Research Article

A Preliminary Standardization Study of Cervical Spine Angles in Korean Normal Adult Men and Women According To Pillow Height in The Supine Position

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Abstract

Purpose: The purpose of this study was to measure the cervical angle in healthy adults in the supine position and to establish a standardized reference value for cervical alignment.
Methods: Fifty-four healthy adults who voluntarily agreed to participate in the study were recruited. Participants maintained a static supine position on a pillow for 1 min. A three-dimensional motion analysis system was used to measure changes in the Z-coordinate positions of markers placed at C1, C4, and C7. A towel was placed on a firm floor, and the pillow was positioned parallel to the X-axis of the motion analysis system, with one corner aligned with the coordinate origin. The participant's head was positioned at the center of the pillow, and movement and conversation were restricted during the measurement period. Cervical angles were calculated based on temporal changes in marker positions and analyzed as an indicator of cervical alignment.
Results: After 1 min, the mean cervical angle was 175.54 ± 2.16° in men, 175.79 ± 2.34° in women, and 175.66 ± 2.22° in the total sample. No significant differences in cervical angle or changes in the Z-coordinate positions of C1, C4, and C7 were observed between or within sex groups ($p > 0.05$). However, height-based analysis revealed significant differences in C1_Z between the 160-cm and >180-cm groups and in C7_Z in the 170-cm group ($p < 0.05$). Weight-based analysis showed significant differences in C1_Z in the 50–59 kg group and in C4_Z in the 60–69 kg group ($p < 0.05$), whereas no significant differences were observed among the other height or weight groups ($p > 0.05$). Post hoc analysis according to cervical alignment type revealed that the straight-neck group showed significant differences in C7_Z compared with the mild straight-neck, normal, mild kyphotic-neck, and kyphotic-neck groups ($p < 0.05$). These findings suggest that specific anthropometric factors may be partially associated with variations in cervical alignment.
Conclusions: The cervical angle of 175.66° measured in the supine position in this study may serve as a clinical reference value for cervical alignment during a sleep-related posture. This standardized value may provide a useful basis for evaluating sleeping posture and informing the ergonomic design and optimization of pillows.

Keywords: cervical angle; supine position; sleep posture; three-dimensional motion analysis; pillow.

I. Introduction

Sleep is an essential restorative process that not only supports biological recovery but also plays a critical role in reducing physical fatigue [1]. Humans spend approximately one-third of their lives asleep [2]. In addition to maintaining physical health, sleep plays a fundamental role in brain health and is considered an indispensable physiological function [3]. Poor sleep quality has been associated with various adverse health outcomes, including diabetes, hypertension, chronic pain, and elevated body mass index, potentially resulting in substantial negative consequences for overall health and well-being [4].

Neck pain is also a prevalent musculoskeletal complaint, with approximately 67% of adults experiencing neck pain at least once during their lifetime. Modern occupational environments and lifestyle patterns frequently involve prolonged sitting, sustained neck flexion, and repetitive cervical movements. Such conditions may contribute to a reduction in normal cervical lordosis, increased abnormal intervertebral motion, and impaired neuromuscular control of the deep cervical musculature due to repetitive overuse, ultimately contributing to the development of neck pain [5]. In particular, inappropriate sleeping postures have been identified as a contributing factor to the exacerbation of neck pain and are closely associated with pillow selection. Cyriax (1988) and Liebenson (1996) reported that cervical positioning during sleep may aggravate neck pain and proposed criteria for an optimal sleeping posture. An ideal sleeping posture is generally characterized by maintenance of the physiological spinal curvature with minimal muscular tension; in the supine position, this includes maintaining the normal cervical curvature [6]. Accordingly, increasing attention has been directed toward pillows designed according to ergonomic principles to optimize cervical support during sleep.

Pillows are an important component of the sleeping environment and can substantially influence both sleep quality and cervical alignment. An ergonomically appropriate pillow can provide stable support for the head and neck during sleep, potentially reducing excessive repositioning and promoting deeper and more restorative sleep. Furthermore, maintenance of the natural cervical curvature through appropriate cervical support has been suggested to contribute to overall spinal alignment and may help prevent musculoskeletal discomfort [7]. In particular, pillow height has a direct influence on cervical postural alignment [8]. Xinzhu Li et al. (2018) reported that a pillow height of 7 cm provided the most appropriate cervical alignment in the supine position [9]. Kwon et al. (1999) similarly reported that pillows designed according to cervical angular characteristics could facilitate the maintenance of physiological cervical curvature [10].

