Decreased neck muscle strength in patients with the loss of cervical lordosis

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A B S T R A C T

Background: The loss of cervical lordosis is associated with some negative clinical outcomes. No previous study has examined cervical muscle strength, specifically in patients with the loss of cervical lordosis. This study aims to investigate whether there is weakness of the cervical muscles or an imbalance between cervical flexor and extensor muscle strength in patients with the loss of cervical lordosis compared with healthy controls matched by age, gender, body mass index (BMI), and employment status.

Methods: Thirty-two patients with the loss of cervical lordosis (23 F, 9 M) and 31 healthy volunteers (23 F, 8 M) were included in the study. Maximal isometric neck extension and flexion strength, and the strength ratio between extension and flexion were used as evaluation parameters. All measurements were conducted by a blinded assessor using a digital force gauge. The participants were positioned on a chair in a neutral cervical position and without the trunk inclined during measurements.

Findings: Maximal isometric neck extension and flexion strength values were significantly lower in the patients versus healthy controls (P < 0.001 and P = 0.040, respectively). The mean (SD) values of the extension/flexion ratio were 1.21 (0.34) in the patients and 1.46 ± 0.33 in the controls (P = 0.004).

Interpretation: According to our results, patients with the loss of cervical lordosis have reduced neck muscle strength, especially in the extensors. These findings may be beneficial for optimizing cervical exercise prescriptions.

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1. Introduction

Anatomically, there is a natural lordotic curvature in the cervical spine (Fig. 1a). This natural lordosis is believed to be an ideal posture in terms of biomechanical principles. The loss of cervical lordosis (Fig. 1b) causes disrupted biomechanics in the cervical spine because the axial load is shifted anteriorly as lordosis is lost, and thus, the increased compressive forces can trigger a progressive degenerative process resulting in cervical kyphosis (Fig. 1c) (Ferrara, 2012; Harrison et al., 2001; Tan et al., 2015). In addition, the loss of cervical lordosis is associated with neck, upper thoracic, and shoulder pain, as well as tension and cervicogenic headaches and poorer health-related quality of life outcomes (McAviney et al., 2005; Morningstar et al., 2003; Tan et al., 2015).

A decreased cervical lordosis may result from muscular spasms, trauma, congenital defects, muscular dystrophies, amyotrophic lateral sclerosis, ankylosing spondylitis, tumor, infection, or surgical complications (Beltios et al., 2013; Lee et al., 2013; Xiaolong et al., 2011). However, the exact etiology and mechanisms remain unclear in a great majority of cases. According to Panjabi et al. (1998) the mechanical stability of the cervical spine is provided by the neck musculature (80%) rather than the osseoligamentous system (20%). Therefore, weakness of the cervical muscles may bring about the mechanical instability of cervical spine, contributing to the loss of cervical lordosis. Additionally, it has been found that proprioceptive balance activities and a balanced co-contraction between agonistic and antagonistic muscles contribute to maintaining spinal stability (Reinert et al., 2015; Cheng et al., 2008), and altered co-contraction of cervical muscles has been shown in young adults with chronic neck pain (Cheng et al., 2014). Furthermore, it has been reported that the strength ratio between reciprocal muscle groups within a limb plays an important role in articular stabilization, and an abnormal ratio can increase the risk of injury (Baumhauer et al., 1995; Knapik et al., 1991; Stafford and Grana, 1984). Similarly, the existence of an imbalance between neck extension and flexion strength may have an important negative effect on the stabilization of the cervical spine.

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Although many studies have examined neck strength in both patients with nonspecific neck pain and healthy subjects (Cagnie et al., 2007; Chiu and Sing, 2002; de Koning et al., 2008; Salo et al., 2006), there is currently no known study that has examined neck muscle strength in the loss of cervical lordosis. Thus, more specific data on the topic are needed. In this study we aimed to determine whether there is a weakness of the cervical muscles or an imbalance between cervical flexion and extension strength in patients with the loss of cervical lordosis.

