Research Article / Araştırma Makalesi

The Morphometry of the Cervical Vertebral Column in the Sagittal Plane: Comparing Methods for Determining Cervical Lordosis Angle

Sagittal Düzlemde Servikal Vertebral Kolonun Morfometrisi: Servikal Lordoz Açısını Belirleme Yöntemlerinin Karşılaştırılması

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Abstract

Background: The aims of this study were to: (i) to analyze the morphometric characteristics of the cervical vertebral column in the sagittal plane; and (ii) compare morphometric methods used for determinating cervical lordosis angle.
Materials and Methods: Direct cervical sagittal radiographs of 175 adults were analyzed and cervical lordosis angle was evaluated by Cobb (C2-C7), central cervical lordosis angle, posterior tangent, and Risser & Ferguson methods. In addition, occipitocervical angle (occiput-C2) and cervical vertical tranlation distance were determined to assess upper cervical lordosis and forward head posture, respectively.
Results: The measured cervical lordosis angles were differed ($p<0.05$) depending on the measurement method. There was a strong negative correlation between cervical lordosis angle and occipitocervical angle ($r = -0.707$), a weak negative correlation between cervical lordosis angle and cervical vertical translation distance ($r = -0.253$) and a moderate positive correlation between occipitocervical angle and cervical vertical translation distance ($r = 0.552$). It was observed that an increase of 1 mm in the cervical vertical translation distance caused an increase in the occipitocervical angle about 0.6 degrees.
Conclusions: In planning cervical surgery, the balance and alignment of the cervical vertebral column in the sagittal plane should be evaluated in detail. The contour of the cervical vertebral column in the sagittal plane and the limits of cervical lordosis angle are important in the evaluation of cervical pathologies. The obsservations from this study will benefit the understanding of vertebral column morphometry will contribute to the literature in anatomy, physiotherapy, radiology, and cervical regional surgery.

Key Words: Cervical lordosis angle, cervical vertebrae, morphometry, radiography, sagittal plane

Öz

Amaç: Bu çalışmanın amaçları şunlardır: (i) sagital düzlemde servikal vertebral kolonun morfometrik özelliklerini analiz etmek; ve (ii) servikal lordoz açısını belirlemek için kullanılan morfometrik yöntemleri karşılaştırmak.
Materyal ve Metod: Yüz yetmiş beş (175) yetişkine ait direkt servikal sagittal radyografiler analiz edildi ve servikal lordoz açısı Cobb (C2-C7), santral servikal lordoz açısı, posterior tanjant ve Risser & Ferguson yöntemleri ile değerlendirildi. Ayrıca, üst servikal lordozu ve baş ileri postürünü değerlendirmek için sırasıyla oksipitoservikal açı (oksiput-C2) ve servikal vertikal translasyon mesafesi belirlendi.
Bulgular: Ölçülen servikal lordoz açıları ölçüm yöntemine bağlı olarak farklılık gösterdi ($p<0,05$). Servikal lordoz açısı ile oksipitoservikal açı arasında güçlü negatif korelasyon ($r=-0,707$), servikal lordoz açısı ile servikal vertikal translasyon mesafesi arasında zayıf negatif korelasyon ($r=-0.253$) ve oksipitoservikal açı ile servikal vertikal translasyon mesafesi arasında orta derecede pozitif korelasyon ($r=0,552$) vardı. Servikal vertikal translasyon mesafesindeki 1 mm'lik artışın oksipitoservikal açıda yaklaşık 0,6 derecelik bir artışa neden olduğu görüldü.
Sonuç: Servikal cerrahi planlanırken, servikal vertebral kolonun sagittal düzlemdeki dengesi ve hizalanması ayrıntılı olarak değerlendirilmelidir. Servikal vertebral kolonun sagittal düzlemdeki konturu ve servikal lordoz açısının sınırları servikal patolojilerin değerlendirilmesinde önemlidir. Bu çalışmadan elde edilen gözlemler, vertebral kolon morfometrisinin anlaşılmasına fayda sağlayacak, anatomi, fizyoterapi, radyoloji ve servikal bölgesel cerrahi literatürüne katkıda bulunacaktır.

