An investigation of sagittal thoracic spinal curvature and mobility in subjects with and without chronic neck pain: cut-off points and pain relationship

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Background/aim: Thoracic spine insufficiency is a subject of interest in neck problems. The aim was to investigate thoracic spinal curvature and mobility in subjects with and without chronic neck pain (CNP), cut-off points, and the relationship with pain.

Materials and methods: Fifty-six patients with CNP (CNP group) and 53 healthy volunteers (control group) were included. Neck pain intensity of the patients was assessed by visual analogue scale and sagittal thoracic curvature and mobility of all participants were assessed by Spinal Mouse (Idiag, Fehraltorf, Switzerland).

Results: Thoracic curvature was higher (P < 0.001) and mobility lower in the CNP group in comparison to the control group (P = 0.013). There was a positive correlation between pain intensity and thoracic curvature (r = 0.391, P < 0.001), while there was a negative correlation between pain intensity and thoracic mobility (r = −0.260, P = 0.006). For detecting neck pain, it was observed that the cut-off points for thoracic curvature and mobility were 45.5° and 30.0°, respectively.

Conclusions: An increase in thoracic curvature of more than 45° and a decrease in mobility more than 30° may be critical for CNP patients.

Key words: Neck pain, thoracic spine, kyphosis, mobility, cut-off point

1. Introduction
Chronic neck pain (CNP) is an important health problem in the modern world (1). Approximately 14%–71% of adults experience CNP at some point in their lifetime and a 1-year prevalence rate ranging between 16% and 75% was shown in adults (2). It might cause personal suffering, disability, and impaired quality of life and work in general, resulting in a great socio-economic burden on patients (3,4).

The causes of CNP have not been completely elucidated. However, postural changes due to muscle imbalance were pointed out as a cause or a consequence of musculoskeletal pain and cervical dysfunction (5). Upper-crossed syndrome (UCS), described by Janda (5), is the best-known example of posture-related muscle pain. In his hypothesis, crossed imbalance of muscles around the shoulder girdle was thought to create joint dysfunction and result in pain. Specific postural changes related to UCS were forward head posture, increased cervical lordosis and thoracic kyphosis, elevated and protracted shoulders, and rotation, abduction, and winging of the scapulae (5). In previous studies, authors have shown that patients with CNP had postural disorders similar to UCS (6–8).

The thoracic spine can be considered a hidden source for preventing and improving neck pain because of the biomechanical interrelationship between the cervical and thoracic spine. Any changes in the cervical spine might be related to postural changes in the thoracic spine. Previous studies demonstrated that an increase in thoracic curvature may be associated with pain and dysfunction of both the spine and shoulders (9,10). Moreover, thoracic spine mobility was also associated with cervical dysfunctions (11–13). Poor thoracic spine mobility was treated in neck pain by thoracic spine manipulation or mobilization with acute positive effects on neck pain and motions (14,15). Otherwise, mobility and stability exercises or additional therapies related to the thoracic region may be useful treatments for pain, range of motion, disability, and quality of life in patients with CNP (16,17). Although sagittal thoracic spinal curvature and mobility insufficiency in neck pain are a matter of interest, contradictory results have been mentioned in the literature (6,10,13,18,19).
Furthermore, to the best of our knowledge, to date, cut-off points for sagittal thoracic spinal curvature and mobility scores for screening for the occurrence of neck pain have not been calculated.

Therefore, the purpose of the present study was to investigate sagittal thoracic spinal curvature and mobility in subjects with and without CNP, and to determine the cut-off points and pain relationship. The following hypotheses were investigated: 1. There are differences in thoracic spinal curvature and mobility between subjects with and without CNP. 2. There is a relationship and cut-off values between the occurrence of neck pain and thoracic curvature and mobility.