2. Methods

The research protocol was approved by the local ethics committee. Thirty-two patients [23 F, 9 M; mean (SD) age 25.0 (5.9) years] with the loss of cervical lordosis were enrolled between March 2015 and September 2015 from among patients who were admitted to the Department of Physical Medicine and Rehabilitation Outpatient Clinic at Yuzuncu Yil University Hospital. Thirty-one healthy controls matched for age, gender, body mass index (BMI), and employment status [23 F, 8 M; mean (SD) age 23.87 (4.92) years] were recruited from the staff of the same hospital and the patients’ relatives with a strictly normal medical record and with normal cervical lordosis (Table 1). All participants gave written consent prior to participation in the study. Cervical lordosis was assessed on lateral cervical radiographs according to the posterior tangent technique (Erkan et al., 2010). The total curvature of the cervical spine, which is the angle between the posterior wall of the C2 and C7 vertebral bodies (Erkan et al., 2010; Grob et al., 2007), was measured. It has been reported that the posterior tangent technique has a good intra- and inter-observer reliability, with a smaller standard error of measurement than four-line Cobb methods (Harrison et al., 2000). However, the literature yields no standard values for the definition of a normal cervical lordosis. As defined by Grob et al. (2007), we considered the loss of cervical lordosis or straightness of the total curvature as $+4°$ to $−4°$, and lordotic and kyphotic as $<−4$ and $>+4$, respectively.

The medical history and physical examination findings of all participants were recorded to assess each participant’s eligibility. Participants with any of the following conditions were excluded from the study: exercise or drug therapy acting on muscular tone and strength (e.g., phenyramidol, steroids, thyroxine); hypo- or hyperthyroidism; underweight (BMI $<18.5$ kg/m$^2$) or obesity (BMI $≥30$ kg/m$^2$); neuromuscular diseases such as cervical disk hernia, fibromyalgia, myofascial pain syndrome, and muscular dystrophies; scoliosis; rheumatic diseases such as ankylosing spondylitis and rheumatoid arthritis; and a history of cervical spine trauma. In addition, because an increased psychologic distress and a higher level of current pain tend to show increased inhibition of muscle activity, thus leading to submaximal performance (Verbunt et al., 2005), individuals with psychiatric issues such as depression and anxiety and patients with severe pain were excluded. Moreover, taking into account the potential inhibition of muscle activity due to pain, all patients were given acetaminophen (500 mg, p.o.) one hour before the measurements.

Maximal isometric neck flexion and extension strength were measured by the same assessor, who was blinded to the participant’s group. The measurements were performed twice and the highest value was used. Our measurement system consists of a digital force gauge (Digital Force Gauge, Model: SH-200, SHAHE) placed into a fixed frame, which was calibrated with standard masses (5, 10, and 15 kg). During the measurements, the participants were positioned on a chair, with hips and knees at 90° flexion and in a neutral cervical position, without the trunk inclined (Fig. 2).

Statistical analyses were performed using the Statistical Package for Social Sciences for Windows version 15.0 (SPSS Inc., Chicago, IL, USA) software program. The descriptive statistics were presented as the mean (standard deviation) for continuous variables and as the number of the cases for the categorical variables. Before performing the statistical analysis, the normality of the distribution of continuous variables was determined with a one-sample Kolmogorov–Smirnov test. The Independent Samples Test was used to compare the means of two controls and patients.

| Table 1 |
| Demographic findings of controls and patients. |
|---|---|---|
| | Healthy controls ($n = 31$) | The loss of cervical lordosis ($n = 32$) | P value |
| Age (years) | 23.87 (4.92) | 25.0 (5.9) | 0.412 |
| Gender (F/M) | 23/8 | 23/9 | 0.660 |
| Weight (kg) | 60.13 (8.08) | 59.91 (7.73) | 0.911 |
| Height (m) | 1.64 (0.8) | 1.62 (0.05) | 0.196 |
| BMI (kg/m$^2$) | 22.31 (2.16) | 22.90 (3.13) | 0.388 |
| Lordosis angle (°) | $−13.09$ (6.08) | $−6.62$ (2.99) | <0.001 |
| Employment status | | | 0.974 |
| Housewife | 8 | 9 |
| University student | 9 | 11 |
| Liberal profession | 5 | 5 |
| Health personnel | 5 | 4 |
| Others | 4 | 3 |

Data expressed as mean (standard deviation) or number; F/M, female/male; BMI, body mass index.
continuous variables. Fisher’s Exact Test was used to compare the sex ratios of the patients and controls. Additionally, the employment status data between the two groups were evaluated using Chi-square tests. A p value of <0.05 was considered to be statistically significant.

