



SLEEP QUALITY AND CERVICAL ALIGNMENT IN CHRONIC NECK PAIN

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ABSTRACT

Objective: Sleep impairment frequently accompanies chronic neck pain, but its relationship with cervical sagittal radiographic morphology remains unclear. To investigate associations between sleep quality, neck-specific disability, and cervical sagittal alignment in adults with chronic neck pain.

Materials and Methods: This retrospective cross-sectional study included 86 adults evaluated at a single institution for neck pain lasting at least 6 months. Sleep quality and functional disability were assessed using the Pittsburgh sleep quality index (PSQI) and neck disability index (NDI), respectively. A PSQI score above 5 was defined as poor sleep quality. Lateral cervical radiographs were used to measure C2-C7 lordosis, C7 slope, T1 slope, and T1 slope-C2-C7 Cobb angle (T1S-CL mismatch). Analyses included group comparisons, Spearman correlation, univariable logistic regression, multivariable logistic regression, and multivariable linear regression.

Results: Forty-five patients (52.3%) had poor sleep quality. They had a smaller median C2-C7 lordosis and a higher median NDI score compared with patients with good sleep quality. Higher PSQI scores correlated with lower C2-C7 lordosis and higher C7 slope, T1S-CL mismatch, NDI score, and symptom duration. In multivariable linear regression, NDI remained positively associated with PSQI after adjustment. No evaluated variable remained independently associated with poor sleep quality in the multivariable logistic regression model.

Conclusion: Poor sleep quality was associated with greater neck-related disability and reduced cervical lordosis in adults with chronic neck pain. Joint assessment of sleep quality, disability, and cervical sagittal alignment may enable broader clinical characterization. These findings should be interpreted cautiously because the study was cross-sectional.

Keywords: Chronic neck pain, sleep disturbance, cervical sagittal alignment, Pittsburgh sleep quality index, Neck disability index

INTRODUCTION

Chronic neck pain may interfere with daily activities, emotional well-being, and occupational functioning, extending its impact beyond the presence of pain alone. Sleep problems are frequently encountered in this patient population and are also associated with greater clinical burden. Evidence from experimental and longitudinal research indicates that sleep impairment and pain may influence each other; however, the mechanisms and relative importance of these reciprocal effects remain uncertain⁽¹⁾. Studies focusing specifically on individuals with neck pain have linked poorer sleep with greater neck-related disability and prolonged symptoms⁽²⁻⁴⁾.

Several mechanisms may account for the relationship between disturbed sleep and persistent neck symptoms. Experimental evidence has linked inadequate sleep with heightened nociceptive processing, reduced endogenous pain control, greater

fatigue, and greater perceived functional limitation. Conversely, ongoing neck pain has been associated with difficulties in sleep onset and continuity, supporting a potentially bidirectional relationship between sleep impairment and pain. Evidence from a cotwin analysis indicates that shared hereditary influences may partly contribute to this relationship, suggesting that it cannot be attributed exclusively to mechanical, behavioral, or lifestyle-related factors⁽²⁾. Nevertheless, previous investigations have concentrated mainly on symptom severity, psychosocial characteristics, and functional disability, whereas the possible role of cervical sagittal morphology has been examined far less extensively.

Radiographic assessment of cervical sagittal balance is increasingly used to characterize cervical spine disorders. The principal measurements include C2-C7 lordosis, C7 slope, T1 slope, and the T1 slope-C2-C7 Cobb angle (T1S-CL mismatch)^(5,6). Together, these variables describe the orientation of the cervicothoracic junction and the degree to which cervical curvature accommodates

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the underlying sagittal profile. Because a greater T1 slope generally requires a corresponding increase in cervical lordosis to preserve forward gaze, an excessive T1S-CL mismatch may indicate inadequate compensatory curvature⁽⁷⁾. Clinical studies have further reported relationships between disturbed cervical alignment, axial neck symptoms, degenerative changes, and worse patient-reported function⁽⁸⁻¹²⁾.