2. Materials and methods

2.1. Subjects

One hundred and thirty-two patients aged between 18 and 65 years with persistent neck pain for more than 3 months who were referred to the University Physiotherapy and Rehabilitation Polyclinic were assessed. Patients with a prior history of injury or surgery relating to the spine, spinal deformity, neurological symptoms or signs, radiological abnormalities indicating cervical radiculopathy or myelopathy (assessed by a cervical magnetic resonance imaging), prior history of any other spinal disorder (such as low back pain), active intervention in the last 3 months including drug therapy or physiotherapy, malignancy, systemic pathology including any rheumatologic disease, and osteoporosis were excluded from the study. In total, 56 patients were included in the CNP group (45 females and 11 males). The control group was composed of 53 out of 85 age- and body mass index (BMI)-matched healthy volunteers (39 females and 14 males). The inclusion criteria for the control group included acceptance to participate in the study, no previous neck pain (lifetime-to-date), no spinal surgery or deformity, and no radiological abnormalities detected prior to the study. Details of included and excluded subjects are provided in a flowchart (Figure 1).

This study was conducted in accordance with the rules of the Declaration of Helsinki. Written informed consent was obtained from each subject. This study was approved by the Ethics Committee of the University (Approval number: 2015-56/32, Clinical Trial Number: The study protocol was registered at http://clinicaltrials.gov (NCT02424058)).

2.2. Assessments

Demographic and physical characteristics, such as age, height, weight, sex, smoking, and alcohol consumption, of all participants were collected using a form. Participants’ BMI was calculated as weight in kilograms divided by height in meters squared.

Assessments related to neck pain intensity, sagittal thoracic spinal curvature, and mobility were carried out. All assessments were conducted by the same physical therapist (STC) using a standardized protocol to ensure the consistency of subject positioning, instructions, and overall testing procedures, and the examiner was blinded to the participants’ groups.

Neck pain intensity was assessed with a 10-cm visual analogue scale (VAS). The VAS is scored on a 10-
cm horizontal line with 0 indicating ‘no pain’ and 10 ‘unbearable pain’. The patients were asked to mark their neck pain on the horizontal line. The reliability of this measure was established by Clark et al. (20).

Sagittal thoracic spinal curvature and mobility were evaluated in standing position with a Spinal Mouse (Idiag, Volkerswill, Switzerland), a computer-assisted and noninvasive device. The demographic information of the participants was recorded on computer. The spinal processes of the vertebra from C7 to S3 were marked. The Spinal Mouse device was slid along the spine from top to bottom for measurement. The evaluation was conducted while the subject was standing in an upright, maximum trunk flexion, and maximum trunk extension positions, consecutively. The sagittal thoracic spinal curvature and mobility (between T1 and T12) were calculated using a software program. The intratester and intertester and day-to-day reliability of the Spinal Mouse device was published previously (21,22).

2.3. Simple size and statistical analyses
Ten participants from each group were randomly recruited for the pilot study. The G*Power software package (G*Power, Version 3.0.10, Franz Faul, Universität Kiel, Germany) was used to determine the required sample size for this study. It was calculated that a sample consisting of 82 subjects (41 per group) was needed to obtain 95% power with $f = 0.81$ effect size, $\alpha = 0.05$ type I error, and $\beta = 0.05$ type II error. It was decided to include 100 subjects (50 per group) due to an expected drop-out rate of 20%.

Data analysis and calculations were conducted using IBM SPSS Statistics 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA: IBM Corp.) and MS-Excel 2007. An overall P-value of less than 0.05 was considered to show a statistically significant result.

The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov–Smirnov test) to determine whether or not they were normally distributed. Descriptive analyses were presented as mean and standard deviation (SD) and frequency tables for the ordinal variables. The sagittal thoracic curvature and thoracic mobility differences between the groups were analyzed by the independent sample t test. Pearson’s correlation test was used to assess the relationship between neck pain intensity, sagittal thoracic curvature, and mobility.

The sagittal thoracic spine curvature and thoracic mobility values in predicting the presence of neck pain were analyzed using receiver operating characteristic (ROC) analysis, ROC graphics, the determined area under the curve (AUC), and 95% confidence intervals of the area. When a significant cut-off value commonly used for the prevention and diagnosis of various health problems in clinical settings was observed, the sensitivity, specificity, and general accuracy rate were calculated. While evaluating the AUC, a 5% type-I error level was used to accept a statistically significant predictive value of the measurements.

3. Results
There was no significant difference between the demographic and physical characteristics of the groups (P > 0.05). They are presented in Table 1.

