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ORIGINAL ARTICLE

Comparison of cervical sagittal parameters among patients with neck pain and healthy controls: a comparative cross-sectional study

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Abstract

Introduction Previous studies have shown poor health-related outcomes among patients with spinal sagittal malalignment of the thoracolumbar or spinopelvic region, and less interest has been paid to the relationship between cervical sagittal balance and functional outcome of the patients. This study aims to compare the cervical sagittal parameters between patients with non-specific neck pain and asymptomatic controls.

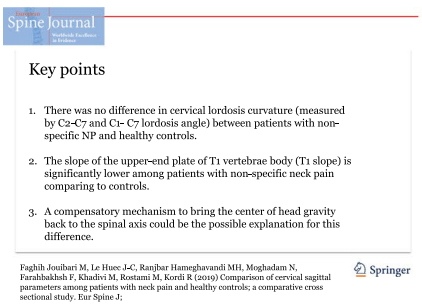
Method Twenty-five patients (21 females/4 males) with non-specific neck pain and 25 age-, sex- and BMI-matched controls (18 females/7 males) participated in the study. Using a standard lateral cervical radiography, the Cobb angle between occiput–C2, C1–C2, C1–C7 and C2–C7 as well as the thoracic inlet angle (TIA) and C7 and T1 slope angles was measured. Also the spine cranial angle (SCA) and the C2–SVA (sacral vertical axis) and C1–SVA were measured. The primary outcome measure of the study was comparison of the sagittal balance variables between the patients and the healthy controls. Secondary outcome measures were correlation between pain intensity of the patients in neck pain group and their demographic and radiographic findings. Data analysis was performed using independent sample *T* test and Pearson's correlation for primary and secondary outcome measurements, respectively.

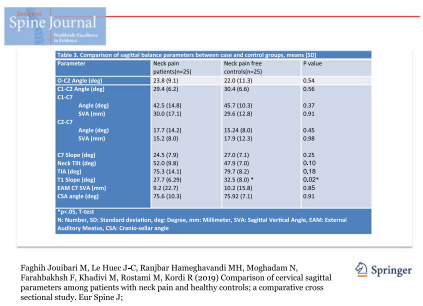
Results There was no difference in cervical lordosis curvature (measured by C2–C7 and C1–C7 lordosis angle) between patients with non-specific NP and healthy controls (P value = 0.45 and 0.37, respectively). We found that T1 slope angle was significantly (P value = 0.02) lower in patients with neck pain.

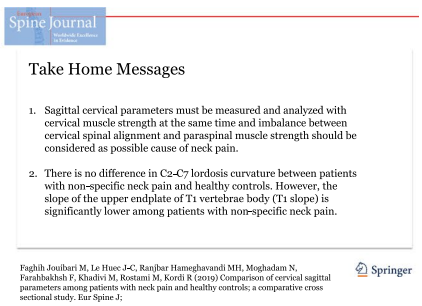
Conclusion Our findings showed that the slope of the upper endplate of T1 vertebrae body (T1 slope) is significantly lower among patients with non-specific neck pain compared to controls. A compensatory mechanism to bring the center of head gravity back to the spinal axis might be the possible explanation for this difference.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.







Keywords Sagittal balance · Non-specific neck pain · Malalignment

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Introduction

In recent years, neck pain (NP) has become a common musculoskeletal problem. One-year prevalence of NP has been reported between 12.1 and 71.5% in general population [1], and it ranks fourth in years lived with disability (YLDs) in the global burden of disease [2], but still little is known about who would develop NP [3]. To recognize the at-risk individuals to develop NP, identification of predisposing factors seems quite necessary.

There is growing evidence that shows poor health-related outcomes among patients with spinal sagittal malalignment [4, 5]. The disability is often related to compensatory spinal and pelvic posture changes, higher fatigue rates and thereby pain [4, 6]. However, most of the previous studies have focused on the thoracolumbar or spinopelvic region and less interest is paid to the relationship between cervical sagittal balance and functional outcome of the patients.