Although sleep disturbance and cervical sagittal alignment have each been studied in relation to neck pain, their relationship within the same patient population remains poorly characterized. Determining whether sleep impairment accompanies specific radiographic patterns, in addition to greater functional limitation, could improve the clinical phenotyping of chronic neck pain. Such an approach is relevant because sleep represents a potentially modifiable component of the condition, whereas sagittal measurements may provide objective information about cervical mechanical configuration. This study investigated whether sleep quality was related to neck-specific disability and sagittal cervical radiographic measurements in adults with chronic neck pain. We expected poorer sleep quality to accompany greater disability and less favorable sagittal alignment, with reduced C2-C7 lordosis considered the primary radiographic pattern of interest.

MATERIALS AND METHODS

Study Design and Setting

This retrospective cross-sectional investigation was conducted at a single orthopedic outpatient center. The source population comprised adults evaluated for neck pain persisting for at least 6 months between January 2024 and December 2025. Records were screened for the concurrent availability of clinical information, completed Pittsburgh sleep quality index (PSQI) and neck disability index (NDI) questionnaires, and technically adequate lateral cervical radiographs. Data obtained during the corresponding clinical assessment were extracted and evaluated at a single time point. Accordingly, the analyses were intended to evaluate associations among variables and not to establish temporal or causal relationships.

The study protocol was approved by the Scientific Research Ethics Committee of University of Health Sciences Türkiye, Adana City Training and Research Hospital (approval no: 1499, date: 25.06.2026). The research procedures conformed to the Declaration of Helsinki, and the dataset was de-identified before statistical analysis. Patient data were analyzed after anonymization. The requirement for written informed consent was handled in accordance with the decision of the ethics committee.

Study Population

Patients were eligible when they were adults with neck pain of at least 6 months' duration and had complete PSQI, NDI, clinical, and lateral cervical radiographic records from the same assessment period. Radiographs were required to permit

reliable measurement of the prespecified sagittal parameters. Records were not considered when patients had undergone previous cervical spine surgery or had a history of cervical trauma, spinal infection, neoplastic disease, inflammatory rheumatic disease, congenital cervical deformity, or a major neurologic deficit. Images with inadequate visualization or technical quality for sagittal measurement were also excluded. Each individual contributed only one record to the analytical cohort. The variables used in the final analyses were complete for all included patients.

Clinical and Questionnaire-based Assessment

Age, sex, and symptom duration were obtained from the clinical records. Previous management was recorded under four categories: medical treatment, physical therapy, lifestyle modification, and exercise participation. Symptom duration was expressed in months.

Sleep status was quantified with the PSQI, which provides a global score from 0 to 21 for sleep during the previous month. Increasing scores represent progressively poorer sleep. The global PSQI score was retained as a continuous variable for correlation and linear regression analyses to preserve the full range of sleep quality information. For categorical analyses, the established PSQI cut-off of >5 was used to distinguish poor from good sleep quality, allowing clinically interpretable group comparisons and logistic regression analyses.

Neck-specific functional limitation was measured with the NDI. The total NDI score was evaluated continuously in the main statistical analyses. For descriptive presentation, scores were grouped as no disability (0-4), mild disability (5-14), moderate disability (15-24), severe disability (25-34), or complete disability (35-50)^(13,14). A separate standardized measure of pain intensity, such as a visual analog scale or numerical rating scale, was not consistently available in the retrospective records for the corresponding assessment period and therefore could not be included in the analyses. Standardized psychological assessments for symptoms such as anxiety and depression were not routinely available in the retrospective records and therefore could not be included in the analyses.

Radiographic Assessment

Sagittal measurements were obtained from lateral cervical radiographs. The radiographic variables comprised C2-C7 lordosis, C7 slope, T1 slope, and T1S-CL mismatch.

C2-C7 lordosis was determined from the angle formed by lines drawn along the inferior endplates of C2 and C7. T1 slope was defined by the inclination of the superior T1 endplate relative to a horizontal line. The corresponding inclination of the superior C7 endplate was recorded as C7 slope. T1S-CL mismatch was derived for each patient as follows:

T1S-CL mismatch=T1 slope-C2-C7 Cobb angle

All measurements were expressed in degrees. Agreement between observers was examined using an intraclass correlation coefficient (ICC) derived from a two-way random-effects,

absolute-agreement model. The resulting ICC is presented with the study findings.