The intraclass correlation coefficient (ICC) was calculated using the day-to-day data from 10 subjects. These daily measurements were performed during 5 days by the same physiatrist using the same system. The ICC calculation was made by considering ANOVA model, and the results of average measures were taken as the ICC values.

### 3. Results

The demographic characteristics of the patients and controls are presented in Table 1. There were no significant differences in the participants’ age, gender, BMI or employment status between the two groups (for all comparisons \( P > 0.05 \)). The maximal isometric strength values of the two groups are shown in Table 2. Significant differences were found between the two groups in the evaluation parameters including the extension (\( P < 0.001 \)) and flexion strength (\( P = 0.040 \)), and extension/flexion ratio (\( P = 0.004 \)). The ICC values (95% CI) were 0.90 (0.76 to 0.97) in flexion, 0.92 (0.81 to 0.98) in extension.

### 4. Discussion

In this comparative case–control study, we evaluated the maximal isometric strengths of cervical flexion and extension, and the strength ratio between extension and flexion in patients with the loss of cervical lordosis compared with healthy controls with similar demographics. Our results demonstrated a significant weakness of both neck extensor and flexor strength in the patients compared with the control subjects. Additionally, the average values of the strength ratio and the strength difference were significantly greater for the controls. These findings suggest that there is a significant relationship between the loss of cervical lordosis and the weakness of neck extensor strength.

There are many studies in the literature on neck muscle strength in both patients with non-specific chronic neck pain and healthy subjects (Cagnie et al., 2007; Chiu and Sing, 2002; de Koning et al., 2008; Salo et al., 2006; Ylinen et al., 2004). However, in previous studies, cervical muscle strength was not investigated specifically in patients with the loss of cervical lordosis. In our study, we found significantly lower neck extension (\( P < 0.001 \)) and flexion (\( P = 0.040 \)) strength in the patients compared with the controls. Moreover, the average of the extension/flexion ratio in our patients was significantly lower than that in the controls. These results revealed the presence of an imbalance caused by a weakness in extensors between cervical extension and flexion strength in patients with the loss of cervical lordosis.

The exact etiology and mechanisms of decreased cervical lordosis remain unclear in a great majority of cases. A recent hypothesis was proposed by Xiaolong et al. (2011) to explain idiopathic cervical kyphosis. According to the hypothesis, weakness of the neck extensors could be the initiating factor for adolescent idiopathic cervical kyphosis. Although this hypothesis has not been tested, it forms a reasonable basis for the present study because kyphosis occurs after the loss of cervical lordosis. Therefore, if weakness of the neck extensors is a risk factor for the development of cervical kyphosis, patients with the loss of cervical lordosis may have reduced neck extensor strength. Indeed, our study results suggest that this hypothesis may be correct. It is possible our findings might be relevant to a causal relationship between the loss of lordosis and extensor weakness in the cervical spine. As in dropped head syndrome, which is characterized by severe weakness of the neck extensor muscles with or without involvement of neck flexors (Gourie-Devi et al., 2003), mild-to-moderate weakness of cervical extensors may lead to an alteration of head–neck posture, like the loss of cervical lordosis.

### Table 2

Comparisons of evaluation parameters of groups.