Anahtar Kelimeler: Morfometri, radyografi, sagittal plan, servikal lordoz açısı, servikal vertebra

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Introduction

The vertebral column has three important roles: transferring body weight through the distal segments; providing mobility to the trunk; also protecting and supporting the vital organs (1). In the sagittal plane it has lordotic curvatures in the lumbar and cervical regions and kyphotic curvatures in the thoracic and sacral regions: these curvatures serve to distribute equally the load on the vertebral column (2). In addition, the balance and relationship between the curvatures is essential for a proper and functional posture (3).

The normal angle of cervical lordosis is between 20° and 35° (4): chronic spasms of the deep cervical muscles affects this angle (5). Although cervical hypolordosis is often asymptomatic, it is generally undesirable. Remaining in a flexion posture for long periods of time increases the load on cervical vertebral bodies and decreases the traction endurance on the vertebral arches. In the long term, this can result in degenerative changes in the vertebral bodies, and as a result may also lead to angular changes in cervical lordosis and instability (6).

Radiographic images are routinely used to evaluate cervical lordosis angles (7), with the angle most often determined from lateral cervical radiographic images being between C2 and C7. Alternatively it can be determined separately between adjacent pairs of cervical segments (C2-C3, C3-C4, C4-C5, C5-C6, C6-C7): upper cervical lordosis angle can be measured between the occiput and C2. The total and segmental cervical lordosis angles are usually determined using the Posterior Tangent and Cobb methods. However cervical lordosis angle, as measured on lateral cervical radiographs, does not always provide consistent values, being dependent on the method used (8).

In the current study the aims were to (i) obtain acceptable standardized values of cervical lordosis angle, and (ii) determine the reliability of frequently used cervical lordosis measurement methods. For this purpose, morphometric measurements using different methodologies were determined on lateral radiographs of the cervical spine.

Materials and Methods

This was a retrospective study approved by the local non-interventional clinical research ethics committee (Protocol no: 5.7.2019/23). Radiographs of 175 adult patients (75 male, 100 female), who were screened between January 2019 and December 2019 in the Radiology Unit of Osmaniye State Hospital, were used. Digital radiographic images (HILIGHT1000 DR, DRS, T.M) were taken from a distance of 120 cm with an exposure time of 16 ms and dose of 95 KvP. Morphometric measurements were analyzed using Akgün PACS VIEWER software, repeated three times and averaged. Patients (age range: 18 to 65 years) were categorized into three groups according to the age criteria of the World Health Organization (WHO) into young adults (18 to 30 years), middle aged adults (31 to 45 years) and older adults (46 to 65 years). Cervical lordosis angle was measured using the Cobb C2-C7 (Fig. 1A), central cervical lordosis angle (CCLA) (Fig. 1B), posterior tangent (Fig. 2A) and Risser & Ferguson (Fig. 2B) methods. In addition, occipitocervical angle (Fig. 3A) and cervical vertical translation distance (Fig. 3B) were determined to assess upper cervical lordosis and forward head posture, respectively.