Table 1. Demographic and physical characteristics of the participants.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>CNP group (n = 56)</th>
<th>Control group (n = 53)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years, X ± SD)</td>
<td>38.30 ± 12.20</td>
<td>34.30 ± 12.15</td>
<td>0.089</td>
</tr>
<tr>
<td>Weight (kg, X ± SD)</td>
<td>72.56 ± 13.65</td>
<td>75.69 ± 14.38</td>
<td>0.246</td>
</tr>
<tr>
<td>Height (m, X ± SD)</td>
<td>1.64 ± 0.08</td>
<td>1.66 ± 0.08</td>
<td>0.131</td>
</tr>
<tr>
<td>BMI (kg/m², X ± SD)</td>
<td>26.88 ± 5.16</td>
<td>27.16 ± 4.76</td>
<td>0.771</td>
</tr>
<tr>
<td>Sex (n, %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>45, 80.4</td>
<td>39, 73.6</td>
<td>0.401</td>
</tr>
<tr>
<td>Male</td>
<td>11, 19.6</td>
<td>14, 26.4</td>
<td></td>
</tr>
<tr>
<td>Smoking (n, %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>44, 78.6</td>
<td>39, 73.6</td>
<td>0.542</td>
</tr>
<tr>
<td>Yes</td>
<td>12, 21.4</td>
<td>14, 26.4</td>
<td></td>
</tr>
<tr>
<td>Alcohol consumption (n, %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>53, 94.6</td>
<td>52, 98.2</td>
<td>0.619</td>
</tr>
<tr>
<td>Yes</td>
<td>3, 5.4</td>
<td>1, 1.9</td>
<td></td>
</tr>
</tbody>
</table>

*P < 0.05; X: Mean; SD: Standard deviation, BMI: Body mass index, CNP: Chronic neck pain
Sagittal thoracic curvature was higher (P < 0.001) and sagittal thoracic mobility lower in the CNP group in comparison to the control group (P = 0.013, Table 2). Moreover, there was a positive correlation between neck pain intensity and sagittal thoracic curvature (r = 0.391, P < 0.001), while there was a negative correlation between neck pain intensity and thoracic mobility (r = -0.260, P = 0.006).

According to the result of the ROC analysis, the area under the curve (AUC = 0.765) was significant for sagittal thoracic spinal curvature (P < 0.001, Table 3). The cut-off point of the sagittal thoracic spinal curvature was 45.5°. In the present study, 60.71% sensitivity and 83.02% specificity were observed for ≥45.5° of sagittal thoracic spinal curvature value (Table 3; Figure 2a). Furthermore, the result of the ROC analysis indicated that the area under the curve (AUC = 0.633) was also significant for thoracic mobility (P = 0.016, Table 3). The cut-off point of thoracic mobility was 30.0°. Furthermore, 89.29% sensitivity and 35.85% specificity were observed for the thoracic mobility value of ≤30.0° (Table 3; Figure 2b).

4. Discussion
This study yielded the following notable findings: (i) Patients with CNP showed greater sagittal thoracic curvature and lower thoracic mobility than those without CNP, (ii) Sagittal thoracic curvature was positively correlated with neck pain, while thoracic mobility was negatively correlated with neck pain, (iii) The cut-off points for sagittal thoracic curvature and mobility for detecting neck pain were 45.5° and 30.0°, respectively.

Associations of neck pain with sagittal thoracic spinal curvature and mobility have not been adequately elucidated. Lau et al. (6) investigated the relationships among the sagittal postures of the thoracic and cervical spine, presence of neck pain, neck pain severity, and disability. They declared that the upper thoracic angle was moderately correlated with neck pain severity and disability. They pointed out that upper thoracic angle was a better predictor of the presence of neck pain than cranio-vertebral angle. Similarly, Nejati et al. (18) showed forward head posture and thoracic kyphosis were accompanied by neck pain. Quek et al. (10) also suggested addressing thoracic kyphosis impairments for cervical spine dysfunction. However, Tsunoda et al. (19) declared no significant association between thoracic kyphosis angle and neck and shoulder pain. On the other hand, Norlander et al. (11) and Norlander and Nordgren (12) suggested that impaired mobility at levels C7-T1 and T1-T2 might irritate the joint mechanoreceptors, causing neck/shoulder pain. Similarly, Hinman (23) stated that an increase in thoracic curvature could be accompanied by a loss of range of movement and increased stiffness. Our study also found that patients with CNP had greater thoracic curvature and lower thoracic mobility than those without CNP. In addition, it was detected that when patients had severe neck pain thoracic curvature increased and thoracic mobility decreased. Our results supported the notion that the loading mechanism of the cervical spine is dictated by the thoracic spine (24), and may be evidence for the contributing role of the thoracic spine in the development of cervical dysfunction.