Outcomes

The primary outcome was poor sleep quality, defined as PSQI >5. Secondary analyses evaluated the PSQI score as a continuous outcome. The main explanatory variables were cervical sagittal radiographic parameters, NDI score, symptom duration, age, sex, and treatment-related variables.

Statistical Analysis

Statistical analyses were conducted using R version 4.6.1. Continuous data are reported as medians with interquartile ranges (IQRs) because the principal clinical and questionnaire scores did not follow a normal distribution or were ordinal in nature. Categorical data are summarized as numbers and percentages.

For the between-group analyses, patients were divided according to PSQI-defined sleep status. Continuous variables were examined with the Mann-Whitney U test, while categorical variables were assessed with Fisher's exact test.

Relationships between the continuous PSQI score and clinical or radiographic measurements were evaluated using Spearman's rank correlation coefficient. The same correlation method was applied separately to investigate the associations between NDI scores and cervical sagittal measurements.

Separate univariable logistic regression models were fitted with poor sleep quality as the binary dependent variable. Effect estimates are presented as odds ratios (ORs) with 95% confidence intervals. The multivariable logistic regression model incorporated age, sex, T1S-CL mismatch, NDI score, and symptom duration. Covariate selection was determined a priori according to clinical relevance, the need to limit the number of predictors relative to the available sample size, and the need to avoid redundancy among closely related sagittal alignment parameters. Because T1S-CL mismatch was calculated from T1 slope and C2-C7 Cobb angle, T1 slope, C2-C7 Cobb angle, and T1S-CL mismatch were not entered simultaneously into the same multivariable model. T1S-CL mismatch was selected as a composite sagittal parameter to represent the relationship between cervicothoracic inclination and cervical lordosis while avoiding simultaneous inclusion of mathematically dependent sagittal variables.

A multivariable linear regression model was also constructed with the total PSQI score as the dependent variable. Age, sex, T1S-CL mismatch, NDI score, and symptom duration were entered simultaneously as covariates. Model estimates are presented as unstandardized regression coefficients with their standard errors (SEs). Variance inflation factors (VIFs) were examined to evaluate multicollinearity among variables included in the final multivariable model, and VIF values >5 were considered suggestive of relevant multicollinearity.

All analyses were two-tailed, and statistical significance was defined as $p < 0.05$.

RESULTS

The final cohort comprised 86 patients, with complete clinical and radiographic data available for all evaluated variables. The median age was 54.00 years (IQR, 51.25-58.00), and 54 patients (62.8%) were female. The median PSQI score was 6.00 (IQR, 4.00-6.00), and 45 patients (52.3%) were classified as having poor sleep quality. According to NDI classification, 47 patients (54.7%) had mild disability and 39 patients (45.3%) had moderate disability (Table 1).

When patients were compared according to sleep quality, the poor sleep quality group had a lower median C2-C7 lordosis than the good sleep quality group [9.00 (IQR, 5.00-13.90) vs. 25.30 (IQR, 6.00-30.30), $p = 0.003$]. T1 slope distribution differed between groups ($p = 0.035$). The poor sleep quality group had higher NDI scores than the good sleep quality group [16.00 (IQR, 10.00-18.00) vs. 12.00 (IQR, 10.00-16.00), $p = 0.040$]. Exercise participation was more frequent in the poor sleep quality group (64.4% vs. 26.8%, $p < 0.001$). Age, sex, C7 slope, T1S-CL mismatch, symptom duration, medical treatment, physical therapy, and lifestyle change did not differ significantly between sleep quality groups (Table 2). The interobserver reliability of radiographic measurements was good, with an ICC of 0.83.

Spearman correlation analysis showed that PSQI score was negatively correlated with C2-C7 lordosis ($\rho = -0.219$, $p = 0.043$) and positively correlated with C7 slope ($\rho = 0.242$, $p = 0.025$), T1S-CL mismatch ($\rho = 0.220$, $p = 0.042$), NDI score ($\rho = 0.436$,

