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Relationship between Smartphone Use and Neck Pain among University Students

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ABSTRACT

This study combined forward head posture, musculoskeletal strain, and ergonomic awareness in a single framework to investigate the relationship between smartphone use intensity and neck pain among University students in Pakistan. Data were analyzed using partial least squares structural equation modeling, and a quantitative cross-sectional design was used. The findings revealed that a high level of smartphone use was associated with a significant increase in FHP and neck pain, and FHP was significantly associated with an increase in MSK strain, which in turn significantly predicted the occurrence of neck pain. Additionally, the serial mediation model of intensity of smartphone use as a predictor of neck pain via forward head posture and musculoskeletal strain was also statistically significant. The positive association between intensity of smartphone use and neck pain was greatly diminished by ergonomic awareness. The model provided a meaningful explanation and prediction, making ergonomic education and safe smartphone use highly relevant for university students.

Introduction

Young adults are a population who are continually exposed to handheld digital devices (John et al., 2026) as smartphones become part of their daily lives at university, as well as for communication, social networking, and leisure. A relevant musculoskeletal exposure is the combination of long screen time use with a seated posture to study (and a flexed neck posture) when viewing (Al-Shalalfeh et al., 2026). The recent evidence shows that overuse of the smartphone may be a risk factor for the occurrence of neck-related symptoms and disability, and increased smartphone-addiction scores are related to the increased frequency of neck pain in undergraduate students (Phuyal et al., 2025). Additionally, students who suffer from text-neck syndrome indicate that they use their smartphones for longer periods of time, and that their posture is less aligned than the non-text-neck syndrome group (Yasaci et al., 2026).

The cervical area is especially sensitive because most people look at their phone with their heads in front of their body, and the increased cervical flexion when looking at the phone makes them prone to injury and develops a forward head posture (Szeto et al., 2020). Experimental studies demonstrate that the activation of both the erector spinae muscle and the upper trapezius muscle in the cervical spine changes when using a smartphone as a tool (Chen et al., 2024). A prolonged forward-tilted posture may also affect the stiffness of the cervical spine and change reflexive stabilization responses, which could be a possible mechanism for the effects of repeated exposure on impaired cervical stability (Kim et al., 2024). Unhealthy cell phone habits have also been linked to changes in cervical sagittal alignment and a decrease in extensibility (Torkamani et al., 2023).

This is an important concern in Pakistan as higher usage of cellphones has been found to be significantly more associated with neck pain among Pakistani university students (Daniyal et al., 2022). However, a significant portion of the university-student literature is still cross-sectional and focuses on the direct exposure-pain relationship without delving into the biomechanical pathways in which symptoms can develop (Maayah et al., 2023). In addition, meta-analysis data indicates that the duration of electronic-device use and the duration of head-down posture are two significant factors among college students that correlate with neck pain, suggesting the need to investigate intermediate postural and muscular mechanisms (Gao et al., 2023).

Thus, the present study defines smartphone use intensity as a multidimensional exposure, namely the use duration, number of uses, usage at night, and non-ergonomic usage. It suggests that forward head posture and musculoskeletal strain are two steps in how smartphone exposure could be mediated to neck pain. Ergonomic awareness is included as a protective boundary condition since ergonomic modifications that can enhance the support of the devices and the working behaviour can reduce the loading to the cervical and shoulder region (Tapanya et al., 2021). The proposed model in this way, thus, gives a mechanical explanation of the neck pain caused by smartphone use among the university students in Pakistan.

Theoretical Linkage

The proposed framework builds on a biomechanical perspective on exposure–response, in which repeated physical exposure may lead to a change in posture, neuromuscular demands, and loading of tissues before the onset of symptoms (Kim et al., 2024). The anterior displacement of the head (or head forward position) is also common when using a smartphone, as the device is often held below the head and this results in increased flexion of the cervical spine (Szeto et al., 2020). This postural deviation alters cervical mechanical demand as well as the recruitment of the cervical erector spinae and upper trapezius (Chen et al., 2024). Smartphone-dependent users have also been shown to have a change in their cervical posture in the sagittal plane and decreased extensor endurance, which supports an exposure-to-postural-change pathway (Torkamani et al., 2023).

Therefore, forward head posture is placed as the first mediator, as it is a behavioral exposure to biomechanical deviation. Head-forward positioning during sustained posture may reduce efficiency of the cervical muscles and/or cervical stability, which may lead to greater muscle activation for maintaining head position (Kim et al., 2024). The biomechanical changes in the posture of the scapulae and clavicles with slouched sitting are also different in people with neck dysfunction, suggesting that cervical posture should be understood as part of an upper-quarter biomechanical system (Konghakote et al., 2024). Because mechanical loading can lead to a change in the function of muscles, a decrease in muscle endurance, muscle fatigue, and discomfort, musculoskeletal strain is then also considered a second mediator.