<table>
<thead>
<tr>
<th></th>
<th>Healthy controls (n = 31)</th>
<th>The loss of cervical lordosis (n = 32)</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extension strength (N)</td>
<td>79.37 (30.53)</td>
<td>53.01 (20.05)</td>
<td>0.000</td>
</tr>
<tr>
<td>Flexion strength (N)</td>
<td>55.73 (22.09)</td>
<td>45.52 (16.23)</td>
<td>0.040</td>
</tr>
<tr>
<td>Extension/flexion</td>
<td>1.46 (0.33)</td>
<td>1.21 (0.34)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Data expressed as mean (standard deviation); N, Newton.

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Fig. 2. A. Measurement of isometric neck flexion strength. Arrow shows the placement of the force gauge. B. Measurement of isometric neck extension strength.
Similar to our findings, previous studies have detected that patients with non-specific neck pain have significantly reduced maximal isometric neck strength relative to healthy controls (Cagnie et al., 2007; Chiu and Sing, 2002; Ylinen et al., 2004). However, Cagnie et al. (2007) demonstrated that women with chronic neck pain have significantly lower neck muscle strength in extension only, whereas Ylinen et al. (2004) found that neck strength reductions were present in all directions tested and were equal for flexion and extension. On the other hand, the level of lower cervical strength in a group with neck pain did not reach statistical significance in a study by Rodríguez and Burns (2008). Because the loss of cervical lordosis is a cause of chronic neck pain, patients with this disorder can show characteristics that are similar to those in patients with non-specific neck pain in terms of the strength of the cervical musculature. Nevertheless, our findings suggest that neck extensors are more severely affected than neck flexors in patients with the loss of cervical lordosis.

Studies have reported conflicting results to determine the normative database of isometric cervical strength in healthy subjects. Compared with the flexion and extension strength of healthy controls in our study (55.73 N and 79.37 N, respectively), Salo et al. (2006) reported higher values, whereas Suryanarayana and Kumar (2005) reported lower values. These conflicting results may be due to different physical characteristics among the subjects investigated, and they also may be due to the different testing methods used because the results of the isometric neck strength measurements are highly dependent on the testing method (Salo et al., 2006). Therefore, we obtained reference ICC values for our measurement system.

Exercise interventions that focus on strengthening the cervical musculature have been found to be beneficial (Borisut et al., 2013; Suryanarayana and Kumar, 2005), and exercise programs are commonly used to improve neck muscle function and thereby decrease pain and disability (Borisut et al., 2013; Gross et al., 2015; Silverman et al., 1991). Therefore, it is important to understand the neck strength status of patients with the loss of cervical lordosis to determine more effective and specific exercise therapies. Taking the present results into consideration, it can be said that exercises that strengthen neck extensors are likely a good choice in patients with the loss of cervical lordosis. Because there is no specific exercise protocol for the loss of cervical lordosis, our results can provide some insight for potential therapeutic exercise strategies and future studies on the subject.

Our study has some limitations. First, because both female and male patients were included in this study, a gender effect cannot be ignored. Nevertheless, although sex difference in strength ratio between reciprocal muscle groups in the lower leg has been reported (Akagi et al., 2013), an association between imbalance of reciprocal muscles and articular instability and injury has been found in both females and males (Baumhauer et al., 1995; Knaphik et al., 1991; Stafford and Grana, 1984). In addition, the existence of similarity in terms of gender ratio between the two groups in the present study can reduce this limitation. Second, because osteoarthritis begins most commonly after 40 years of age and its associated chronic pain can affect neck muscle strength, only young individuals (age 18–40 years) were included in this study. Including young individuals in the study means that our results cannot be generalized to older groups of people. Third, the study cannot distinguish whether weak neck extensors promote the loss of cervical lordosis or vice versa. However, to our knowledge, this is the first study to determine whether neck muscles are weak in the loss of cervical lordosis. Therefore, despite these weaknesses, our findings are still valuable.

5. Conclusions

Patients with the loss of cervical lordosis have weak neck extension and flexion strength. The loss of cervical lordosis is especially associated with the weakness of neck extensors. Accordingly, neck extensor strengthening exercises are likely suitable options for patients with the loss of cervical lordosis.

Conflicts of interest

None.

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