Table 1. Baseline characteristics of the study cohort

Variable	Overall cohort, n=86
Age, years	54.00 (51.25-58.00)
Female sex	54 (62.8%)
Male sex	32 (37.2%)
C2-C7 lordosis, (°)	11.00 (5.12-26.75)
C7 slope, (°)	27.00 (24.00-33.00)
T1 slope, (°)	24.50 (21.50-28.00)
T1S-CL mismatch, (°)	11.00 (-2.05-19.06)
NDI score	13.00 (10.00-17.00)
PSQI score	6.00 (4.00-6.00)
Symptom duration, months	12.00 (10.00-14.00)
Medical treatment	55 (64.0%)
Physical therapy	17 (19.8%)
Lifestyle change	48 (55.8%)
Exercise	40 (46.5%)
Good sleep quality	41 (47.7%)
Poor sleep quality	45 (52.3%)
Mild disability	47 (54.7%)
Moderate disability	39 (45.3%)

Values are presented as median (interquartile range) or n (%). NDI: Neck disability index, PSQI: Pittsburgh sleep quality index, T1S-CL mismatch: T1 slope-C2-C7 Cobb angle

$p < 0.001$), and symptom duration ($\rho = 0.270$, $p = 0.012$). No significant correlations were observed between PSQI score and age or T1 slope (Table 3).

NDI score showed significant correlations with all evaluated radiographic parameters. It was negatively correlated with C2-C7 lordosis ($\rho = -0.409$, $p < 0.001$) and positively correlated with C7 slope ($\rho = 0.526$, $p < 0.001$), T1 slope ($\rho = 0.651$, $p < 0.001$), and T1S-CL mismatch ($\rho = 0.759$, $p < 0.001$) (Supplementary Table 1).

In univariable logistic regression analysis, C2-C7 lordosis (OR=0.924, 95% CI: 0.884-0.965, $p < 0.001$), T1 slope (OR=0.918, 95% CI: 0.867-0.972, $p = 0.003$), NDI score (OR=1.111, 95% CI: 1.001-1.234, $p = 0.048$), and exercise participation (OR=4.943, 95% CI: 1.966-12.427, $p < 0.001$) were associated with poor sleep quality. Male sex showed a borderline association with poor sleep quality but did not reach statistical significance (OR=2.386, 95% CI: 0.965-5.903, $p = 0.060$). Physical therapy was not significantly associated with poor sleep quality in the univariable analysis (OR=2.618, 95% CI: 0.833-8.229, $p = 0.100$) (Supplementary Table 2).

In the multivariable logistic regression model including age, sex, T1S-CL mismatch, NDI score, and symptom duration, none of the variables remained independently associated with poor sleep quality (Table 4). When PSQI score was analyzed as a continuous outcome using multivariable linear regression, NDI score remained positively associated with PSQI score after adjustment ($\beta = 0.255$, SE=0.058, $p < 0.001$). T1S-CL mismatch showed a negative association with PSQI score after adjustment ($\beta = -0.047$, SE=0.018, $p = 0.009$). The overall model was statistically significant (adjusted $R^2 = 0.216$, $F = 5.681$, $p < 0.001$). VIF values for the multivariable linear regression model were 1.178 for age, 1.181 for male sex, 2.430 for T1S-CL mismatch, 3.060 for NDI score, and 1.789 for symptom duration. All VIF values were below 5, indicating no severe multicollinearity in the final model (Table 5).

DISCUSSION

The main observation in this cohort was that poorer sleep accompanied greater neck-related disability and reduced C2-

Table 2. Comparison of patients according to sleep quality

Variable	Good sleep quality, n=41	Poor sleep quality, n=45	p-value
Age, years	53.00 (52.00-55.00)	54.00 (51.00-59.00)	0.193
C2-C7 lordosis, (°)	25.30 (6.00-30.30)	9.00 (5.00-13.90)	0.003
C7 slope, (°)	26.00 (23.70-33.00)	27.00 (25.00-33.00)	0.762
T1 slope, (°)	24.00 (21.50-33.00)	26.00 (12.80-26.00)	0.035
T1S-CL mismatch, (°)	7.00 (-1.00-19.00)	14.00 (-2.20-21.00)	0.326
NDI score	12.00 (10.00-16.00)	16.00 (10.00-18.00)	0.040
Symptom duration, months	12.00 (10.00-13.00)	12.00 (10.00-14.00)	0.232
Female sex	30 (73.2%)	24 (53.3%)	0.075
Male sex	11 (26.8%)	21 (46.7%)	
Medical treatment	25 (61.0%)	30 (66.7%)	0.656
Physical therapy	5 (12.2%)	12 (26.7%)	0.110
Lifestyle change	20 (48.8%)	28 (62.2%)	0.278
Exercise	11 (26.8%)	29 (64.4%)	<0.001