Ergonomic awareness is not considered another biomechanical exposure, but rather a boundary condition. The physical effects of smartphone exposure are modifiable as ergonomic support during smartphone use can significantly lower the muscular loading and fatigue in the neck and shoulders (Tapanya et al., 2021). Additionally, ergonomic information and behavioral feedback can help to decrease uninterrupted technology-use patterns, though not all interventions have a consistent effect on improving posture or pain (Lindegård et al., 2024). The theoretical framework combines exposure, posture and strain, with pain, and ergonomic awareness is a condition that might be protective and affect the strength of the relationship between exposure/pain.

Hypotheses Development

The intensity of smartphone use represents the combination of longer use, more frequent checking, using them at night, and especially the interaction in non-ergonomic ways. Recently, higher scores for smartphone addiction have been linked to higher levels of functional disability in the neck among university students (John et al., 2026). Overuse of smartphones is also linked to increased risk of neck pain among medical and nursing undergraduate students (Phuyal et al., 2025), and duration of use of these devices is a predictor of the duration of neck pain in university students (Maayah et al., 2023). It is important to note that experiences from Pakistan indicate that those students who use cell phones for a longer period get more neck pain than those who use them less (Daniyal et al., 2022). Together, these results suggest that there exists an exposure-related association between intensive use of smartphones and negative cervical outcomes.

H1: Smartphone use intensity is positively associated with neck pain among university students.

There's also a postural aspect to using smartphones, since they are typically viewed below eye level. The study of Szeto et al. (2020) shows that the cervical region and upper thoracic region have much greater cervical and upper thoracic flexion when using the smartphone than when not using it. A forward-tilted positioning of a smartphone can negatively affect the stability of the cervical spine and the reflexive stabilization responses (Kim et al., 2024). Unhealthy use of the smartphone has also been linked to changes in craniovertebral alignment and increased forward-head position (Torkamani et al., 2023). Recent studies indicate that those who have text-neck syndrome also report higher amounts of exposure to the phone and poorer alignment of the neck and back (Yasaci et al., 2026). These converging results suggest that there are directional effects from smartphone exposure to postural deviation.

H2: Smartphone use intensity is positively associated with forward head posture.

The mechanical load on cervical and shoulder structures is higher in forward head posture due to the change in the anterior load on the structures that must be constantly controlled by the cervical musculature. By conducting controlled experiments, it has been found that the activation of the cervical erector spinae and upper trapezius muscles is significantly altered with increased head-flexion angles during smartphone tasks (Chen et al., 2024). The same can be said for all of the other upper-quarter changes that happen with non-neutral sitting, such as the changes in clavicular protraction, scapular internal rotation, and scapular anterior tilt, which are seen with slouched sitting (Konghakote et al., 2024). Heavy smartphone use has also been associated with decreased cervical muscular endurance, suggesting that repetitive postural loading may be associated with decreased muscular capacity (Elvan et al., 2024).

H3: Forward head posture is positively associated with musculoskeletal strain.

MSK strain is the most proximal physiological mechanism by which prolonged mechanical loading can lead to symptoms. Lower flexor endurance of the cervical spine is strongly correlated with higher severity of neck pain in university smartphone users (Elvan et al., 2024). Experimental studies also indicate that neck and shoulder muscular loading, fatigue, and discomfort have been shown to be higher during unsupported smartphone use, and significantly lower during ergonomic arm support (Tapanya et al., 2021). Electromyographic studies recently conducted have also shown that there is a change in the activation pattern of the upper trapezius, a decrease in quality of posture, and an increase in functional disability in people with text-neck syndrome (Yasaci et al., 2026). Therefore, cervical and shoulder muscle strain is physiologically plausible as an antecedent of neck-pain symptoms.