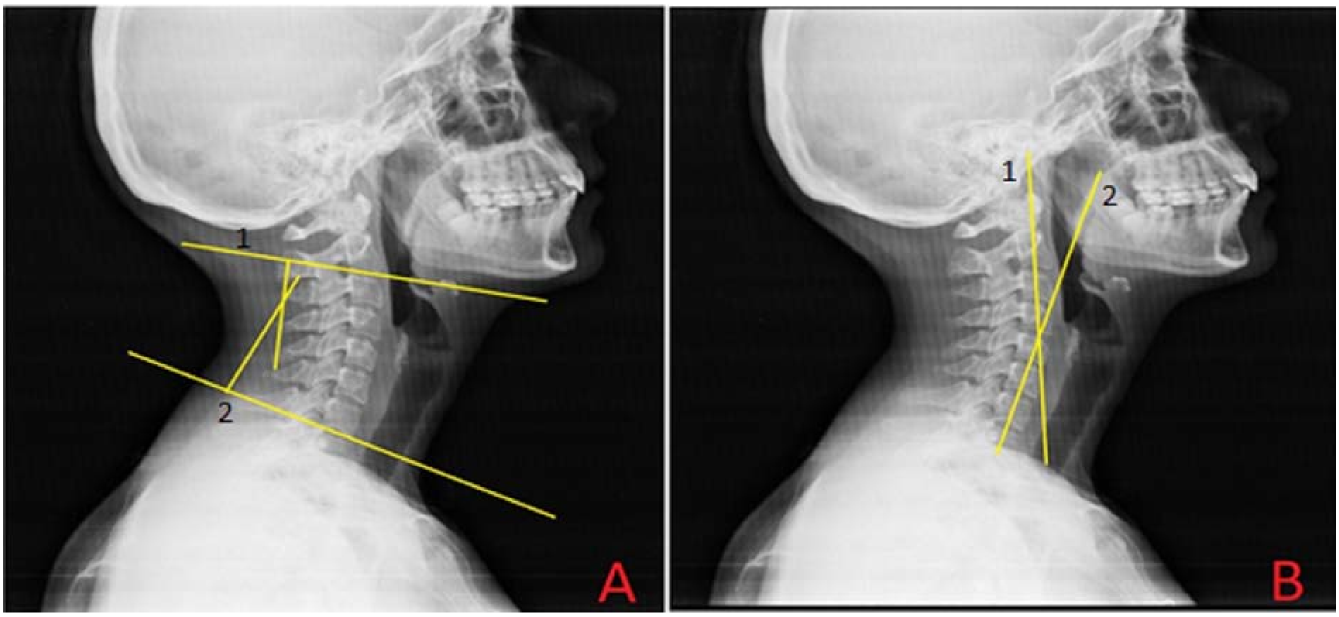

Figure 1. A. The Cobb C2-C7 method in which the Cobb angle is taken as the angle between lines drawn parallel to the inferior endplates of C2 (line 1) and C7 (line 2). B. The central cervical lordosis angle (CCLA) method in which the angle between a line (1) drawn through the midpoint of the C2 endplate and the midpoint of the C3 body, and a line (2) drawn through the midpoints of the C6 and C7 bodies.