Conversely, sleeping with the cervical spine positioned outside its physiological range may increase muscular tension in the neck and shoulder regions, potentially contributing to musculoskeletal pain involving the head, neck, shoulders, and temporomandibular joint [11]. A study examining the relationship between cervical lordosis and neck pain reported that patients with a cervical angle of less than 20° were more likely to experience pain [12]. Therefore, selecting a comfortable pillow that facilitates maintenance of cervical lordosis may be important for achieving restorative sleep, and consideration of physiological cervical curvature should be an important factor in pillow selection. Nevertheless, cervical alignment is rarely considered systematically when individuals select pillows for sleep.

The C2–C7 Cobb angle is one of the most widely used radiographic measures for evaluating cervical lordosis and kyphosis. Although sagittal alignment varies considerably among individuals, the normal cervical spine generally maintains a lordotic curvature of approximately 20°–35° [13]. Appropriate cervical curvature has been associated with reduced neural compression and improved postoperative recovery [14]. Moreover, a systematic review examining the effects of posture on cervical alignment emphasized that standardization of posture is essential for valid comparisons of cervical sagittal balance parameters both within and between patients [15].

Previous studies have demonstrated that cervical alignment measurements may differ according to body position and imaging modality. A study comparing sagittal cervical angles measured using standing radiographs and supine magnetic resonance imaging (MRI) reported significant differences in the C2–C7 angle between the two imaging conditions, with greater cervical angles observed on radiographs than on MRI. The mean difference in cervical angle between the two modalities was 4.49° [16]. Similarly, a computed tomography (CT) study evaluating cervical sagittal alignment in the supine position reported that cervical lordosis was more pronounced on standing radiographs than on supine CT scans, in which the mean cervical lordosis was 5.93° ± 9.0°. This difference may be attributable to the differential effects of gravity on the cervical spine between upright and supine positions [17]. Conversely, another study reported a high correlation between cervical alignment measurements obtained from supine MRI and standing radiographs, with correlation coefficients of $r = 0.85$ for Cobb angle measurements and $r = 0.83$ for the posterior tangent method, indicating substantial agreement between the two measurement approaches [18].

Despite these findings, previous studies have predominantly focused on cervical alignment measured in sitting or standing positions, and a standardized reference value for cervical alignment in the supine position has not yet been established. Cervical alignment in the supine position may vary according to pillow height and material, while the effects of gravity and redistribution of body weight may produce alignment characteristics that differ from those observed in upright postures. Therefore, establishing a standardized measurement condition for cervical alignment in the supine position is necessary, particularly in the context of sleep posture and ergonomic pillow design.

Accordingly, the purpose of this study was to measure the cervical angle in healthy adults in the supine position under standardized pillow conditions and to establish a reference value for cervical alignment in this position. The findings of this study may provide a quantitative basis for evaluating cervical alignment during sleep and contribute to the development and ergonomic optimization of pillows designed to support physiological cervical alignment.

II. Materials and Methods

2.1. Participants

This study included 54 healthy adults (26 women and 28 men) in their 20s who were recruited from S University in Asan, Chungcheongnam-do, Republic of Korea. Before participation, all participants were provided with a detailed explanation of the purpose and procedures of the study. The required sample size was calculated using G*Power version 3.1.9.7 (Heinrich Heine University Düsseldorf, Düsseldorf, Germany). an a priori power analysis for the t-test indicated that a minimum sample size of 45 participants was required, assuming an effect size of 0.50, an alpha level of 0.05, a statistical power of 0.95, and an allocation ratio of 1:1. Considering an anticipated dropout rate of approximately 20%, a total of 54 participants were recruited.

Participants were eligible if they met all of the following criteria: (1) no congenital or acquired cervical deformity; (2) no acute or chronic neck pain; (3) no history of cervical spine disorders, including intervertebral disc herniation; (4) no related musculoskeletal injury within the previous 3 months; (5) no neurological abnormalities; and (6) no known allergy to the fabric material used for the pillow cover.

Participants were screened through individual interviews. Before enrollment, they received detailed information regarding the purpose and procedures of the experiment, participant protection, and study safety. They were also informed that any personal or physical information obtained during the study would be kept confidential and used solely for research purposes. Written informed consent was obtained from all participants before participation. The study protocol was reviewed and approved by the Institutional Review Board of Sunmoon University (SM-202505-008-1).

Purposive sampling, rather than simple random sampling, was used to achieve a relatively balanced distribution of participants across height and weight categories. Weight categories were defined as 40–49, 50–59, 60–69, 70–79, 80–89, and ≥90 kg. Recruitment was based on reference mean body weights of 57.3 kg for women and 72.2 kg for men in the Korean population. Nine participants were recruited for each weight category to minimize overrepresentation of a particular body-size range and to maintain a balanced distribution within the study population. In addition, participants were selected within the normal body mass index (BMI) range of 18.5–24.9 to minimize the potential influence of body composition on cervical alignment [19].

