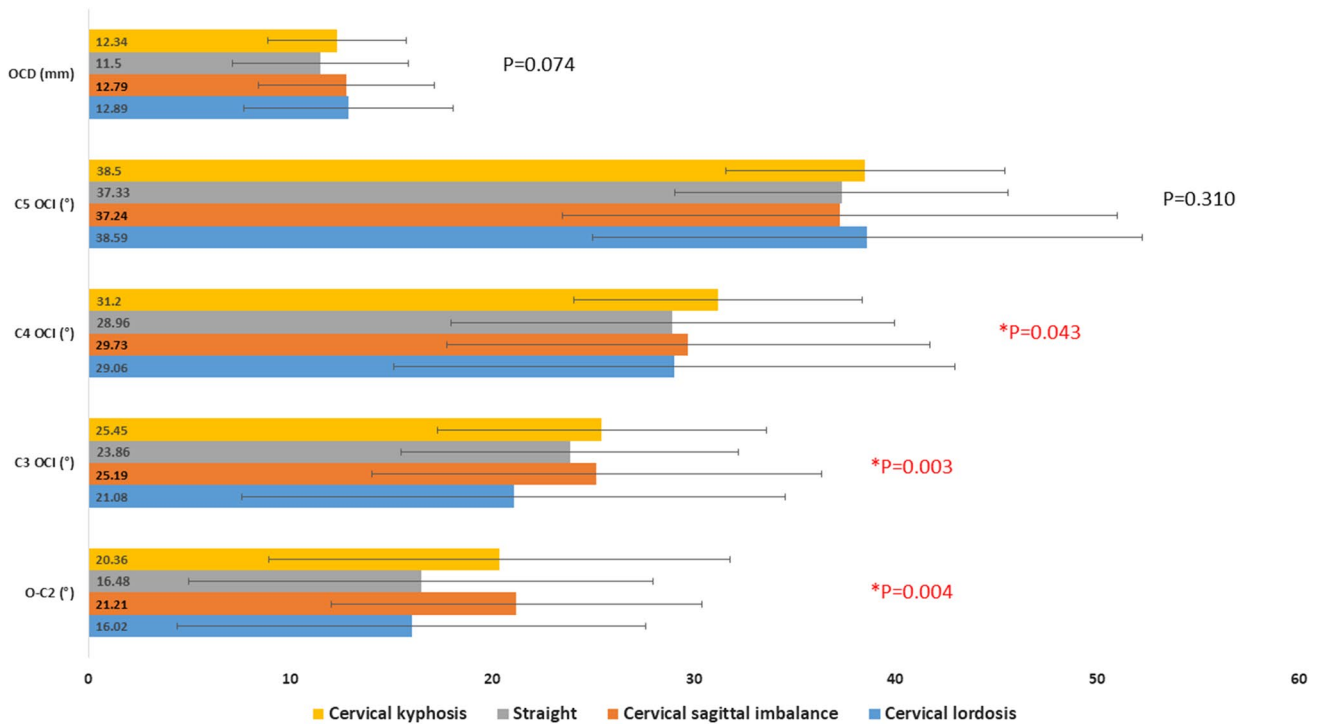
This study is, to the best of our knowledge, the first study that demonstrated the change of motion at the craniocervical junction among difference types of cervical sagittal alignment. Our study results can help surgeons better understand the compensatory mechanism at the craniocervical junction in various types of cervical sagittal alignment. For patients with cervical spine deformities, normal sagittal alignment should be restored in order to reduce or eliminate this compensatory mechanism. Because the functional head compensatory mechanism is a result of active neck extension muscle activity, continuation of this mechanism might lead to increased neck symptoms and rapid degeneration of the cervical spine.

This study also had several limitations, including (a) lack of longitudinal data due to the cross-sectional nature of the study, (b) lack of clinical information of patients in each group, and (c) imaging modality limitations that did not allow us to evaluate the upper cervical spine paravertebral muscles.

