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Original Article

Beyond Screen Time: Associations of Smartphone Use and Addiction Severity with Cervical Proprioception and Sleep-Related Outcomes

Zeynal YASACI, Hatice Nur ARSLAN, Gülnihal ÇAPADAN, Nuray TARI, Nurşin UZUN
Department of Physiotherapy and Rehabilitation, İnonu University Faculty of Health Sciences, Malatya, Türkiye

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What is already known on this topic?

- *Excessive smartphone use is linked to poor sleep and cervical musculoskeletal problems.*
- *Smartphone addiction may be associated with impaired cervical proprioception.*
- *The role of forward head posture remains uncertain.*

What this study adds on this topic?

- *Longer daily smartphone use was independently associated with poorer sleep and bedtime procrastination.*
- *Greater smartphone addiction severity was independently associated with flexion joint position error.*
- *The addiction–bedtime procrastination association was not robust, and neither smartphone measure was associated with neck disability.*

ABSTRACT

Objective: To examine the independent associations of average daily smartphone usage and smartphone addiction severity with cervical proprioception and sleep-related outcomes in university students.

Pearson correlations and hierarchical multiple regression were used, with Benjamini–Hochberg FDR correction for multiple comparisons.Methods: This cross-sectional study included 159 students aged 18-24 years. Smartphone addiction was assessed with the Smartphone Addiction Scale–Short Version, and average daily smartphone usage was obtained from built-in screen-time records. Cervical proprioception was evaluated using laser-measured joint position error (JPE). Sleep quality, insomnia severity, bedtime procrastination, anxiety, and depressive symptoms were assessed using the Pittsburgh Sleep Quality Index, Insomnia Severity Index, Bedtime Procrastination Scale, Generalized Anxiety Disorder-7 (GAD-7), and Patient Health Questionnaire-9 (PHQ-9), respectively. Pearson correlations and hierarchical multiple regression were used, with Benjamini–Hochberg FDR correction for multiple comparisons.

Results: Mean smartphone usage was 342.21 ± 133.70 min/day. In hierarchical regression models, average daily smartphone usage was independently associated with insomnia severity ($\beta = 0.39$, $P < .001$), poor sleep quality ($\beta = 0.36$, $P < .001$), and bedtime procrastination ($\beta = 0.28$, $P = .004$). These associations remained significant after additional adjustment for PHQ-9 and GAD-7 scores. Patient Health Questionnaire-9 was independently associated with insomnia severity and sleep quality, whereas GAD-7 was not significant. Smartphone addiction severity was independently associated with flexion JPE ($\beta = 0.31$, $P = .001$). Its association with bedtime procrastination was not significant after adjustment for depressive and anxiety symptoms.

Conclusion: Smartphone usage duration was consistently associated with sleep-related disturbances, whereas smartphone addiction severity was independently associated with flexion JPE. Causal or temporal relationships cannot be inferred.

Keywords: Bedtime procrastination, cervical proprioception, insomnia, joint position error, sleep quality, smartphone use

Introduction

Smartphone use is widespread, particularly among young adults. In 2024, Internet use reached 68% globally and 79% among individuals aged 15-24 years, while approximately 54% of the world's population owned a smartphone.[1,2] Daily use exceeding 5 hours has been reported among many university students.[3] Excessive use has been associated with musculoskeletal, sleep-related, and psychological problems.

Corresponding author: Zeynal Yasaci, e-mail: zeynalyasaci@inonu.edu.tr

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The forward head posture frequently adopted during smartphone use increases mechanical loading on the cervical spine.[4] This posture, commonly described as "text neck," has been associated with cervical muscle fatigue, mechanical stress, and postural dysfunction.[5] Prolonged or repeated postural loading may also affect cervical sensorimotor control. Proprioceptive information from mechanoreceptors located in the deep cervical muscles contributes to the perception and control of head and neck position and plays an important role in postural stability. Temporary forward head posture has been associated with reduced cervical joint position accuracy, and higher smartphone addiction severity has also been related to greater cervical joint position error.[5-7] In a study of 176 young adults, Çağrıl and Saraçoğlu reported greater joint position error (JPE) in cervical flexion, extension, and left rotation among participants classified as being at high risk of smartphone addiction. However, their study compared groups based on addiction classification and did not examine the separate adjusted contributions of addiction severity and device-recorded usage duration.[8]