Height was categorized into four groups: 150–159, 160–169, 170–179, and ≥180 cm. Recruitment was conducted to achieve a relatively balanced distribution across height categories as well as weight categories.

Participants were classified according to cervical alignment based on changes in the Z-coordinate positions of the C1, C4, and C7 markers while maintaining a static supine position for 1 min. Classification was based on the difference between the initial measurement and the measurement obtained after 1 min. The classification criteria were based on previous studies by Lim et al. (2023) and Zhang et al. (2024) [20,21], and the detailed criteria are presented in Table 1.

Table 1. Classification of cervical alignment based on changes in Z-coordinate position

Classification	Criterion (Z-coordinate change)	Interpretation
Straight neck	≤ −1.5	Hyperlordotic tendency
Mild straight neck	> −1.5 to ≤ −0.5	Slight lordotic tendency
Normal	> −0.5 to ≤ 0.5	Stable alignment
Mild kyphotic neck	> 0.5 to ≤ 1.5	Slight kyphotic tendency
Kyphotic neck	> 1.5	Kyphotic tendency

Note. Classification criteria were based on previous studies by Lim et al. (2023) and Zhang et al. (2024) [20,21].

2.2. Experimental Procedures

A three-dimensional motion analysis system (Qualisys system; Qualisys AB, Gothenburg, Sweden) equipped with five cameras (Oqus 300; Qualisys AB, Gothenburg, Sweden) was used to measure the cervical angle and changes in the Z-coordinate positions of the C1, C4, and C7 markers in the supine position (Figure 1). The Z-coordinate positions of the C1, C4, and C7 markers (C1_Z, C4_Z, and C7_Z, respectively) were defined as indicators of cervical alignment, with the Z-coordinate representing the vertical position of each marker within the three-dimensional coordinate system.

Before the main experiment, a pilot test was conducted with one healthy male and one healthy female whose heights approximated the Korean population mean. The purpose of the pilot test was to verify the reliability and feasibility of the measurement equipment and experimental procedures and to facilitate standardized implementation of the main experiment. During the pilot test, the distances between the C1 and C4 spinous processes and between the C4 and C7 spinous processes were measured, and the mean values were calculated. These mean distances were subsequently used to determine the spacing between markers attached to the pillow. The results of the pilot measurements are presented in Table 2.

Table 2. Distances between the cervical spinous processes (C1–C4 and C4–C7)

Sex	C1–C4 distance (mm)	C4–C7 distance (mm)
Men	7.1	6.6
Women	6.3	5.7
Total	6.7	6.15

Figure 1. Five-camera Qualisys three-dimensional motion analysis system

2.3. Pillow

The pillow used in this study was a memory foam pillow (Sillion, Republic of Korea, 2025) manufactured from polyurethane foam. The pillow measured 50 cm in length, 38 cm in width, and 5–7 cm in height. The pillow cover was made of a conventional fabric material designed to provide comfortable contact with the skin (Figure 2).

Unlike a conventional flat pillow, the pillow used in this study had a customized contoured structure designed to provide continuous support from the lower thoracic region to the upper cervical region. Its design was intended to support maintenance of the physiological cervical lordotic curvature during the supine position.

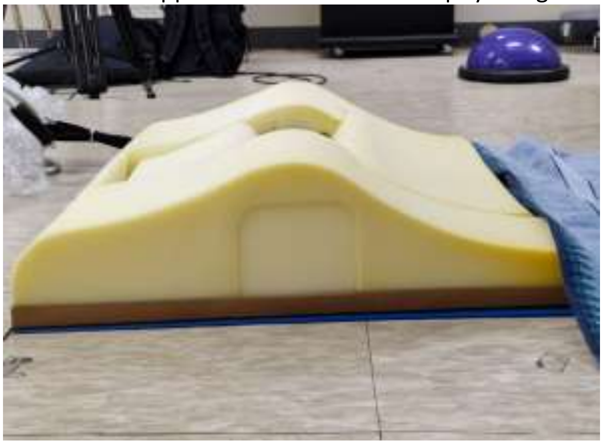

Figure 2. Memory foam pillow used in the study (Cellion, Korea, 2026)

2.4. Outcome Measures

All participants visited the laboratory once for the measurement session. All measurements were performed under identical conditions, with participants lying in the supine position on the same pillow and maintaining a static posture.

The experiment was conducted on a firm floor covered with a towel. The pillow was positioned parallel to the X-axis of the three-dimensional motion analysis system, and one corner of the pillow was aligned with the coordinate origin. The midpoint of the lateral edge of the pillow was designated as the reference position corresponding to the C4 spinous process. Based on the mean distances obtained during the pilot test, markers were attached to the lateral edge of the pillow along a vertical line.