**Table 3** Head motion from flexion to extension in relation to C2-5 cervical vertebrae

	C3 OCI F-E (°)	C4 OCI F-E (°)	C5 OCI F-E (°)	O-C2 angle F-E (°)	OCD F-E (mm)
Cervical lordosis	21.08 ± 13.46	29.06 ± 13.9	38.59 ± 13.61	16.02 ± 11.62	12.89 ± 5.17
Cervical sagittal imbalance	25.19 ± 11.14	29.73 ± 11.98	37.24 ± 13.75	21.21 ± 9.19	12.79 ± 4.35
Straight	23.86 ± 8.35	28.96 ± 10.99	37.33 ± 8.25	16.48 ± 11.5	11.5 ± 4.37
Cervical kyphosis	25.45 ± 8.13	31.2 ± 7.13	38.5 ± 6.93	20.36 ± 11.42	12.34 ± 3.44

OCI occipitocervical inclination, O-C2 angle occiput-C2 angle, OCD occipitocervical distance, F-E angle differences from flexion to extension



**Fig. 4** Head positional changes from flexion to extension in relation to C2 to C5 cervical vertebrae of four cervical sagittal alignment groups. O-C2 angle is occiput-C2 angle, OCI is occipitocervical incli-

nation, OCD is occipitocervical distance. \*is statistically significant difference between four cervical alignment group at the *p* value of less than 0.05 by Kruskal–Wallis test

**Table 4** Post hoc analysis of the head motion in relation to cervical spine vertebrae

	C3 OCI F-E	C4 OCI F-E	O-C2 angle F-E
Lordosis vs sagittal imbalance	0.063	0.471	0.008*
Lordosis vs straight	0.029	0.361	0.588
Lordosis vs kyphosis	0.001*	0.007*	0.004*
Sagittal imbalance vs straight	0.633	0.752	0.026
Sagittal imbalance vs kyphosis	0.438	0.287	0.762
Straight vs kyphosis	0.049	0.026	0.019

OCI occipitocervical inclination, O-C2 angle occiput-C2 angle, F-E angle differences from flexion to extension

\*Statistically significant difference at *p* value of less than 0.0125 by Mann–Whitney *U* test

**Table 5** The overall multinomial regression analysis between cervical alignment groups and motion of head from flexion to extension in relation to C2-5 cervical vertebrae

Reference group	Comparison group (s)	Overall statistically significant ( <i>p</i> value)				
		C3 OCI F-E	C4 OCI F-E	C5 OCI F-E	O-C2 angle F-E	OCD F-E
Lordosis	Sagittal imbalance straight kyphosis	0.015*	0.483	0.756	0.005*	0.102
Sagittal imbalance	Straight kyphosis	0.4	0.260	0.601	0.016*	0.146
Straight	Kyphosis	0.171	0.085	0.28	0.017*	0.132

OCI occipitocervical inclination, O-C2 angle occiput-C2 angle, F-E angle differences from flexion to extension