The health effects of smartphone use are not limited to biomechanical alterations. In particular, smartphone use may disrupt circadian rhythm and delay sleep onset by suppressing melatonin secretion through blue light exposure and increased cognitive arousal.[9] In recent years, bedtime procrastination has emerged as an important behavioral mechanism underlying the adverse effects of smartphone use on sleep. Defined as the voluntary delay of bedtime in the absence of external constraints, bedtime procrastination has been reported to mediate the relationship between smartphone addiction and poor sleep quality.[10,11] Furthermore, large-scale studies consistently indicate that smartphone addiction is an independent risk factor for poor sleep quality and insomnia symptoms.[12] These findings indicate that smartphone-related behaviors may be relevant to health through both biomechanical and behavioral pathways.

Previous studies have generally examined the musculoskeletal and sleep-related correlates of smartphone use separately. The extent to which usage duration and addiction severity show distinct adjusted associations with cervical proprioception and sleep-related outcomes remains unclear, particularly when both dimensions are evaluated within the same sample. Therefore, this study aimed to examine the independent associations of device-recorded average daily smartphone usage and smartphone addiction severity with cervical joint position sense, sleep quality, insomnia severity, and bedtime procrastination in university students. It was hypothesized that both smartphone-related variables would be independently associated with these outcomes.

Methods

Study Design and Participants

This cross-sectional investigation included university students aged between 18 and 24 years from different faculties of İnönü University and was conducted between September 2025 and April 2026. A total of 190 university students were assessed for eligibility. Twenty-three declined to participate, and 8 were excluded because they met one or more exclusion criteria. The final analysis included 159 participants . The study protocol complied with the ethical principles outlined in the Declaration of Helsinki and received approval from the Health Sciences Scientific Research Ethics Subcommittee of the İnönü University Scientific Research and Publication Ethics Committee (Decision No: 2025/7864 Date: May 29, 2025). Prior to enrollment, all participants were informed about the study procedures and provided written informed consent.

Participants were included in the study if they met the following eligibility criteria: 18-24 years old, had been active smartphone users for at least 1 year, were able to comply with all assessment procedures, and provided voluntary participation. Exclusion criteria included a history of neurological disorders, a previously diagnosed cervical musculoskeletal disorder, vestibular dysfunction, or systemic diseases; any upper extremity injury or condition that could limit functional assessments; and uncorrected visual impairments that might interfere with proprioceptive testing.

Outcome Measures

Smartphone addiction was assessed using the 10-item Smartphone Addiction Scale–Short Version (SAS-SV). Items are rated from 1 ("strongly disagree") to 6 ("strongly agree"), yielding scores of 10-60; higher scores indicate greater addiction severity. Scores ≥31 for males and ≥33 for females indicate high risk.[13,14] Participants opened the built-in Screen Time or Digital Wellbeing function on their smartphones, and the displayed average daily smartphone usage over the previous 7 days was recorded in min/day. In the current study, Cronbach's alpha coefficient were 0.86 for SAS-SV, 0.81 for the NDI, 0.76 for the PSQI, 0.79 for the ISI, 0.83 for the BPS, 0.89 for the GAD-7, and 0.88 for the PHQ-9.

Cervical-related functional impairment was assessed using the Neck Disability Index (NDI), a validated self-report instrument consisting of 10 items that examine the effects of neck pain on everyday functioning. Each item is scored between 0 and 5, yielding a total score from 0 to 50, with higher scores reflecting increased disability.[15,16]

Cervical joint position sense was assessed using a head-to-neutral repositioning test with a head-mounted laser pointer. Participants sat in a chair with back support, 90 cm from a 60 × 60 cm target positioned at eye level. Before each assessment, the laser pointer was aligned with the center of the target while the participant maintained a neutral head position. After a familiarization trial with their eyes open, participants closed their eyes and actively performed cervical flexion, extension, right rotation, or left rotation at a self-selected comfortable speed before attempting to return to the neutral starting position. Movement speed was not externally standardized. Three recorded trials were performed for each movement direction. The absolute linear displacement errors across the 3 trials were averaged in centimeters, and only the mean linear displacement value was retained in the dataset. This mean value was subsequently converted to angular error using the following formula: JPE (°) = arctan [mean error distance (cm)/90 cm] × 180/π. Therefore, the reported JPE value represents the angular conversion of the mean absolute linear displacement across 3 trials.[17] All JPE assessments were performed by the same trained assessor, who was not involved in administering or scoring the smartphone-use measures and questionnaires and was therefore blinded to these results during the proprioceptive assessments.