Three markers were positioned in a straight line: one marker was placed at the midpoint of the lateral edge, one marker was placed 6.7 mm superior to the midpoint, and one marker was placed 6.15 mm inferior to the midpoint (Figure 3). The positions of all markers were standardized before each experiment. The participant's posture was adjusted so that the C4 spinous process was precisely aligned with the marker corresponding to C4 on the pillow.

Measurement began immediately when the participant assumed the supine position on the pillow and continued for 1 min. Participants were instructed to remain relaxed and refrain from talking or unnecessary movement during the measurement period (Figure 4). As time elapsed, relaxation of the cervical musculature and pressure exerted by the weight of the head caused positional changes in the markers attached to the lateral edge of the pillow. The cervical angle calculated from these marker displacements was defined as the cervical angle observed in the supine position.

The measurement data were collected at a sampling frequency of 100 Hz using QTM (Qualisys Track Manager) version 2.5 (Qualisys AB, Gothenburg, Sweden) [22]. Marker coordinates were recorded immediately after the participant assumed the supine position and again after 1 min. The coordinates of all markers along the X-, Y-, and Z-axes were analyzed to quantify changes in the spatial position of the pillow and the participant's head over time.

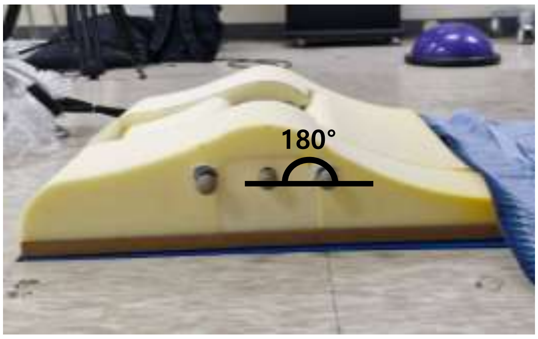

Figure 3. Marker attached pillow

Figure 4. Supine position

2.5. Data Analysis

All statistical analyses were performed using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the general characteristics of the participants, and the mean and standard deviation (SD) of the cervical angle measured after 1 min were calculated.

The Shapiro–Wilk test was performed to assess the normality of the changes in the Z-coordinate positions of C1, C4, and C7 between the initial measurement and the 1-min measurement. As the data were normally distributed, paired-samples t-tests were used to evaluate within-group changes according to sex, height, and weight categories. Independent-samples t-tests were used to compare changes between groups.

Pearson's correlation analysis was subsequently performed to examine the associations of sex, height, and body weight with the cervical angle measured after 1 min. Finally, participants were classified into five cervical alignment categories—straight neck, mild straight neck, normal, mild kyphotic neck, and kyphotic neck—based on changes in cervical angle between the initial and 1-min measurements. Post hoc comparisons among the cervical alignment groups were performed using the least significant difference (LSD) test.

For all statistical analyses, statistical significance was set at $p < 0.05$.

III. Results

3.1. Participant Characteristics

Among the 54 participants, 28 were men and 26 were women. The mean age was 21.14 ± 1.41 years for men, 21.08 ± 1.09 years for women, and 21.11 ± 1.25 years for the total sample. The mean height was 177.11 ± 5.73 cm for men, 162.65 ± 4.63 cm for women, and 170.15 ± 8.94 cm for the total sample. The mean body weight was 72.89 ± 16.95 kg for men, 66.54 ± 15.63 kg for women, and 69.83 ± 16.49 kg for the total sample.
The mean cervical angle measured after 1 min was 175.54 ± 2.16° in men, 175.79 ± 2.34° in women, and 175.66 ± 2.22° in the total sample. The mean post-measurement C1_Z values were 86.76 ± 2.28 in men, 86.80 ± 1.93 in women, and 86.78 ± 2.10 in the total sample. The corresponding C4_Z values were 86.27 ± 2.80, 86.77 ± 1.63, and 86.51 ± 2.30, respectively. The post-measurement C7_Z values were 82.41 ± 3.98 in men, 83.34 ± 1.83 in women, and 82.86 ± 3.15 in the total sample. Detailed participant characteristics are presented in Table 3.

Table 3. Participant characteristics

Gender / Variable	Male(n=28)	Female(n=26)	Total(n=54)
Age(years)	21.14±1.41	21.08±1.09	21.11±1.25
Height(cm)	177.11±5.73	162.65±4.63	170.15±8.94
Weight (Kg)	72.89±16.95	66.54±15.63	69.83±16.49
Post Angle	175.54±2.16	175.79±2.34	175.66±2.22
Post C1_Z	86.76±2.28	86.80±1.93	86.78±2.10
Post C4_Z	86.27± 2.80	86.77± 1.63	86.51±2.30
Post C7_Z	82.41±3.98	83.34±1.83	82.86±3.15

3.2. Changes in Cervical Angle and Z-Coordinate Positions According to Sex

Paired-samples and independent-samples t-tests were performed to compare pre-to-post changes in cervical angle and the Z-coordinate positions of C1, C4, and C7 according to sex. The results are presented in Table 4.
No significant within-group difference was observed in cervical angle between the pre- and post-measurements in either sex group (p > 0.05). Similarly, no significant between-group difference was observed in cervical angle changes between men and women (p > 0.05).
No significant sex-related differences were observed in the pre-to-post changes in the Z-coordinate positions of C1, C4, or C7 (p > 0.05). These findings indicate that sex did not significantly influence changes in cervical angle or cervical marker position during the 1-min supine measurement period.