In 2001, Gore showed that degenerative radiographic findings at C6/C7 might be considered a risk factor for development of neck pain in the future [7]. Also, Moon et al. [8] run a cross-sectional study among air force pilots and found a lower C2–C7 Cobb angle among subjects with neck pain compared to controls. Iyer et al. [9] further highlighted the importance of the segmental cervical alignment parameters and found that increasing cervical lordosis (C2–C7 angle) and T1 slope are associated with lower level of NDI in preoperative measurements of patients who were candidate of cervical surgery due to myelopathy, radiculopathy or canal stenosis. On the other hand, considering both segmental and global sagittal balance measurements, Grob et al. [10] found no significant difference between the subjects with and without neck pain. This finding was further supported by other studies [11–13]. In 2014, Lee et al. [14] using magnetic resonance imaging (MRI) investigated the possible role of the cervicothoracic junction and thoracic inlet anatomic features in development of chronic neck pain. They also found no difference between the measured sagittal parameters between patients with neck pain and asymptomatic controls. However, they identified depth of the T1-manubrium arch and thoracic inlet inclination as predictors for neck pain.

During a degenerative process, cervical spine dictates compensatory changes required to keep horizontal gaze and consequently alters cervical sagittal alignment, subsequently resulting in further acceleration of degenerative changes in the cervical spine. This vicious cycle finally influences muscles, ligaments, bony structures and neural elements and can trigger NP in the patients [15, 16]. The aim of this study is to compare the cervical sagittal parameters between patients with non-specific neck pain and asymptomatic controls.

Methods

Participants

A group of 25 patients with non-specific NP [17] were selected from patients referred to our clinic (NP group), and 25 age-, sex- and BMI-matched volunteers who had no history of NP at least for 1 year before their enrollment agreed to take part as the control group in this study (Table 1). Subjects who were older than 18 years with no prior spinal surgery and no clinical spinal deformity were included in the study. The exclusion criteria for both groups were as follows: a history of spine surgery or trauma to cervical spine; being under medical treatment for NP and/or taking oral nonsteroidal anti-inflammatory drugs (NSAIDs); systematic diseases involving the cervical spine (e.g., rheumatoid arthritis); depression; pregnancy; any condition that requires prescription of muscle relaxant agents (e.g., seizure); and history of cardiovascular, metabolic and pulmonary diseases. We informed all participants about the purpose of the study, its course and methods of data collection. They were ensured that their anonymity is protected. All of the enrolled subjects signed a written informed consent. The study protocol was approved by the ethical committee of university.

Basic evaluation

All recruited subjects of the study were invited to our department for performing study measurements. General characteristics of each participant, including age, sex, height and weight, were recorded before the radiographic evaluation. Patients of the NP group were asked to score the intensity of pain using a 100-mm visual analog scale (VAS), on which 0 represents no pain and 100 indicates the most intense pain ever experienced.

Table 1 Descriptive characteristics of the participants of the study, means (SD) or *N* (%)

Variable	Neck pain patients ($n=25$)	Neck pain-free controls ($n=25$)	*P* value*
Age (years)	42.6 (11.6)	44.7 (12.1)	0.54
Female/male	21/4	18/7	0.49
Height (cm)	165.4 (7.8)	168.6 (7.8)	0.15
Weight (kg)	73.8 (12.9)	75.5 (15.2)	0.67
BMI (kg/m^2)	26.9 (4.1)	26.4 (4.7)	0.71

N number, *SD* standard deviation

*T test or Fisher's exact test as indicated, significance level at $P<0.05$

Radiographic measures

The standing lateral cervical spine radiographs were obtained from all the subjects of the study using a picture archiving and communication system (PACS). The imaging studies were performed in the clavicle position which is previously described by William et al. [18]. According to this protocol, patients were asked to stand straight up, looking straight ahead, with elbows in full flexion and shoulders in passive flexion while hands remained in a relaxed fist. The X-ray beam was centered at the level of C4 according to the surface anatomic landmark [19]. Sagittal alignment measures, shown in Fig. 1, were calculated for each subject. Definition of the measured variables is given in Table 2 [20–24]. The same blinded radiologic technologists performed all diagnostic imaging examinations, and all the subjects were positioned by the same researcher. Radiographic measurements were all performed by one of the authors who was blind of the grouping of subjects.