Values are presented as median (interquartile range) or n (%). Continuous variables were compared using the Mann-Whitney U test. Categorical variables were compared using Fisher's exact test. PSQI score was not compared between groups because sleep quality grouping was defined according to PSQI. NDI: Neck disability index, PSQI: Pittsburgh sleep quality index, T1S-CL mismatch: T1 slope-C2-C7 Cobb angle

Table 3. Correlations between PSQI score and clinical/radiographic parameters

Variable	Spearman's rho	p-value
Age, years	0.077	0.481
C2-C7 lordosis, (°)	-0.219	0.043
C7 slope, (°)	0.242	0.025
T1 slope, (°)	0.079	0.471
T1S-CL mismatch, (°)	0.220	0.042
NDI score	0.436	<0.001
Symptom duration, months	0.270	0.012

NDI: Neck disability index, PSQI: Pittsburgh sleep quality index, T1S-CL mismatch: T1 slope-C2-C7 Cobb angle

Table 4. Multivariable logistic regression analysis for poor sleep quality

Variable	OR	95% CI	p-value
Age	1.026	0.976-1.078	0.316
Male sex	1.824	0.679-4.901	0.234
T1S-CL mismatch	0.985	0.932-1.040	0.584
NDI score	1.140	0.949-1.369	0.162
Symptom duration	0.961	0.780-1.184	0.709

ORs for continuous variables are reported per 1-unit increase. OR: Odds ratio, CI: Confidence interval, NDI: Neck disability index, T1S-CL mismatch: T1 slope-C2-C7 Cobb angle

Table 5. Multivariable linear regression analysis for PSQI score

Variable	β	SE	t-value	p-value	VIF
Age	-0.002	0.016	-0.116	0.908	1.178
Male sex	0.031	0.319	0.098	0.922	1.181
T1S-CL mismatch	-0.047	0.018	-2.664	0.009	2.430
NDI score	0.255	0.058	4.377	<0.001	3.060
Symptom duration	0.006	0.067	0.096	0.924	1.789

Model statistics: adjusted $R^2=0.216$; $F=5.681$; $p<0.001$. β values are unstandardized regression coefficients from the multivariable linear regression model. NDI: Neck disability index, PSQI: Pittsburgh sleep quality index, T1S-CL mismatch: T1 slope-C2-C7 Cobb angle, SE: Standard error, VIF: Variance inflation factor

C7 lordosis, with PSQI scores also showing relationships with several cervical sagittal measurements. By examining sleep status, patient-reported disability, and cervical alignment within the same cohort, the present analysis provides a combined clinical and radiographic perspective on chronic neck pain.

In the present cohort, 52.3% of patients were classified as having poor sleep quality. Patients with poor sleep quality had significantly lower C2-C7 Cobb angles and higher NDI scores compared with those with good sleep quality. PSQI score also showed a moderate positive correlation with NDI score. This pattern accords with earlier studies linking impaired sleep to greater pain-related functional limitation^(1-4,15). Finan et al.⁽¹⁾ described reciprocal interactions between sleep and pain, including increased nociceptive sensitivity and reduced pain-regulatory capacity following inadequate sleep. Similarly, Andreucci et al.⁽²⁾ reported an association between sleep quality and chronic neck pain in a cotwin design, although their findings also suggested that this relationship may be partly influenced by shared genetic factors. Accordingly, the observed relationships do not establish that sleep impairment causes radiographic alterations or disability; rather, they indicate associations between sleep status and the clinical characteristics of chronic neck pain.