Table 4. Differences in cervical angle and Z-coordinate positions according to sex

	Angle				C1_Z				C4_Z				C7_Z			
	pre	post	t	p	pre	post	t	p	pre	post	t	p	pre	post	t	p
Male	175.86 ±2.17	175.54 ±2.16	0.754	0.46	86.55 ±2.11	86.76 ±2.28	-1.912	0.07	86.11 ±2.57	86.27 ±2.80	-0.737	0.47	82.79 ±3.24	82.41 ±3.98	0.744	0.46
Female	175.33 ±2.86	175.79 ±2.34	-0.411	0.68	86.32 ±2.50	86.80 ±1.93	-1.637	0.11	86.4 ±1.58	86.77 ±1.63	-1.805	0.08	82.79 ±2.39	83.34 ±1.83	-1.504	0.15
t	0.580	0.170			0.131	0.006			0.318	0.624			0.000	1.180		
p	0.45	0.68			0.72	0.94			0.58	0.43			0.99	0.28		

3.3. Changes in Cervical Angle and Z-Coordinate Positions According to Height

Pre-to-post changes in cervical angle and the Z-coordinate positions of C1, C4, and C7 were analyzed according to height group. The results are presented in Table 5.
No significant differences in cervical angle were observed between the pre- and post-measurements within any height group or between height groups ($p > 0.05$).
However, paired-samples t-tests examining changes in the Z-coordinate positions of C1, C4, and C7 within each height group revealed significant differences in selected groups. For C1_Z, significant pre-to-post differences were observed in the 160-cm group ($t = −2.480$, $p = 0.01$) and the >180-cm group ($t = −2.432$, $p = 0.02$). For C7_Z, a significant pre-to-post difference was observed in the 170-cm group ($t = −2.068$, $p = 0.04$). No significant differences were observed for the remaining height groups ($p > 0.05$).

Table 5. Differences in cervical angle and Z-coordinate positions according to height

	Angle				C1_Z				C4_Z				C7_Z			
	pre	post	t	p	pre	post	t	p	pre	post	t	p	pre	post	t	p
<150cm (n=12)	174.81 ±3.17	175.16 ±2.37	-0.435	0.67	86.28 ±3.28	87.00 ±2.36	-1.098	0.27	86.29 ±2.81	86.41 ±3.11	-1.647	0.10	82.62 ±4.66	81.86 ±4.66	-0.471	0.64
160cm (n=14)	176.39 ±2.48	175.79 ±0.73	1.634	0.13	86.18 ±1.98	86.56 ±1.92	-2.480	0.01*	86.05 ±1.69	86.55 ± 1.80	-1.538	0.12	82.88 ±3.26	83.06 ±3.04	-0.220	0.83
170cm (n=16)	176.07 ±2.03	176.43 ±1.97	-1.121	0.28	86.50 ±1.94	86.52 ±2.15	-0.879	0.38	86.43 ±1.84	86.52 ±2.05	-0.517	0.61	83.22 ±2.75	83.80 ±2.12	-2.068	0.04*
>180cm (n=12)	174.86±2.31	174.99 ±1.59	-0.288	0.78	86.80 ±2.11	87.17 ±2.15	-2.432	0.02*	86.29 ±2.44	86.55 ±2.51	-0.941	0.35	82.28 ±2.83	82.39 ±2.50	0.000	1.00
f	1.412	1.239			0.718	0.302			0.076	0.009			0.260	0.984		
p	0.25	0.31			0.91	0.82			0.97	1.00			0.85	0.41		

3.4. Changes in Cervical Angle and Z-Coordinate Positions According to Body Weight
Pre-to-post changes in cervical angle and the Z-coordinate positions of C1, C4, and C7 were analyzed according to body-weight group. The results are presented in Table 6.
No significant pre-to-post differences in cervical angle were observed within the body-weight groups, and no significant differences were observed between groups ($p > 0.05$).
However, significant pre-to-post changes in Z-coordinate position were observed in selected body-weight groups. For C1_Z, a significant difference was observed in the 50–59 kg group ($t = −2.310$, $p = 0.02$). For C4_Z, a significant difference was observed in the 60–69 kg group ($t = −2.073$, $p = 0.04$). No significant differences in C1_Z, C4_Z, or C7_Z were observed in the other body-weight groups ($p > 0.05$).