Sleep quality and insomnia-related symptoms were evaluated using the Pittsburgh Sleep Quality Index (PSQI) and the Insomnia Severity Index (ISI). The PSQI measures subjective sleep quality and sleep disturbances experienced during the previous month, with total scores ranging from 0 to 21; scores higher than 5 indicate clinically meaningful sleep impairment.[18] The ISI is a 7-item questionnaire designed to assess the severity of insomnia symptoms. Each item is scored from 0 to 4, resulting in a total score between 0 and 28, where higher scores indicate more severe insomnia symptoms.[19] Bedtime procrastination was assessed using the Bedtime Procrastination Scale (BPS), a 9-item self-report instrument evaluating the tendency to postpone bedtime in the absence of external obligations. Responses are rated on a 5-point Likert scale ranging from 1 ("almost never") to 5 ("almost always"), with higher scores representing greater bedtime procrastination.[20]

Anxiety and depressive symptoms were assessed using the Generalized Anxiety Disorder-7 (GAD-7) and Patient Health Questionnaire-9 (PHQ-9),

respectively. Generalized Anxiety Disorder-7 scores range from 0 to 21, with 5, 10, and 15 indicating mild, moderate, and severe anxiety.[21] Patient Health Questionnaire-9 scores range from 0 to 27, with scores ≥10 indicating moderate-to-severe depressive symptoms.[22]

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics, version 22.0 (NY, USA). Distributional characteristics were evaluated using histograms, normal Q–Q plots, skewness, and kurtosis. Although several variables deviated from normality according to formal tests, visual inspection and skewness and kurtosis values did not indicate severe departures from normality. Pearson correlations were therefore used as the primary analyses, with Spearman correlations conducted as sensitivity analyses. Continuous variables are presented as mean ± standard deviation, and categorical variables as frequencies and percentages. Pearson correlations were used to examine the associations of average daily smartphone usage and SAS-SV score with cervical JPE, NDI, sleep-related outcomes, anxiety, and depressive symptoms. The correlation between average daily smartphone usage and SAS-SV score was also calculated.[23]

Hierarchical multiple linear regression analyses were conducted to examine adjusted associations with the study outcomes. Body mass index (BMI) and sex were entered in Model 1, followed by SAS-SV score and average daily smartphone usage in Model 2. For sleep-related outcomes, PHQ-9 and GAD-7 scores were added together in Model 3 as a sensitivity analysis because their causal positions could not be established in this cross-sectional study. Regression assumptions were evaluated using residual histograms, normal P–P plots, and plots of standardized residuals against standardized predicted values. Multicollinearity was assessed using tolerance and variance inflation factor values, and influential observations were examined using standardized and studentized residuals, Cook's distance, leverage, and Mahalanobis distance. No data were missing for the variables included in the analyses. Additional analyses examined the associations between NDI and JPE in each movement direction using Pearson correlations with 95% CI. Because the causal role of NDI was uncertain, it was added as a third block in sensitivity models for the JPE outcomes rather than included in the primary models. An exploratory subgroup analysis was also conducted among participants with NDI scores below 5 using Spearman correlations. Benjamini–Hochberg false discovery rate correction was applied separately to the 20 primary exposure–outcome correlations, the 4 NDI–JPE correlations, and the 8 subgroup correlations. All tests were 2-sided, with statistical significance set at $P < .05$.[24] No a priori sample-size calculation was performed. With 159 participants, $\alpha = 0.05$, and 80% power, the minimum detectable Pearson correlation was approximately $|r| = .22$.

Results

Participant Characteristics

A total of 159 university students were included, comprising 107 women (67.3%) and 52 men (32.7%). Mean average daily smartphone usage was 342.21 ± 133.70 min/day, and the mean SAS-SV score was 31.35 ± 11.14. Based on the sex-specific SAS-SV cutoff values, 70 participants (44.0%) were classified as being at high risk of smartphone addiction. The mean NDI score was 10.76 ± 6.26; 26 participants (16.4%) had no disability, 98 (61.6%) had mild disability, 31 (19.5%) had moderate disability, and 4 (2.5%) had severe disability. Additional participant characteristics are presented in Table 1.