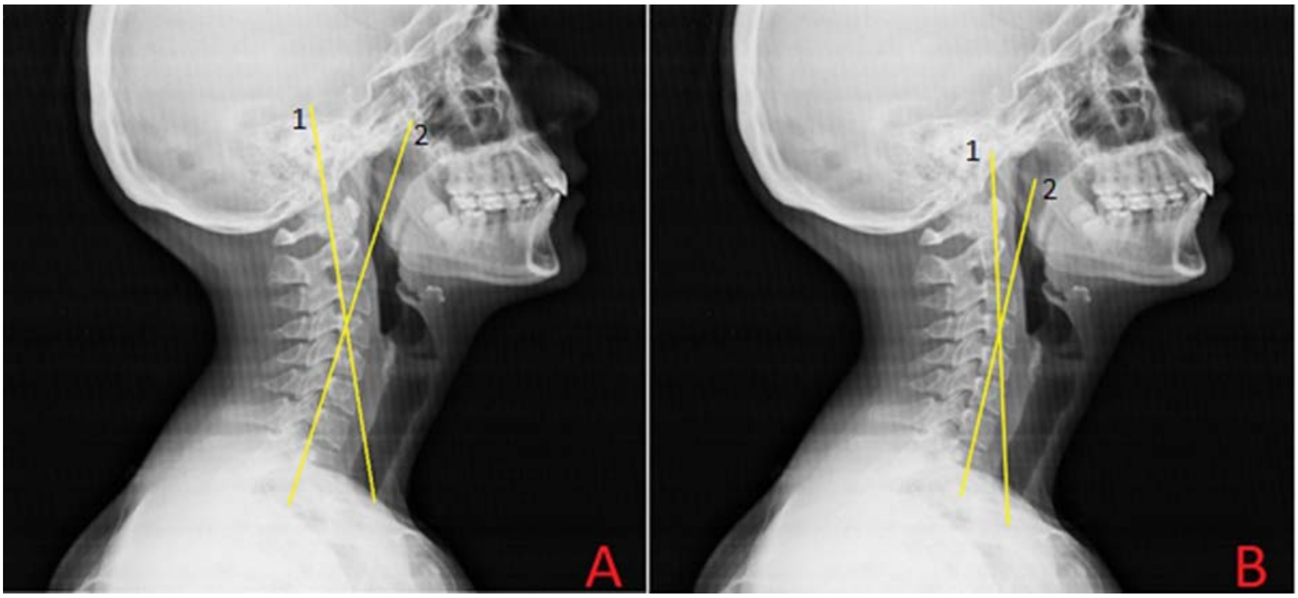

Figure 2. A. The posterior tangent method in which the angle is measured between lines drawn parallel to the posterior margins of C2 (line 1) and C7 (line 2). B. The Risser & Ferguson method in which is the angle between a line (1) drawn between the midpoints of the bodies of C2 and C4, and a line (2) drawn between the midpoints of the bodies of C4 and C7. This measurement method was developed to determine the degree of scoliosis (Rowe and Yochum, 1996). In the current study, this method was used to determine the degree of cervical lordosis by adapting it to the cervical region.

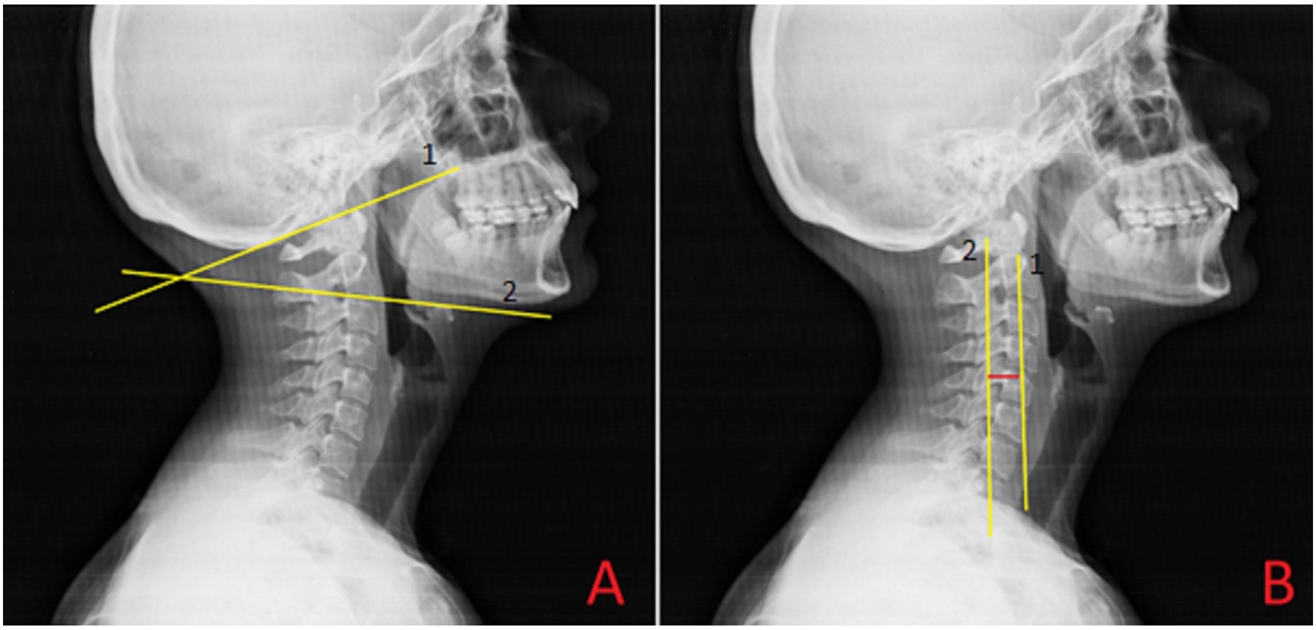

Figure 3. A. The occipitocervical angle is the angle between the the McGregor line (1) and a line (2) drawn parallel to the C2 inferior endplate: the McGregor line is the line from the posterosuperior aspect of the hard palate to the most caudal point on the midline occipital curve (Shoda, 2004). B. Cervical vertical translation distance is the distance between vertical lines passing through the middle of C2 (line 1) and the posteriosuperior aspect of C7 (line 2): it represents the cervical vertical translation distance.