Table 6. Differences in cervical angle and Z-coordinate positions according to body weight

	Angle				C1_Z				C4_Z				C7_Z			
	pre	post	t	p	pre	post	t	p	pre	post	t	p	pre	Post	t	p
40~49kg (n=9)	175.25±3.29	175.21±2.03	0.041	0.97	85.98 ±3.33	86.84 ±2.04	-0.415	0.68	86.72 ±1.76	86.92 ±1.72	-0.474	0.64	83.50 ±1.57	83.18 ±2.06	-1.007	0.31

50~59kg (n=9)	175.68±2.91	176.48±1.04	-1.911	0.09	86.24 ±2.64	86.57 ±2.52	-2.310	0.02 *	86.14 ±1.96	86.37 ±2.01	-0.059	0.95	82.57 ± 2.71	83.43 ± 2.15	-1.718	0.09
60~69kg (n=9)	175.94±1.26	176.00±3.17	1.057	0.94	87.08 ±1.37	87.20 ±1.38	-1.362	0.17	86.19 ± 1.36	86.63 ± 1.44	-2.073	0.04 *	82.17 ± 4.24	82.79 ± 3.66	-0.059	0.95
70~79kg (n=9)	175.76±0.66	176.14±0.62	-0.759	0.47	85.91 ±2.44	85.88 ±2.74	-0.533	0.59	85.27 ± 3.32	85.18 ± 3.24	-0.178	0.86	82.01 ± 3.70	81.77 ± 3.65	-0.296	0.77
80~89kg (n=9)	175.39±0.51	175.20±0.39	0.596	0.57	86.35 ±2.12	86.77 ±2.14	-1.836	0.07	86.07 ±2.60	86.68 ±2.72	-1.836	0.07	82.73 ± 2.46	83.19 ± 1.95	-1.836	0.07
90kg~ (n=9)	175.62±1.43	174.94±1.39	1.253	0.25	87.06 ±1.66	87.42 ±1.76	-1.955	0.05	87.23 ± 1.10	87.28 ± 2.30	-1.125	0.26	83.77 ± 1.68	82.87 ± 4.93	-0.059	0.95
f	0.080	0.686			0.434	0.564			0.849	0.869			0.542	0.290		
p	1.00	0.64			0.82	0.73			0.52	0.51			0.74	0.92		

3.5. Associations of Sex, Height, and Body Weight With Cervical Angle

Pearson correlation analysis was performed to examine the associations of height and body weight with the cervical angle measured after 1 min. The results are presented in Table 7.

No statistically significant correlations were observed between cervical angle and either height or body weight. The correlation between height and cervical angle was negligible ($r = -0.001$, $p = 0.99$), whereas the correlation between body weight and cervical angle was weak and negative ($r = -0.084$, $p = 0.55$).

Table 7. Correlations of height and body weight with cervical angle

		Height(cm)	Weight(kg)
Cervical angle after 1 minute	r	-0.001	-0.084
	p	0.99	0.55

3.6. Analysis According to Cervical Alignment Type

A one-way analysis of variance (ANOVA) was performed to compare changes in the Z-coordinate positions of C1, C4, and C7 among the five cervical alignment groups. A significant between-group difference was observed only for C7_Z ($F = 2.604$, $p = 0.04$), whereas no significant differences were observed for C1_Z or C4_Z (Table 8).

Post hoc analysis using the least significant difference (LSD) test revealed significant differences in C7_Z between the straight-neck group and each of the mild straight-neck, normal cervical alignment, mild cervical kyphosis, and cervical kyphosis groups ($p < 0.04$). No significant differences were observed among the other cervical alignment groups ($p > 0.05$).

These findings indicate that changes in the C7_Z position differed significantly according to cervical alignment type, whereas changes in the C1_Z and C4_Z positions did not demonstrate significant between-group differences (Figure 5).