The association between poor sleep quality and chronic neck pain has also been reported in longitudinal and cross-sectional clinical studies^(3,4,16). Yabe et al.⁽³⁾ showed that sleep disturbance was associated with neck pain over a 3-year follow-up period, supporting the potential role of sleep disturbance in symptom persistence. Lee and Oh⁽⁴⁾ also demonstrated that sleep quality was related to neck pain, shoulder pain, disability, physical activity, and perceived health in middle-aged women. In addition, longitudinal population-based data

have suggested that insomnia is associated with an increased risk of chronic musculoskeletal complaints, including neck-related complaints⁽¹⁶⁾. In line with these studies, our results showed that worse PSQI scores were associated with higher NDI scores. Importantly, NDI remained positively associated with PSQI score after adjustment in the multivariable linear regression model. This suggests that neck-related disability is an important clinical correlate of sleep quality in patients with chronic neck pain. The categorical and continuous PSQI analyses should be regarded as complementary rather than interchangeable, because dichotomization at a clinical cut-off reduces within-group information, whereas continuous analysis retains variation across the full PSQI range. Accordingly, the absence of independently significant predictors in the multivariable logistic regression model does not necessarily contradict the associations identified in the linear regression model. The two models evaluate different representations of sleep quality and may differ in statistical sensitivity, particularly in a modest-sized cohort.

Radiographically, patients with poor sleep quality demonstrated a smaller C2-C7 lordosis than those with good sleep quality. Cervical sagittal configuration can be characterized using measurements such as C2-C7 lordosis, T1 slope, C7 slope, and T1S-CL mismatch, each of which reflects a different component of cervicothoracic balance^(5,6). Reduced cervical lordosis may reflect altered sagittal mechanics, compensatory muscle activity, or pain-related postural adaptation. Earlier clinical studies have reported that deviations in cervical sagittal alignment may accompany axial symptoms and poorer patient-reported function^(8,9,11,12). Our findings are broadly consistent with this literature, as lower lordosis was observed in patients with poor sleep quality and was negatively correlated with both

PSQI and NDI scores. Although the between-group difference in C2-C7 lordosis was statistically significant, the correlation between continuous PSQI score and C2-C7 lordosis was weak ($\rho = -0.219$). These findings are not necessarily contradictory because the between-group analysis evaluates differences in lordosis distributions across the PSQI-defined cut-off, whereas Spearman correlation evaluates the monotonic relationship across the full range of PSQI scores. The modest correlation may also reflect the limited dispersion of PSQI scores and the within-group variability in cervical lordosis. Therefore, the association between PSQI and cervical lordosis should be interpreted as statistically significant but weak in magnitude. The cross-sectional design does not permit determination of whether diminished lordosis precedes sleep impairment, whether pain and disturbed sleep alter posture or muscular activity, or whether these findings arise from a common underlying process.

The relationship between T1 slope, cervical lordosis, and clinical symptoms requires careful interpretation. T1 slope is biomechanically related to cervical lordosis, and higher T1 slope generally requires greater cervical lordosis to maintain horizontal gaze and sagittal balance⁽⁷⁾. In our study, T1 slope distribution differed between sleep quality groups and was associated with poor sleep quality in univariable logistic regression. However, T1 slope was not significantly correlated with PSQI score. Moreover, T1 slope, C2-C7 lordosis, and T1S-CL mismatch are closely related sagittal alignment parameters, and T1S-CL mismatch is mathematically derived from T1 slope and C2-C7 Cobb angle. Therefore, these parameters were not entered simultaneously into the multivariable models. T1S-CL mismatch was retained as the representative composite sagittal parameter to avoid redundant modeling of overlapping sagittal constructs. Accordingly, the T1 slope finding should be interpreted as exploratory rather than definitive.

T1S-CL mismatch also warrants cautious interpretation because it is mathematically derived from T1 slope and C2-C7 lordosis rather than being an independent sagittal measurement. In the unadjusted correlation analysis, T1S-CL mismatch was positively correlated with both PSQI and NDI scores. However, after multivariable adjustment, its association with PSQI changed direction and became negative. This reversal indicates that the adjusted coefficient is dependent on the covariate structure of the model and may reflect shared variance, particularly with NDI, rather than an independent inverse relationship between T1S-CL mismatch and sleep quality. Although T1 slope, C2-C7 lordosis, and T1S-CL mismatch were not entered simultaneously and VIF values did not indicate severe multicollinearity among the variables included in the final model, these findings do not eliminate the mathematical dependence of T1S-CL on its component sagittal measurements. Therefore, the adjusted negative coefficient should be interpreted cautiously and should not be regarded as evidence that greater T1S-CL mismatch is associated with better sleep quality.