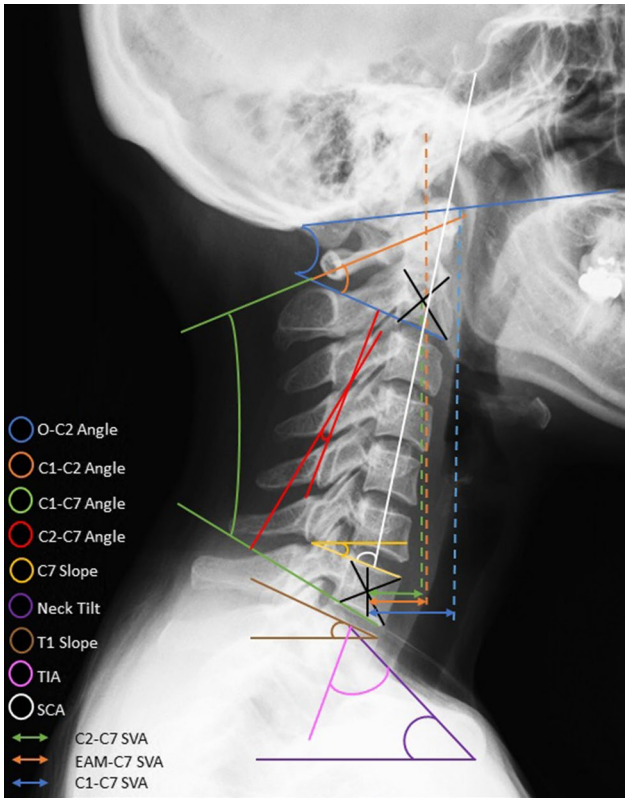

Fig. 1 Measured variables of the study in the lateral cervical X-ray

Outcome measurement and statistical analysis

Data analysis was performed with SPSS 16 (SPSS Inc, Chicago, IL). Data normality was assessed using one-sample Kolmogorov–Smirnov test. The primary outcome measure of the study was comparison of the sagittal balance variables between the patients and the healthy controls. This was done using independent two-sample *T* test. We determined the level of significance at $P < 0.05$. We also computed the post hoc power of the study using G*Power software [25] (Erdfelder, Faul and Buchner, 1996). Secondary outcome measures were correlation between pain intensity of the patients in neck pain group and their demographic findings. This analysis was done using Pearson's correlation test.

Table 2 Definition of sagittal alignment measures which were used in this study

O–C2 angle	The angle between the McGregor line and lower endplate of the C2 vertebra
C1–C2 angle	The angle between a line connecting the anterior tubercle to the posterior margin of the C1 spinous process and the inferior endplate of C2
C1–C7 angle	The angle between a line connecting the anterior tubercle to the posterior margin of the C1 spinous process and the horizontal line of the C7 lower endplate
C1–C7 SVA	Distance between C1 vertical line and C7 vertical line
C2–C7 angle	The angle between the horizontal line of the C2 lower endplate and the horizontal line of the C7 lower endplate
C2–C7 SVA	Distance between C2 vertical line and C7 vertical line
C7 slope	The angle between the superior endplate of C7 and the horizontal line
Neck tilt	The angle formed by a vertical line of sternum tip and the line drawn in the center of the upper endplate of the sternum connecting the center of the T1 upper endplate
TIA	Angle between a line perpendicular to the superior endplate of T1 and a line connecting the upper endplate of T1 to the sternum
T1 slope	The angle between a horizontal line and superior endplate of T1 in standing lateral radiograph
EAM–C7 SVA	The distance between the vertical line from anterior of the external auditory canal and the vertical line passing the center of C7
SCA angle	The angle between a line from the sella turcica center and C7 endplate and the C7 plateau line

O–C2 occiput–C2, *McGregor line* line connecting posterior edge of the hard palate to the opisthion, *TIA* thoracic inlet angle, *SVA* sagittal vertical axis, *EAM* external auditory meatus, *SCA* spine cranial angle

Results

Comparing the cervical sagittal indices between the groups, we found that T1 slope angle was significantly (*P* value = 0.02) lower in patients with neck pain (Table 3). The other cervical sagittal parameters were not significantly different between the groups. We also computed the post hoc achieved power of the study with a type I error of 0.05 for comparison of T1 slope between two groups. According to this analysis, the power of study was 0.75 which could be considered acceptable. The mean (SD) of pain intensity of patients with neck pain was 74 (14) according to VAS. There was no significant correlation between the pain intensity (measured by VAS) and demographic features of patients in NP group such as weight ($P = 0.462$), height ($P = 0.777$) and age ($P = 0.986$).

Discussion

The results of this study showed that there was no difference in C2–C7 lordosis curvature (measured by C2–C7 lordosis angle) between patients with non-specific NP and healthy controls. These findings are in line with the study by Grob et al. [10] which showed no difference in cervical spinal curvature including global and segmental lordosis between subjects with NP and asymptomatic controls. Gay [26] in a systematic review reported that there is little evidence to support the contention that altered cervical curvatures are of prognostic significance in patients with neck pain. Other studies also confirmed that there is no association between neck pain and cervical spinal curvature alteration [27–29].