Correlation Analyses

Average daily smartphone usage and SAS-SV scores were positively correlated (Pearson's $r = 0.66$; Spearman's $\rho = 0.64$; both $P < .001$). Both smartphone-related variables were positively correlated with all sleep-related outcomes after FDR correction (average daily usage: $r = 0.41$-0.48; SAS-SV: $r = 0.38$-0.40; all pFDR < 0.001). Smartphone Addiction Scale–Short Version score was also correlated with GAD-7 ($r = 0.23$, pFDR = 0.005) and PHQ-9 ($r = 0.35$, pFDR < 0.001), whereas average daily smartphone usage was not. Neither smartphone-related variable was significantly correlated with NDI.

Both smartphone-related variables were positively correlated with JPE in all movement directions (Table 2). Neck Disability Index was not significantly correlated with extension JPE ($r = -0.08$, 95% CI −0.23 to 0.08), flexion JPE ($r = 0.02$, 95% CI −0.14 to 0.17), right rotation JPE ($r = 0.11$, 95% CI −0.04 to 0.26), or left rotation JPE ($r = -0.05$, 95% CI −0.20 to 0.11; all pFDR ≥ .608). Spearman sensitivity analyses yielded a comparable pattern.

Hierarchical Regression Analyses

The addition of average daily smartphone usage and SAS-SV score explained an additional 24.3% of the variance in ISI, 20.7% in PSQI, and 19.4% in bedtime procrastination scores (all $P < .001$; Table 3). Average daily smartphone usage was independently associated with ISI ($\beta = 0.39$, $P < .001$), PSQI ($\beta = 0.36$, $P < .001$), and bedtime procrastination ($\beta = 0.28$, $P = .004$). SAS-SV score was independently associated only with bedtime procrastination in the primary models ($\beta = 0.20$, $P = .038$).

After PHQ-9 and GAD-7 scores were added to the sensitivity models, average daily smartphone usage remained statistically significant for all 3 sleep-related outcomes. Patient Health Questionnaire-9 was independently associated with ISI ($\beta = 0.25$, $P = .003$) and PSQI ($\beta = 0.41$, $P < .001$), whereas GAD-7 was not statistically significant. The association between SAS-SV score and bedtime procrastination was attenuated and was no longer statistically significant ($\beta = 0.14$, $P = .180$).

For the cervical JPE outcomes, the smartphone-related variables explained an additional 7.5%–23.0% of the variance across movement directions (Table 4). Average daily smartphone usage was independently associated with JPE in all 4 directions ($\beta = 0.217$-0.323, $P = .025$

Table 1. Demographic Characteristics and Clinical Outcome Measures of the Participants (N=159)

Variables	Value
Age (years)	20.89 ± 2.47
Sex (F/M) (%)	107 (67.3)/52 (32.7)
BMI (kg/m^2)	22.99 ± 3.49
Dominant extremity (R/L) (%)	148 (93.1)/11 (6.9)
Average daily smartphone usage (min/day)	342.21 ± 133.70
SAS-SV score	31.35 ± 11.14
High risk according to sex-specific SAS-SV cutoffs (%)	70 (44.0)
Neck Disability Index	10.76 ± 6.26
GAD-7 score	8.38 ± 4.81
PHQ-9 score	10.36 ± 4.62
Insomnia Severity Index	11.50 ± 5.06
PSQI score	6.45 ± 2.54
Bedtime procrastination score	26.42 ± 7.67
Flexion joint position error (°)	4.36 ± 2.12
Extension joint position error (°)	5.31 ± 2.59
Right rotation joint position error (°)	5.27 ± 2.05
Left rotation joint position error (°)	5.21 ± 2.13

Average daily smartphone usage was obtained from the smartphones' built-in screen-time records and expressed in min/day.
BMI, body mass index; GAD-7, Generalized Anxiety Disorder-7; JPE, joint position error; PHQ-9, Patient Health Questionnaire-9; PSQI, Pittsburgh Sleep Quality Index; SAS-SV, Smartphone Addiction Scale–Short Version.