The Statistical Package for Social Sciences for Windows 20 (SPSS 20 inc.) program was used for statistical analysis of the data obtained. Kolmogorov-Smirnov normality analysis was performed to check whether the data conformed to a normal distribution: nonparametric tests (Friedman test, Wilcoxon test) were used for data not showing a normal distribution. Results were evaluated at 95% confidence interval and significance level of $p<0.05$.

Results

Radiographic images of 175 adult individuals (75 male, 100 female) were evaluated, of these 72 were young adults, 64 middle aged adults and 39 older adults. The cervical lordosis angle according to the method used are shown in Table 1. Normality test (Kolmogorov-Smirnov) was performed to determine whether the data obtainedby four different methods for determining the lower cervical lordosis angle were normaally distributed. It was observed that the data obtained from the four different methods were not normally distributed (p<0.05): consequently, non-parametric tests were used to analyse the data. The Friedman test determined whether the extent of total cervical lordosis obtained from the four different methods in the same group differed according to the method used.

According to Friedman's test, the degree of cervical lordosis differed depending on the method used (p<0.05). The Wilcoxon Test was used to determine which methods were different. There was no significant difference (p = 0.629) between the cervical lordosis angle using the Risser & Ferguson and Cobb methods (Table 2).

Table 1: Distribution of cervical lordosis angle (º) according to the methods used (n:175).

Methods	Cobb C_{2-7}	CCLA	Posterior Tangent	Risser&Ferguson
Mean	11.19±9.64	11.70±9.64	12.0±10.02	11.06±8.94
(Range)	(-7.90–38.10)	(-6.30–41.60)	(-7.20–42.80)	(-7.30–34.20)

Table 2. Results of the Wilcoxon Test used to determine differences between the various measurement methods used to measure cervical lordosis angle.

	CCLA -Cobb	Posterior Tangent -Cobb	Risser and Ferguson -Cobb	Posterior Tangent - CCLA	Risser & Ferguson - CCLA	Risser & Ferguson -Posterior Tangent
z	-3.994	-7.732	-0.482	-2.607	-4.808	-5.788
p	0.000	0.000	**0.629**	0.009	0.000	0.000

The relationship between cervical lordosis angle, occipitocervical angle and cervical vertical translation distance was evaluated using correlation analysis. Since some of the variables did not meet the normality criteria, correlation analysis was performed using Spearman's Rho. A strong negative correlation was observed between cervical lordosis angle and occipitocervical angle (r = -0.707); a weak negative correlation between cervical lordosis angle and cervical vertical translation distance (r=-0.253) and a moderate positive correlation between occipitocervical angle and cervical vertical translation distance (r = 0.552) (Table 3).

Table 3. Results of the Spearman's Rho correlation analysis to determine relationships between various measurement methods used.

	Occipitocervical angle	Cervical vertical translation distance
Cervical lordosis angle	-0.707**	-0.253**
Occipitocervical angle		0.552**

***Significant at the 0.01 level (2-tailed)*

In addition, the relationship between the cervical vertical translation distance and occipitocervical angle was examined from which it was noted that an increase of 1 mm in the cervical vertical translation distance was associated with an increase of approximately 0.6º in occipitocervical angle. This positive relationship is shown in Figure 4.