Table 8. Comparison of changes in C1_Z, C4_Z, and C7_Z according to cervical alignment type

	C1_Z	C4_Z	C7_Z
Stsraight Neck	0.49±0.64	0.14±2.15	-2.17±4.25
Mild Straight Neck	0.25±0.36	0.34±0.56	-0.11±0.60
Nomal Cervical	0.26±0.29	0.40±0.87	0.53±1.55

Mild Cervical Kyphosis	0.19±0.49	0.02±0.90	0.59±1.30
Cervical Kyphosis	0.69±2.87	1.03±0.37	1.12±3.30
f	0.290	0.285	2.604
P	0.88	0.89	0.04*

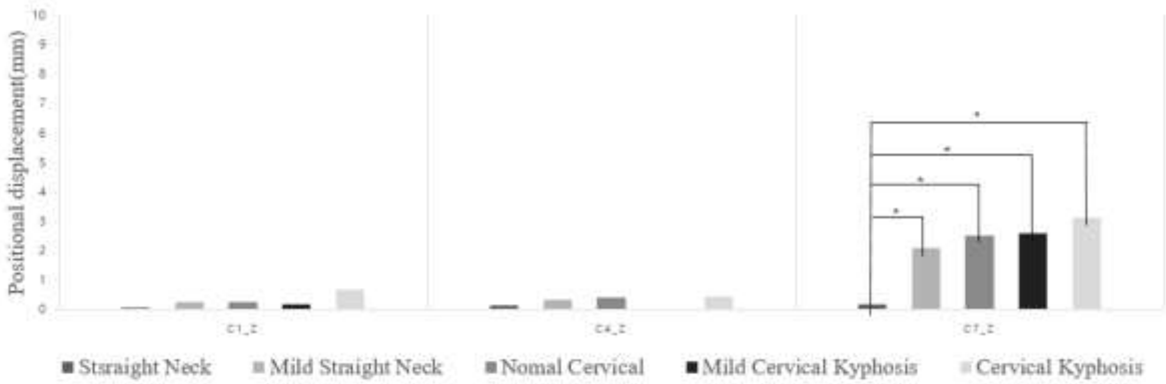

Figure 5. Comparison of changes in C1_Z, C4_Z, and C7_Z among cervical alignment groups

IV. Discussion

The purpose of this study was to measure the cervical angle in healthy adults in the supine position and to propose a standardized reference for cervical alignment during sleep-related positioning. The mean cervical angle observed in the present study was 175.66°, and no clear differences were identified according to sex, height, body weight, or cervical alignment type, although statistically significant differences were observed in a limited number of specific variables. These findings suggest that cervical alignment in the supine position may remain relatively stable across different demographic and anthropometric characteristics under standardized conditions. Importantly, the cervical angle defined in this study is not equivalent to the conventional C2–C7 Cobb angle. Instead, it represents an externally derived angle calculated from marker-coordinate data obtained using a three-dimensional motion analysis system (Qualisys system), with markers attached along the lateral edge of the pillow. In this measurement approach, the cervical angle approaches 180° as cervical lordosis decreases. Therefore, the present study provides preliminary evidence regarding the stability of cervical alignment in the supine position and supports the possibility of establishing standardized reference values for cervical alignment in sleep-related environments.

The overall mean cervical angle was 175.66°, with nearly identical values observed in men and women (175.54° and 175.79°, respectively). Mean cervical angles across body-weight categories also remained close to 175°, indicating a generally stable pattern. Although the 50–59 kg and 60–69 kg groups demonstrated slightly greater mean angles of 176.48° and 176.00°, respectively, whereas the ≥90 kg group showed a somewhat lower mean angle of 174.94°, these differences were limited in magnitude. Collectively, these findings indicate that overall cervical alignment in the supine position is relatively stable and that the effects of sex and body weight may be limited under short-term standardized conditions.

No statistically significant differences were identified according to sex, suggesting that sex may not be a major determinant of short-term changes in cervical alignment in the supine position. In a similar context, Guvercin et al. (2023) reported no significant sex-related differences in several cervical parameters, including Atlanta dental distance, transverse ligament thickness, and positional displacement, which is partially consistent with the present findings. However, the same study reported that anatomic cervical lordosis was significantly greater in women than in men. The authors further noted that age-related changes in anatomic cervical lordosis were more pronounced in women and suggested that this may be associated with relative weakening of the posterior tension band [23]. Similarly, Zhang et al. (2024) reported that men exhibited significantly greater values than women in specific cervical parameters, including C2–C7 lordosis [24]. Taken together, previous studies suggest that sex may influence anatomical cervical alignment and lordotic curvature under some conditions. Nevertheless, the present findings indicate that under short-term, standardized supine conditions, the influence of sex on cervical alignment may be relatively limited.

Most height-related comparisons were not statistically significant, although significant changes were observed in selected groups. This finding suggests that cervical alignment may be more sensitive to positional or postural changes within certain height ranges. Ahmed et al. (2020) reported that taller individuals may have greater cervical spinal canal dimensions, potentially allowing more effective distribution of mechanical pressure or loading across the cervical region [25]. Although the present study did not identify a consistent linear relationship between height and cervical angle, the significant changes observed in selected height groups suggest that anthropometric characteristics may influence local cervical responses under specific conditions.