Table 2. Correlations of Smartphone Use and Addiction with Clinical and Proprioceptive Variables (FDR Corrected)

Variable	Average Daily Smartphone Usage, *r* (95% CI), pFDR	SAS-SV Score, *r* (95% CI), pFDR
Neck Disability Index	−0.10 (−0.25 to 0.06), 0.211	0.08 (−0.08 to 0.23), 0.322
PSQI score	0.43 (0.30-0.55), <0.001**	0.38 (0.24-0.50), <0.001**
Insomnia Severity Index	0.48 (0.35-0.59), <0.001**	0.40 (0.26-0.52), <0.001**
Bedtime procrastination score	0.41 (0.27-0.53), <0.001**	0.39 (0.25-0.52), <0.001**
GAD-7 score	0.13 (−0.02 to 0.28), 0.111	0.23 (0.08-0.37), 0.005**
PHQ-9 score	0.13 (−0.03 to 0.28), 0.120	0.35 (0.20-0.48), <0.001**
Extension joint position error (°)	0.28 (0.13-0.41), <0.001**	0.19 (0.04-0.34), 0.019*
Flexion joint position error (°)	0.42 (0.28-0.54), <0.001**	0.45 (0.32-0.57), <0.001**
Right rotation joint position error (°)	0.43 (0.29-0.55), <0.001**	0.39 (0.25-0.51), <0.001**
Left rotation joint position error (°)	0.35 (0.21-0.48), <0.001**	0.28 (0.13-0.42), <0.001**

Values are presented as Pearson correlation coefficients (*r*), 95% confidence intervals calculated using Fisher's *z* transformation, and Benjamini–Hochberg false discovery rate—adjusted *P*-values (pFDR).
Average daily smartphone usage was obtained from the smartphones' built-in screen-time records and expressed in min/day.
GAD-7, Generalized Anxiety Disorder-7; PHQ-9, Patient Health Questionnaire-9; PSQI, Pittsburgh Sleep Quality Index; SAS-SV, Smartphone Addiction Scale–Short Version.
*pFDR < 0.05.
** pFDR < 0.01.

to <.001), whereas SAS-SV score was independently associated only with flexion JPE ($\beta = 0.308$, $P = .001$).

Adding NDI as a third block did not improve model fit for any JPE outcome (all $P \geq .097$) and did not materially change the smartphone-related coefficients. In the exploratory subgroup with NDI scores below 5 (n = 26), average daily smartphone usage ($\rho = 0.39$-0.54) and SAS-SV scores ($\rho = 0.41$-0.56) were positively correlated with all JPE outcomes, with all associations remaining significant after FDR correction. However, the 2 smartphone-related variables were highly correlated within this subgroup ($\rho = 0.92$).

Discussion

The present study examined the adjusted associations of average daily smartphone usage and smartphone addiction severity with cervical proprioception and sleep-related outcomes within the same sample. Average daily smartphone usage was consistently associated with sleep-related outcomes, whereas smartphone addiction severity was independently associated with flexion JPE. These findings indicate distinct patterns of association for the 2 smartphone-related measures; however, the underlying mechanisms were not examined.

In the present study, both average daily smartphone usage and smartphone addiction severity were positively associated with cervical JPE across all movement directions, indicating impaired proprioceptive accuracy with increasing smartphone exposure. These findings are consistent with the cross-sectional study by Torkamani et al,[7] in which university students with higher smartphone addiction scores demonstrated significantly greater JPE values in all directions. Similarly, Pashine et al[25] reported that prolonged smartphone use negatively affected cervical rotation and proprioception in asymptomatic individuals; however, the independent contribution of usage duration was not specifically evaluated in that study. These findings are also broadly consistent with the study by Çağrıl and Saraçoğlu,[8] who reported significantly greater JPE in cervical flexion, extension, and left rotation among young adults classified as smartphone-addicted, while no significant group difference was observed for right rotation. Unlike their dichotomous comparison of smartphone-addicted and non-addicted participants, the present study examined SAS-SV score as a continuous variable and simultaneously included device-recorded average daily smartphone usage in the regression models. In the adjusted analyses, smartphone addiction severity remained independently associated only with flexion JPE, whereas average daily smartphone usage was associated with multiple movement directions. These methodological differences may partly account for the differences in the direction-specific findings. By controlling for potential confounding variables such as BMI and sex through hierarchical regression analyses, the present findings provide additional evidence regarding the independent effects of smartphone-related behaviors on cervical sensorimotor function. Although the smartphone-related associations remained statistically significant after correction of the linear-to-angular conversion, their magnitudes were modest. A one-standard-deviation increase in the significant smartphone-related exposures corresponded to an estimated increase of approximately 0.46°-0.68° in JPE. AlDahas et al[17] reported SEM values ranging from 0.46° to 0.91° for absolute neutral-head-position JPE in asymptomatic participants tested in sitting, corresponding to an approximate MDC_{95} range of 1.28°-2.52°. However, their protocol included 6 recorded trials, whereas the present study used 3 trials, and sample-specific reliability and measurement-error estimates were unavailable. Therefore, these published values should be considered contextual rather than definitive thresholds for the present sample. The clinical significance of the observed associations remains uncertain, and the findings should be interpreted as statistical associations rather than evidence of a clinically detectable proprioceptive deficit.