The strong correlations observed between NDI and radiographic

parameters further support the clinical relevance of cervical sagittal morphology in chronic neck pain. NDI showed significant associations with C2-C7 Cobb angle, C7 slope, T1 slope, and T1S-CL mismatch. These findings are compatible with prior work showing relationships between cervical sagittal parameters and patient-reported disability, particularly in cervical degenerative or postoperative populations^(9,12). Nevertheless, our cohort differs from many surgical series because it consisted of patients evaluated for chronic neck pain rather than a homogeneous operative population. This may make the findings more relevant to outpatient clinical assessment, but it also increases heterogeneity and limits direct comparison with surgically treated cohorts.

Exercise participation was more frequent in the poor sleep quality group and was associated with poor sleep quality in univariable logistic regression. This result should be interpreted carefully. It should not be concluded that exercise worsens sleep quality. A more plausible explanation is that patients with more severe symptoms, higher disability, or greater health concerns may have been more likely to perform exercise or to be advised to exercise. Lee and Oh⁽⁴⁾ similarly evaluated physical activity within the broader relationship between sleep quality, pain, and disability, supporting the idea that physical activity should be considered as part of a multidimensional clinical context rather than as an isolated causal factor. In addition, population-based evidence suggests that exercise may modify the relationship between sleep problems and chronic musculoskeletal pain rather than represent a simple harmful exposure⁽¹⁵⁾. Because of the cross-sectional design, reverse association and indication bias cannot be excluded.

Study Limitations

Several methodological considerations should be acknowledged. Most importantly, the cross-sectional assessment allows identification of associations but does not establish their temporal sequence, directionality, or causality. No formal a priori sample size calculation was performed because the study was retrospective and the sample size was determined by the number of eligible patients with complete clinical, questionnaire-based, and radiographic data. No post-hoc power analysis was performed. Therefore, although the number of poor sleep quality events was acceptable for the five-covariate logistic regression model according to the commonly used events-per-variable rule of thumb, the adjusted regression analyses may still have been underpowered to detect small independent associations. Exercise participation was more frequent among patients with poor sleep quality; however, this unadjusted association should be interpreted within the limitations of the cross-sectional design. Indication bias is likely, as patients with more severe symptoms, greater disability, or higher health concerns may have been more likely to perform exercise or to be advised to exercise.

An important limitation is the absence of a separate standardized measure of pain intensity. Because pain severity may be

associated with both sleep quality and neck-related disability, its omission introduces the possibility of residual confounding and limits interpretation of the observed associations between sleep quality and cervical sagittal parameters. In addition, standardized psychological assessments were not available. Anxiety, depression, catastrophizing, and psychological distress may be associated with both sleep quality and chronic neck pain; therefore, failure to account for these factors may have resulted in residual confounding^(1,2). Other unmeasured factors, including exercise type and intensity, adherence, medication use, and occupational factors, could not be fully accounted for. Therefore, treatment-related variables were interpreted descriptively and should not be considered evidence of causal effects on sleep quality. In addition, lateral cervical radiographs represent alignment at a single static time point and cannot characterize dynamic postural changes, paraspinal muscle function, or movement adaptations related to pain. Finally, the PSQI reflects overall perceived sleep quality but does not establish the presence of specific sleep disorders such as insomnia, obstructive sleep apnea, or circadian rhythm disorders.

CONCLUSION

In this cross-sectional cohort of patients with chronic neck pain, poor sleep quality was common and was associated with greater neck-related disability and lower C2-C7 lordosis, with additional associations observed between PSQI score and selected cervical sagittal parameters. NDI score remained positively associated with PSQI score after adjustment, whereas no variable remained independently associated with dichotomized poor sleep quality in the multivariable logistic regression model.

These findings suggest that sleep quality, functional disability, and cervical sagittal morphology may represent interrelated components of the chronic neck pain phenotype. However, because of the cross-sectional design, causal or directional relationships cannot be inferred. Future prospective studies with larger cohorts and broader clinical, psychological, and dynamic postural assessments are needed to clarify the mechanisms underlying these associations.