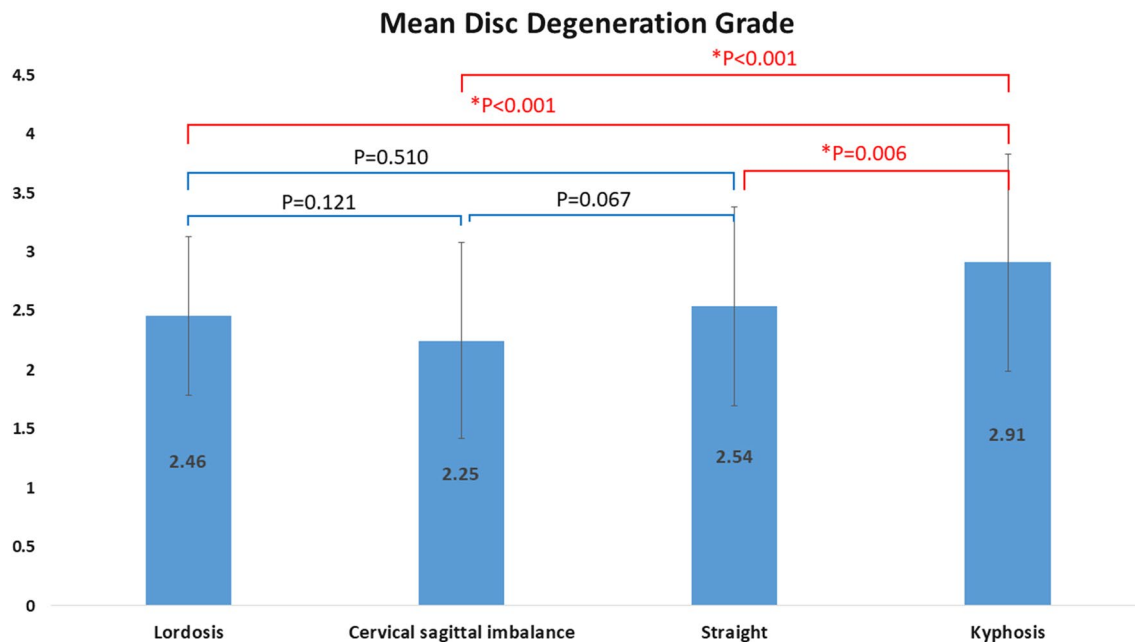
\*is statistically significant difference at *p* value of less than 0.05

**Table 6** The multinomial regression analysis of the significant parameters in each comparison group

Reference group	Parameters	Comparison group (s)					
		Sagittal imbalance		Straight		Kyphosis	
		Odd ratio(95% CI)	<i>p</i> value	Odd ratio (95% CI)	<i>p</i> value	Odd ratio (95% CI)	<i>p</i> value
Lordosis	C3 OCI F-E	1.039 (1.003–1.076)	0.034*	1.026 (1.001–1.053)	0.044*	1.041 (1.013–1.053)	0.003*
	O-C2 angle F-E	1.043 (1.008–1.079)	0.015*	1.004 (0.981–1.027)	0.760	1.035 (1.01–1.062)	0.007*
Sagittal imbalance	O-C2 angle F-E			0.962 (0.929–0.996)	0.029*	0.993 (0.958–1.029)	0.683
Straight	O-C2 angle F-E					1.03 (1.005–1.057)	0.019*

OCI is occipitocervical inclination, O-C2 angle occiput-C2 angle, F-E angle differences from flexion to extension

\*Statistically significant difference at *p* value of less than 0.05



**Fig. 5** The mean value of disc degeneration in four group of cervical sagittal alignment. \*is statistically significant difference between four cervical alignment group at the *p* value of less than 0.0125 by Mann—Whitney *U* test



In conclusion, cervical sagittal alignment affected craniocervical junction movement, having an impact on the angular parameters. In the sagittal imbalance and kyphosis alignment patients, head was more extended in relation to the cervical spine. The change in motion at the craniocervical junction (O-C2 F-E and C3 OCI) can be used to predict cervical sagittal alignment.

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## Compliance with ethical standards

**Conflict of interest** There are not conflicts of interest, and disclosures outside of submitted work were provided in the Conflict of Interest forms. Disclosures outside of submitted work: JCW- Royalties – Biomet, Seaspine, Amedica, DePuy Synthes; Investments/Options – Bone Biologics, Pearldiver, Electrocore, Surgitech; Board of Directors – North American Spine Society, AO Foundation (20,000 honorariums for board position, plus travel for board meetings), Cervical Spine Research Society; Editorial Boards – Spine, The Spine Journal, Clinical Spine Surgery, Global Spine Journal; Fellowship Funding (paid directly to institution): AO Foundation; ZB- consultancy: Cerapedics, The Scripps Research Institute, Xenco Medical (past), AO Spine (past); Research Support: SeaSpine (past, paid to the institution), Next Science (paid directly to institution), Motion Metrix (paid directly to institution); North American Spine Society: committee member; Lumbar Spine Society: Co-chair Research committee, AOSpine Knowledge Forum Degenerative; Associate member; AOSNA Research committee- committee member.

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