The direction-specific association patterns may reflect differences in behavioral or biomechanical exposure, although the present study was not designed to test the underlying mechanisms. Sustained cervical flexion during smartphone use may increase mechanical loading on the cervical spine and contribute to cervical muscle fatigue.[4] Temporary forward head posture has also been associated with reduced cervical joint position accuracy, and the high density of muscle spindles within the deep cervical muscles supports their role in cervical proprioceptive control.[6,26] However, Mashabi et al[27] found no significant differences in cervical JPE among asymptomatic female university students with different visually classified levels of text-neck severity and reported no meaningful association between text-neck severity and JPE. Although their exposure measure differed from ours, their findings suggest that posture alone may not explain the associations observed in the present study. Their results should also be interpreted cautiously because the posture groups were small and unequal and text-neck severity was based on visual assessment. Because cervical posture, muscle fatigue, and deep cervical muscle function were not directly assessed in the study, these explanations remain hypothetical. NDI was not significantly correlated with any JPE outcome,

Table 3. Hierarchical Regression Analyses for Sleep-Related Outcomes

Panel A. Final Model 2 regression coefficients

Outcome	Predictor	B (95% CI)	β (95% CI)	*P*	Tolerance	VIF
ISI	BMI	0.336 (0.143-0.530)	0.232 (0.099-0.365)	.001	0.986	1.014
	Sex	−1.176 (−2.627 to 0.274)	−0.109 (−0.243 to 0.025)	.111	0.966	1.035
	Average daily smartphone usage	0.015 (0.008-0.022)	0.394 (0.215-0.573)	<.001	0.549	1.822
	SAS-SV score	0.061 (−0.020 to 0.142)	0.135 (−0.043 to 0.313)	.136	0.553	1.808
PSQI	BMI	0.119 (0.020-0.219)	0.164 (0.027-0.301)	.019	0.986	1.014
	Sex	−1.202 (−1.949 to −0.455)	−0.223 (−0.362 to −0.084)	.002	0.966	1.035
	Average daily smartphone usage	0.007 (0.003-0.010)	0.356 (0.172-0.540)	<.001	0.549	1.822
	SAS-SV score	0.031 (−0.011 to 0.072)	0.134 (−0.048 to 0.316)	.148	0.553	1.808
Bedtime procrastination	BMI	0.208 (−0.103 to 0.520)	0.095 (−0.047 to 0.237)	.188	0.986	1.014
	Sex	−2.205 (−4.543 to 0.132)	−0.135 (−0.278 to 0.008)	.064	0.966	1.035
	Average daily smartphone usage	0.016 (0.005-0.027)	0.281 (0.091-0.471)	.004	0.549	1.822
	SAS-SV score	0.138 (0.008-0.269)	0.201 (0.011-0.391)	.038	0.553	1.808

Panel B. Model fit and incremental effect size

Outcome	Model 1 R^2	Model 1 adjusted R^2	Model 2 R^2	Model 2 adjusted R^2	ΔR^2	ΔF	*P* for ΔF	Cohen's f^2
ISI	0.063	0.051	0.305	0.287	0.243	26.877	<.001	0.35
PSQI	0.062	0.05	0.27	0.251	0.207	21.864	<.001	0.284
Bedtime procrastination	0.022	0.01	0.216	0.196	0.194	19.01	<.001	0.247

BMI, body mass index; ISI, Insomnia Severity Index; PSQI, Pittsburgh Sleep Quality Index; SAS-SV, Smartphone Addiction Scale–Short Version.

and adding NDI to the sensitivity models did not improve model fit or materially change the smartphone-related coefficients. Positive bivariate associations were also observed in the exploratory subgroup with NDI scores below 5; however, the small subgroup size and the high correlation between the 2 smartphone-related variables limited interpretation of their independent contributions. Because the causal role of NDI cannot be established from cross-sectional data, these findings indicate only that the smartphone–JPE coefficients remained largely unchanged in models including self-reported neck disability. They do not demonstrate causal independence or establish that proprioceptive alterations precede pain or disability. Participants with a previously diagnosed cervical musculoskeletal disorder were excluded; however, current neck pain was not systematically assessed, and pain intensity was not measured using a standardized scale. Longitudinal studies incorporating direct pain measurements and repeated assessments are needed to clarify these relationships. Average daily smartphone usage and SAS-SV scores showed weak correlations with NDI in opposite directions ($r = -0.10$ and $r = 0.08$ respectively), but both estimates were close to zero and their 95% confidence intervals included zero. This pattern may reflect sampling variability or measurement error and should not be interpreted as evidence of distinct associations with neck disability.