On the other hand, regarding the evaluation of sagittal thoracic curvature, or kyphosis, different measurements such as spinal radiographs, kyphometer, flexicurve, and the Spinal Mouse have been used. These measurements

### Table 2. Differences in sagittal thoracic curvature and mobility between the groups.

<table>
<thead>
<tr>
<th>Values</th>
<th>CNP group (n = 56) X ± SD</th>
<th>Control group (n = 53) X ± SD</th>
<th>t values</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic curvature (degrees)</td>
<td>47.76 ± 9.25</td>
<td>38.35 ± 9.19</td>
<td>-5.32</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Thoracic mobility (degrees)</td>
<td>17.87 ± 12.87</td>
<td>24.52 ± 14.66</td>
<td>-2.52</td>
<td>0.013*</td>
</tr>
</tbody>
</table>

*P < 0.05

### Table 3. Area under the curve regarding sagittal thoracic curvature and mobility values.

<table>
<thead>
<tr>
<th>Values</th>
<th>AUC ± standard error</th>
<th>95% Confidence interval</th>
<th>p</th>
<th>Cut-off point</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>General accuracy rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic curvature (degrees)</td>
<td>0.765 ± 0.045</td>
<td>0.677–0.853</td>
<td>&lt;0.001</td>
<td>≥45.50</td>
<td>60.71</td>
<td>83.02</td>
<td>71.56</td>
</tr>
<tr>
<td>Thoracic mobility (degrees)</td>
<td>0.633 ± 0.053</td>
<td>0.529–0.738</td>
<td>0.016*</td>
<td>≤30.00</td>
<td>89.29</td>
<td>35.85</td>
<td>63.30</td>
</tr>
</tbody>
</table>

*P < 0.05, AUC: Area under the curve
have been reported to be valid and reliable in many studies (22,25,26). Especially in health checkups, the Spinal Mouse was proven to be very useful for measuring both spinal curvature and mobility, considering its cost and the limited time available to perform such measurements (27). Thus, we opted for the Spinal Mouse to evaluate sagittal thoracic spinal curvature and mobility in this study.

In addition, there is a general consensus that the prevalence of CNP is increasing globally. It may be important to determine the cut-off points of thoracic spinal curvature and mobility for the prevention and diagnosis of neck pain. Therefore, we calculated these points for thoracic curvature (45.5°) and mobility (30.0°) in this study. Mejia et al. (28) reported 20° to 45° for thoracic kyphosis as neutral in standing position. Lower and higher values were classified as hypo- and hyperkyphosis, respectively. Therefore, precautions should be taken against neck pain when patients have thoracic hyperkyphosis. Moreover, there is no standard value for thoracic mobility. However, it may be beneficial to consider this value of thoracic mobility, measured using the Spinal Mouse, in health checkups.

There were some limitations in the current study. First of all, the cut-off points of sagittal thoracic curvature and mobility in patients with CNP were represented in the study. Establishing the best cut-off points of sagittal thoracic curvature and mobility for both females and males should be considered since various biomechanical factors may contribute to the occurrence of neck pain. Secondly, the cervical, thoracic, and lumbar spine work together in our daily activities. However, the relationship between neck pain and sagittal curvature and mobility of the lumbar spine was not explored in this study. The relationship between neck pain and lumbar spine curvature and mobility or cut-off points may be a subject for further studies.

In conclusion, increased sagittal thoracic spine curvature and decreased thoracic mobility were seen and pain intensity was related to them in patients with CNP. It was concluded that the thoracic region should be taken into account for assessment and treatment of patients with CNP.

References