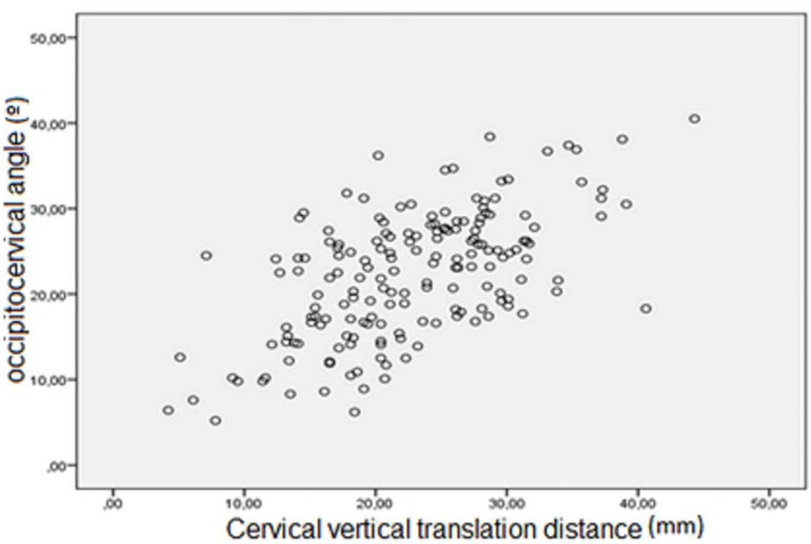

Figure 4. Scatterplot showing the relationship between occipitocervical angle (º) and cervical vertical translation distance (mm).

Discussion

The vertebral column has a unique structure endowed with curvatures to facilitate maintenance of the erect posture. It is considered that its anatomical structure allows an understanding of the conditions of the body during the evolutionary development of modern humans and could provide an holistic approach to spinal problem (9). The vertebral column, which is exposed to constantly changing dynamic forces (compression, stretching, gliding) in daily life, can also be affected by a variety of factors such as occupational exposure, a sedentary lifestyle and postural habits (10). The lordotic shape of the cervical region is important in terms of maintaining the biomechanical balance of the neck and head. Although cervical hypolordosis is often asymptomatic it is generally undesirable. The rate of loss of cervical lordosis, according to (4), can be as much as 30% in asymptomatic patients: earlier (11) reported the rate as being 42%. Remaining in a flexed posture for a long period of time increases the load on the vertebral body, while at the same time decreases the traction endurance of the vertebral arch. In the long term, this may cause degenerative changes in the bodies of the cervical vertebrae, angular changes in cervical lordosis and cervical instability (12). Over time and with increasing age, morphological changes may occur in the cervical region: changes in cervical lordosis angle can be considered normal to some extent (13). However, the relationship between degeneration of the cervical spine and aging is controversial (14). Studies have indicated a disparity in the effect of aging on cervical lordosis, with some demonstrating a decrease in lordosis, while others suggest an increase in degeneration and lordosis with advancing age (15, 16). In contrast, it has also been reported that there are no age-related changes in cervical lordosis. Park et al. (2014), who compared young and middle-aged individuals found no significant age-related difference in cervical lordosis angle (17). Similarly, Erkan et al. (2010) did not observe a significant relationship between age and cervical lordosis angle (4). However, Nojiri et al. (2003) observed an increase in lower cervical lordosis angle (C2-C7) and a decrease in upper cervical lordosis (occiput-C2) angle at age 40 (18). More recently, Tang et al. (2019) reported an increase in cervical lordosis and thoracic kyphosis in cervical sagittal alignment with increasing age (19). The current study showed that the mean cervical lordosis angle, determined by the Risser & Ferguson method, was highest in the older age group (46 to 65 years), being 17.8°, and lowest in the younger age group (18 to 30 years), being 6.9°.

Harrison et al. (2000) state that the Cobb and posterior tangent methods are safe to use with high correlation coefficients; however, the posterior tangent method had a lower standard error of measurement than the Cobb method. They noted that the posterior tangent method more accurately characterized the cervical spinal curvature (20). Gwinn et al. (2009) concluded that effective measurement of lordosis (straight line measurement between C2 and C7) is easier and more reliable than either the Cobb or posterior tangent methods (21). According to Boy et al. (2014) the posterior tangent method is more practical than the Cobb method, but, nevertheless, state that the Cobb and posterior tangent methods can be used with high confidence in determining the cervical lordosis angle (22). Similarly, Silber et al. (2004) reported that the tangent method was more useful than the Cobb method (23). A study by Ohara et al. (2006) comparing the Cobb, posterior tangent, and central cervical lordosis angle methods showed a strong correlation between the three methods when cervical lordosis was preserved; however, a weak and statistically insignificant relationship was observed when there was a presence of neck flattening or a kyphotic neck (24). In a prospective study of 138 patients, Donk et al. (2017) observed that absolute angle measurement from C2 to C7 cannot accurately define sagittal cervical alignment: they reported that the modified Toyoma method is a more practical method for evaluating sagittal cervical alignment (25).