Average daily smartphone usage was independently associated with both insomnia severity and sleep quality, and the smartphone-related variables explained substantial additional variance in ISI ($\Delta R^2 = 0.243$) and PSQI scores ($\Delta R^2 = 0.207$). These associations remained statistically significant after PHQ-9 and GAD-7 scores were added to the sensitivity models. Patient Health Questionnaire-9 was also independently associated with ISI and PSQI scores, whereas SAS-SV and GAD-7 scores were not statistically significant in the final models. These findings are consistent with the large-scale cross-sectional study by Yin et al,[28] which reported associations of both objectively measured smartphone use and smartphone addiction with poorer sleep quality among university students, and with the systematic review by Kumar et al,[29] which identified consistent associations between excessive smartphone use and impaired sleep quality. In the present study, however, sleep-related outcomes were more consistently associated with usage duration than with addiction severity after the covariates were considered. Because of the cross-sectional design, the direction and mechanisms of these associations cannot be determined.

In the primary model, bedtime procrastination was the only sleep-related outcome independently associated with both average daily smartphone usage and SAS-SV score. However, after PHQ-9 and GAD-7 scores were added to the sensitivity model, average daily smartphone usage remained statistically significant, whereas the SAS-SV coefficient was attenuated and was no longer statistically significant. Therefore, the independent association between smartphone addiction severity and bedtime procrastination was not robust to additional adjustment for concurrent depressive and anxiety symptoms.

Previous studies have proposed bedtime procrastination as a behavioral pathway linking problematic smartphone use with impaired sleep. Correa-Iriarte et al[30] reported that bedtime procrastination mediated the association between problematic smartphone use and sleep quality, while Huang et al[31] identified indirect associations through bedtime procrastination and fear of missing out. Although these studies provide a theoretical context for the present findings, the current cross-sectional analysis was not designed to test mediation or underlying psychological mechanisms. Consequently, impulsivity, reward-seeking behavior, and impaired self-regulation should be regarded as plausible explanations rather than mechanisms demonstrated by the present study.

Table 4. Hierarchical Regression Analyses for Cervical Joint Position Error Outcomes

Panel A. Final Model 2 regression coefficients

JPE outcome	Predictor	B (95% CI)	β (95% CI)	*P*	Tolerance	VIF
Flexion	BMI	−0.020 (−0.105 to 0.065)	−0.033 (−0.174 to 0.108)	0.644	0.986	1.014
	Sex	−0.190 (−0.828 to 0.449)	−0.042 (−0.184 to 0.100)	0.559	0.966	1.035
	Average daily smartphone usage	0.003 (0.0004-0.0064)	0.217 (0.028-0.406)	0.025	0.549	1.822
	SAS-SV score	0.059 (0.023-0.094)	0.308 (0.120-0.496)	0.001	0.553	1.808
Extension	BMI	−0.069 (−0.182 to 0.044)	−0.093 (−0.246 to 0.060)	0.231	0.986	1.014
	Sex	0.307 (−0.544 to 1.158)	0.056 (−0.099 to 0.211)	0.477	0.966	1.035
	Average daily smartphone usage	0.005 (0.0011-0.0090)	0.260 (0.055-0.465)	0.013	0.549	1.822
	SAS-SV score	0.005 (−0.042 to 0.053)	0.022 (−0.178 to 0.222)	0.828	0.553	1.808
Right rotation	BMI	0.012 (−0.072 to 0.095)	0.020 (−0.124 to 0.164)	0.784	0.986	1.014
	Sex	−0.402 (−1.028 to 0.225)	−0.092 (−0.235 to 0.051)	0.207	0.966	1.035
	Average daily smartphone usage	0.005 (0.0020-0.0079)	0.323 (0.132-0.514)	0.001	0.549	1.822
	SAS-SV score	0.031 (−0.004 to 0.066)	0.170 (−0.020 to 0.360)	0.079	0.553	1.808
Left rotation	BMI	−0.009 (−0.100 to 0.081)	−0.015 (−0.161 to 0.131)	0.84	0.986	1.014
	Sex	−0.522 (−1.200 to 0.156)	−0.116 (−0.267 to 0.035)	0.13	0.966	1.035
	Average daily smartphone usage	0.005 (0.0019-0.0082)	0.320 (0.121-0.519)	0.002	0.549	1.822
	SAS-SV score	0.012 (−0.026 to 0.050)	0.062 (−0.136 to 0.260)	0.537	0.553	1.808