Ethics

Ethics Committee Approval: The study protocol was approved by the Scientific Research Ethics Committee of University of Health Sciences Türkiye, Adana City Training and Research Hospital (approval no: 1499, date: 25.06.2026).

Informed Consent: Patient data were analyzed after anonymization. The requirement for written informed consent was handled in accordance with the decision of the ethics committee.

Footnotes

Authorship Contributions

Surgical and Medical Practices: M.B., Concept: M.B., Design: M.B., F.S., Data Collection or Processing: M.B., Analysis or Interpretation: M.B., Literature Search: F.S., Writing: M.B., F.S.

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Supplementary Table 1-2 links: <https://d2v96fxpocvxx.cloudfront.net/68ab204c-182b-49da-b227-bc7efe058632/content-images/21adfe98-e216-4330-a219-8bfd04610d46.pdf>

REFERENCES

1. Finan PH, Goodin BR, Smith MT. The association of sleep and pain: an update and a path forward. *J Pain*. 2013;14:1539-52.
2. Andreucci A, Madrid-Valero JJ, Ferreira PH, Ordoñana JR. Sleep quality and chronic neck pain: a cotwin study. *J Clin Sleep Med*. 2020;16:679-87.
3. Yabe Y, Hagiwara Y, Sekiguchi T, Sugawara Y, Tsuchiya M, Yoshida S, et al. Sleep disturbance is associated with neck pain: a 3-year longitudinal study after the great East Japan earthquake. *BMC Musculoskelet Disord*. 2022;23:459.
4. Lee MK, Oh J. The relationship between sleep quality, neck pain, shoulder pain and disability, physical activity, and health perception among middle-aged women: a cross-sectional study. *BMC Womens Health*. 2022;22:186.
5. Martini ML, Neifert SN, Chapman EK, Mroz TE, Rasouli JJ. Cervical spine alignment in the sagittal axis: a review of the best validated measures in clinical practice. *Global Spine J*. 2021;11:1307-12.
6. Lee SH, Hyun SJ, Jain A. Cervical sagittal alignment: literature review and future directions. *Neurospine*. 2020;17:478-96.
7. Park JH, Cho CB, Song JH, Kim SW, Ha Y, Oh JK. T1 slope and cervical sagittal alignment on cervical CT radiographs of asymptomatic persons. *J Korean Neurosurg Soc*. 2013;53:356-9.
8. Li J, Zhang D, Shen Y. Impact of cervical sagittal parameters on axial neck pain in patients with cervical kyphosis. *J Orthop Surg Res*. 2020;15:434.
9. Xu Y, Liu S, Wang F, Wu X. Cervical sagittal parameters were closely related to neck disability index score after anterior cervical decompression and fusion. *J Orthop Surg Res*. 2020;15:325.
10. Sakamoto R, Nakamoto H, Yoshida Y, Ohtomo N, Nagata K, Kato S, et al. Does T1 slope minus cervical lordosis mismatch affect surgical outcomes of cervical laminoplasty in the absence of preoperative severe kyphosis? *BMC Musculoskelet Disord*. 2022;23:810.
11. Kim JH, Kim JH, Kim JH, Kwon TH, Park YK, Moon HJ. The relationship between neck pain and cervical alignment in young female nursing staff. *J Korean Neurosurg Soc*. 2015;58:231-5.
12. Lee HJ, Jeon DG, Park JH. Correlation between kinematic sagittal parameters of the cervical lordosis or head posture and disc degeneration in patients with posterior neck pain. *Open Med (Wars)*. 2021;16:161-8.
13. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28:193-213.
14. Vernon H, Mior S. The neck disability index: a study of reliability and validity. *J Manipulative Physiol Ther*. 1991;14:409-15.
15. Mork PJ, Vik KL, Moe B, Lier R, Bardal EM, Nilsen TI. Sleep problems, exercise and obesity and risk of chronic musculoskeletal pain: the Norwegian HUNT study. *Eur J Public Health*. 2014;24:924-9.
16. Uhlig BL, Sand T, Nilsen TI, Mork PJ, Hagen K. Insomnia and risk of chronic musculoskeletal complaints: longitudinal data from the HUNT study, Norway. *BMC Musculoskelet Disord*. 2018;19:128.