In the current study, it was observed that cervical lordosis angle using the Risser & Ferguson method was in close proximity to those generated by the Cobb and posterior tangent methods, both of which are widely used in clinical practice. In addition, there was no significant difference ($p = 0.629$) between the values of cervical lordosis measurements using the Risser & Ferguson and Cobb methods.

As the lordotic curvature of the lower cervical spine (C2-C7) increases, the lordotic curvature of the upper cervical spine decreases (26): earlier studies also support this negative relationship(18, 27). It has been suggested that changes in cervical spine lordosis, such as a decrease in lordosis or the development of cervical kyphosis, can lead to changes in the vertical axis and may also be associated with a forward translation of the head in compensation (28). In the current study, a strong negative correlation between cervical lordosis and occipitocervical angle ($r = -0.707$), a weak negative correlation between cervical lordosis and cervical vertical translation distance ($r = -0.253$), and a moderate positive correlation between occipitocervical angle and cervical vertical translation distance ($r = 0.552$) was observed.

In adults with normal vertebral column morphology, cervical lordosis is typically observed with the apex of the curvature located between the C2 and T1, generally being between C4 and C5 (7). While the Cobb and tangent methods are widely used to reference the vertebrae at the ends of the cervical lordosis, an adaptation of the lumbar lordosis center measurement method, the CCLA method, references the C2, C3, C6 and C7 vertebrae. Furthermore, the Risser & Ferguson method, which is typically used to determine the degree of scoliosis, has been adapted to reference the C2 and C7 as well as the apex vertebra (C4). These two methods may facilitate a more comprehensive interpretation of cervical lordosis by defining the entire cervical curvature. However, the use of multiple reference points and marked regions can also increase the potential for errors.

It is recommended that the balance and alignment of the

vertebral column in the sagittal plane should be considered when planning cervical surgery. An understanding of the sagittal plane morphology of the cervical region and the extents of its lordotic curvature is essential in the evaluation of pathological conditions (29). Changes in cervical lordosis angle and vertical translation distance may cause an increase in the load on the joints and muscles, resulting in postural disorders and clinical complications. The current prevalence of complications associated with the cervical region is expected to grow in line with the rise in sedentary lifestyles and the ubiquity of technology. This can be attributed to a lack of physical activity and extended periods of exposure to digital devices (30).
One potential limitation of this study may be the lack of assessment of the entire vertebral column from lateral radiographs, that is cervical lordosis, thoracic kyphosis, lumbar lordosis and pelvic ratio. Furthermore, evaluation of cervical lordosis angle may be limited by the fact that the momentary posture of the patients may not accurately reflect their normal daily posture. In addition, patients with a normally aligned cervical spine may show abnormal positioning on radiographs due to the presence of current symptoms.

Conclusion

Evaluating cervical alignment will be beneficial in terms of resolving the complaints and complications associated with the cervical region and the eventual success of cervical surgery. In addition, evaluation of the change in cervical alignment is also important in terms of examining the causes of complaints and complications and the efficacy of treatment. The current study explored different measurement methods for determining cervical lordosis angle correctly in order to inform appropriate exercise programs, as well as evaluate the effectiveness of treatment. These findings have the potential to expand the existing knowledge in a number of fields and make a valuable contribution to the existing literature.

Ethical Approval: *Ethical approval was waived by the local Ethics Committee in view of the retrospective nature of the study and all the procedures being performed were part of the routine care (Protocol no: 5.7.2019/23).*

Author Contributions:
Concept: M.T., N.B., Ö.O.
Literature Review: M.T.
Design : M.T., H.E.
Data acquisition: M.T.
Analysis and interpretation: M.T., H.E., N.K.Ş.
Writing manuscript: M.T., H.E.
Critical revision of manuscript: H.E., R.W.S.

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