Panel B. Model fit and incremental effect size

JPE outcome	Model 1 R^2	Model 1 adjusted R^2	Model 2 R^2	Model 2 adjusted R^2	ΔR^2	ΔF	*P* for ΔF	Cohen's f^2
Flexion	0.002	−0.011	0.232	0.212	0.23	23	<.001	0.299
Extension	0.012	−0.001	0.087	0.063	0.075	6.338	0.002	0.082
Right rotation	0.005	−0.007	0.211	0.19	0.205	20.027	<.001	0.26
Left rotation	0.008	−0.004	0.14	0.118	0.132	11.834	<.001	0.153

Panel A presents coefficients from the final Model 2. Model 1 included BMI and sex. Model 2 additionally included SAS-SV score and average daily smartphone usage over the previous 7 days. Average daily smartphone usage was obtained from the smartphones' built-in screen-time records and expressed in min/day. Sex was coded as female = 1 and male = 2. Smartphone usage coefficients are presented to 4 decimal places because the JPE outcomes were measured in degrees and the unstandardized coefficients were small. The 95% confidence intervals for β were calculated from the standard errors of the standardized coefficients using 154 residual degrees of freedom. Cohen's f^2 represents the incremental effect size of the smartphone-related variables entered together in Model 2 and was calculated as $\Delta R^2/(1 - R^2$ of Model 2).

B, unstandardized regression coefficient; β, standardized regression coefficient; BMI, body mass index; JPE, joint position error; SAS-SV, Smartphone Addiction Scale–Short Version; VIF, variance inflation factor.

Smartphone addiction severity was positively correlated with anxiety and depressive symptoms, whereas average daily smartphone usage was not significant after FDR correction. These findings indicate different correlation patterns for usage duration and addiction severity; however, their direction and underlying mechanisms cannot be determined from the present cross-sectional data.

Strengths and Limitations

The strengths of this study include the use of device-based smartphone usage records, objective cervical JPE assessment, FDR correction, hierarchical regression models, and sensitivity analyses. The simultaneous assessment of smartphone usage, addiction severity, cervical proprioception, sleep, and psychological symptoms also provided a multidimensional perspective.

Several limitations should be considered. The cross-sectional design prevents causal or temporal conclusions. Although smartphone usage was obtained from device records and JPE was objectively assessed, SAS-SV, sleep-related outcomes, anxiety, and depressive symptoms were evaluated using self-report questionnaires during the same assessment; therefore, common-method variance may have influenced associations among these measures. The university-student sample limits generalizability. Participants with a previously diagnosed cervical musculoskeletal disorder were excluded; however, current neck pain was not systematically assessed, and pain intensity was not measured using a standardized scale. Finally, only the mean of the 3 JPE trials was retained, preventing retrospective calculation of sample-specific reliability, SEM, and MDC values and limiting interpretation of the clinical relevance of the JPE findings. The use of 3 recorded trials, rather than the more commonly reported 6-trial protocol, may also have reduced measurement reliability. In addition, movement speed was self-selected and was not externally standardized.

Conclusion

Average daily smartphone usage was independently associated with poorer sleep quality, greater insomnia severity, and bedtime procrastination, and these associations remained statistically significant after additional adjustment for depressive and anxiety symptoms. Smartphone addiction severity was independently associated with cervical flexion JPE, whereas its association with bedtime procrastination was not robust in the sensitivity analysis. Neither smartphone-related variable was significantly associated with NDI scores in the present sample. Longitudinal studies are needed to clarify the direction, temporal sequence, and clinical relevance of these associations.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Artificial Intelligence Usage Statement: This study used OpenAI ChatGPT to assist with English-language editing and grammatical revision during the preparation of the manuscript.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of University of İnönü (Approval no: 2025/7864, Date: May 29, 2025).

Informed Consent: Verbal/Written informed consent was obtained from the participants who agreed to take part in the study.

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