According to our findings, T1 slope was significantly lower in patients with neck pain while C2–C7 SVA and C1–C7 SVA were similar in both groups. The importance of morphologic features of T1 vertebral body in the upright physiologic posture and the horizontal gaze of the subjects has been reported previously [30]. This might be related to the effect of the shape and orientation of T1 vertebral body on the amount of lordosis and cervical tilt required to keep the sagittal balance of the cervical spine [20]. Diminishing T1 slope to bring axis of head gravity closer to the base of cervical spine (T1) could be explained as a compensatory change in sagittal parameters of cervical spine to prevent further contracture of paraspinal muscles and decrease the muscle work during upright position [31]. This might suggest that compensatory activities in patients with NP pull back the axis of head gravity and lead to lower T1 slope angle in these patients.

Our results showed that the global cervical balance was maintained in both groups, as there was no significant difference in C2–C7 SVA and SCA, but in patients with neck pain, it was at the expense of diminished T1 slope. Also, occiput–C2 angle and C2–C7 angle which have been previously shown to inversely correlate [9] had no clinically significant relation with T1 slope ($r = 0.14$ and $r = 0.30$, respectively).

Cervical sagittal parameters merely play as some facets of a multifactorial matrix in development of NP. Theoretically, cervical muscle strength has an indispensable role in the development of NP as increased SVA can be adopted by hypertrophy of cervical extensor muscles. Panjabi et al. [32] estimated that the neck musculature contributes about 80% to the mechanical stability of the cervical spine, and the osseoligamentous compartment contributes the remaining 20%. The posterior cervical muscles help stabilize the head, keep the alignment of the cervical spine and play key role in neck motion [33]. So hypertrophied paraspinal muscles may make sagittal spinal alterations remain subclinical. We think that sagittal cervical parameters must be measured and analyzed with cervical muscle strength at the same time and imbalance between cervical spinal alignment and paraspinal muscle strength should be considered as possible cause of neck pain.

Limitations

In this study, the cervical sagittal balance was measured using a lateral cervical X-ray and the global spinal sagittal measurements were not determined; therefore, the reciprocal

Table 3 Comparison of sagittal balance parameters between case and control groups, means (SD)

Parameter	Neck pain patients ($n = 25$)	Neck pain-free controls ($n = 25$)	*P* value
O–C2 angle (deg)	23.8 (9.1)	22.0 (11.3)	0.54
C1–C2 angle (deg)	29.4 (6.2)	30.4 (6.6)	0.56
C1–C7			
Angle (deg)	42.5 (14.8)	45.7 (10.3)	0.37
SVA (mm)	30.0 (17.1)	29.6 (12.8)	0.91
C2–C7			
Angle (deg)	17.7 (14.2)	15.24 (8.0)	0.45
SVA (mm)	15.2 (8.0)	17.9 (12.3)	0.98
C7 slope (deg)	24.5 (7.9)	27.0 (7.1)	0.25
Neck tilt (deg)	52.0 (9.8)	47.9 (7.0)	0.10
TIA (deg)	75.3 (14.1)	79.7 (8.2)	0.18
T1 slope (deg)	27.7 (6.29)	32.5 (8.0)*	0.02*
EAM–C7 SVA (mm)	9.2 (22.7)	10.2 (15.8)	0.85
CSA angle (deg)	75.6 (10.3)	75.92 (7.1)	0.91

N number, *SD* standard deviation, *deg* degree, *mm* millimeter, *SVA* sagittal vertical angle, *EAM* external auditory meatus, *CSA* craniosellar angle

*$P < 0.05$, *T* test

influence of other spinal regions including lumbar and thoracic spine was not identified. As another limitation, the subjects of the NP and control groups were matched for age, BMI and sex; however, it is reported that other factors such as smoking and level of physical activity have major roles in the incidence of chronic musculoskeletal pains [34]. Therefore, it is suggested to consider these factors when matching subjects for future studies. In this study, subjects with history of no neck pain from at least 1 year before the enrollment were considered as control group. However, it could be better to define control subjects as those with no history of neck pain at all, to prevent any previous compensation mechanism as confounding factor.

Conclusion

This study shows that there is no difference in C2–C7 lordosis curvature between patients with non-specific neck pain and healthy controls. However, the slope of the upper endplate of T1 vertebrae body (T1 slope) is significantly lower among patients with non-specific neck pain. A compensatory mechanism to bring the center of head gravity back to the spinal axis might be the possible explanation for this difference.

Compliance with ethical standards

Conflict of interest This work was supported by Tehran University of Medical Sciences.

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