Body weight also showed no overall significant effect on cervical angle, although significant changes were identified within selected weight categories. These findings are partially consistent with previous studies reporting associations between body composition and cervical alignment. Kim et al. (2018) reported that greater fat accumulation around the cervical extensor musculature was associated with reduced cervical lordosis and that this reduction may be related to neck pain [26]. Le Huec et al. (2022), in a multinational study of asymptomatic adults, found that the Arab-Berber population had a higher body mass index than other groups and demonstrated differences in mean cervical inclination angle [27]. These findings suggest that body mass index may influence spinal alignment in addition to reflecting body weight alone. Similarly, Tomczak et al. (2019) reported that older age and higher body mass index were associated with a smaller craniovertebral angle, indicating a more anterior head position [28]. Collectively, these studies suggest that body weight and body composition may have some influence on head and cervical positioning, although sagittal cervical alignment may remain relatively stable in healthy individuals under controlled supine conditions.

No significant correlations were found between height, body weight, and cervical angle. This suggests that basic anthropometric characteristics may not be directly associated with short-term cervical angle changes under the present experimental conditions. Kawasaki et al. (2022) similarly reported no significant correlation between age or body type and the craniovertebral angle [29]. In contrast, Tao et al. (2021) reported that a greater T1 slope was associated with increased lower cervical lordosis at C2–C7 and that age and sex exerted partial effects on these relationships. However, no significant associations were identified between age or sex and upper cervical alignment at C0–C2 [30]. These findings support the possibility that anthropometric and demographic factors may exert region-specific rather than uniform effects on cervical alignment.

In the present study, significant between-group differences were identified only for selected changes in the Z-coordinate positions of C1, C4, and C7. This suggests that specific cervical segments may respond more sensitively to positional changes depending on cervical alignment type. In particular, the straight-neck group appeared to demonstrate greater positional responsiveness than the other alignment groups, suggesting that structural characteristics of the cervical spine may influence stability in the supine position. This interpretation is partially consistent with the findings of Wang et al. (2024), who compared sagittal cervical alignment and muscle function according to cervical lordosis type. They reported that the relaxation ratios of the splenius capitis, upper trapezius, and sternocleidomastoid muscles were greater in individuals with cervical lordosis than in those with cervical kyphosis [31]. These findings indicate that cervical alignment type may influence muscle behavior. Greater muscle relaxation could theoretically permit larger changes in cervical angle in the supine position; however, this mechanism does not fully correspond with the response observed in the present study. The discrepancy may be attributable to differences in participant age, sample size, measurement posture, and experimental conditions between studies.

The standardized cervical angle identified in the present study may have clinical implications for sleep-related cervical alignment. Establishing a range within which cervical lordotic alignment remains relatively stable may provide a basis for determining appropriate pillow height and design. In addition, standardized cervical angle values may be useful when recommending individualized sleeping postures or when establishing reference criteria for cervical rehabilitation exercises and postural correction. Jeon et al. (2014) and Oakley et al. (2021) reported that maintaining appropriate cervical alignment is associated with the prevention of neck pain, reduction of neural compression, and improvement of sleep-related outcomes [32,33]. The present findings extend these clinical considerations by providing a quantitative reference derived specifically from measurements obtained in the supine position.

This study has several limitations. First, the participants were limited to healthy young adults, and therefore the findings cannot be directly generalized to individuals with neck pain, cervical spine disorders, or other clinical conditions. Second, the study was restricted to a single posture, namely the supine position, and to a short measurement period. Consequently, the findings may not fully reflect the range of postural changes and prolonged cervical alignment patterns that occur during natural sleep. Third, individual differences in cervical

muscle tone, habitual sleeping posture, and spontaneous positional adjustment may have influenced cervical angle measurements and could not be completely controlled.
Future studies should therefore include broader age ranges and clinical populations and compare cervical alignment across different sleeping postures, including side-lying and prone positions. Long-term monitoring during actual sleep is also needed to determine how cervical alignment changes over extended periods. Furthermore, the simultaneous assessment of physiological variables, such as electromyographic activity and sleep-related movement, may allow a more comprehensive understanding of the interaction between cervical alignment, muscle behavior, and sleeping posture. Such investigations may strengthen both the scientific validity and the clinical applicability of standardized cervical alignment measurements in the supine position.

V. Conclusions

This study aimed to measure and standardize the cervical angle in healthy adults in the supine position. The mean cervical angle of 175.66° identified in this study differs from conventional Cobb angle measurements reported in upright positions and may serve as a clinically relevant reference measure for cervical alignment in a posture directly associated with sleep. These findings may provide a basis for ergonomic pillow design, correction of sleeping posture, and the development of rehabilitation strategies for patients with musculoskeletal disorders. Ultimately, standardized assessment of cervical alignment in the supine position may contribute to improving sleep quality and preventing cervical musculoskeletal disorders.

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