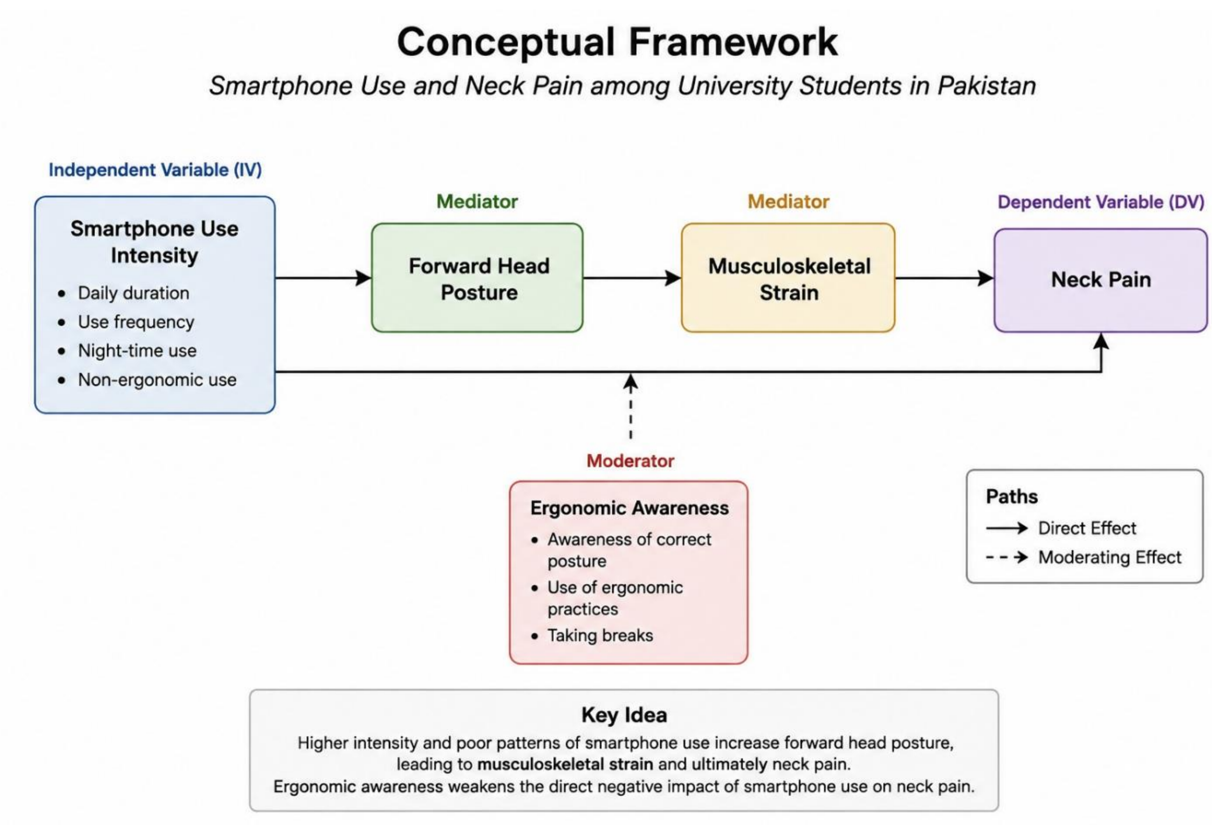
H4: Musculoskeletal strain is positively associated with neck pain among university students.

The proposed framework also outlines the sequential nature of the process, as increased exposure to smartphones is hypothesized to encourage forward head posture, which in turn leads to postural deviations and musculoskeletal strain, which will lead to neck pain. Gao et al. (2023) found prolonged electronic-device exposure to be a significant risk factor for neck pain among college students, as did prolonged head-down posture. Field studies have shown that the use of a smartphone is associated with more cervical flexion (Szeto et al., 2020), and experimental studies indicate that the forward-tilted posture of smartphone use can affect cervical stabilization mechanisms (Kim et al., 2024). Importantly, recent research has also demonstrated that the text-neck posture is not necessarily correlated with neck disability, which further supports the idea that posture alone is not sufficient to generate symptoms and further underscores the need for a physiological-strain mechanism between posture and symptoms of disability (Souza et al., 2024).

H5: Forward head posture and musculoskeletal strain sequentially mediate the positive relationship between smartphone use intensity and neck pain.

Last but not least, the implications of heavy usage of a smartphone can vary based on students' ergonomic awareness. Although there is limited evidence on direct rvidence testing to address ergonomic awareness as a statistical moderator, strong evidence on intervention reveals that biomechanical exposure can be modified using ergonomic practices when related to smartphones. Smartphone use significantly contributes to cervical and shoulder muscle loading and fatigue, and ergonomic arm support can effectively alleviate them even with prolonged use of the smartphone (Tapanya et al., 2021). Randomized evidence in young technology users also suggests that providing ergonomic information and behavioral feedback can decrease prolonged uninterrupted device use, but with mixed results regarding posture and pain (Lindegård et al., 2024). Therefore, students with knowledge of neutral cervical posture, positioning the devices appropriately, providing physical support, and regular break taking should be better equipped to avoid a symptomatic load on their necks from intensive smartphone exposure.

H6: Ergonomic awareness negatively moderates the relationship between smartphone use intensity and neck pain, such that the positive relationship is weaker at higher levels of ergonomic awareness.



Methodology

Research Design

In this study, a quantitative, explanatory, and cross-sectional research design was used to explore the relations between FHP, MSD, EE, and NH among university students in Pakistan. A cross-sectional design was deemed suitable since data about smartphone exposure, postural behavior, musculoskeletal symptoms, and ergonomic awareness were collected at one time. A structured self-administered questionnaire, mainly distributed online and administered on campus, where possible, was used in the study. The proposed framework includes direct relationships, sequential mediation, and moderation, along with the focus on predicting the outcomes of neck pain, which led to the use of partial least squares structural equation modeling (PLS-SEM) (Hair et al., 2022; Ringle et al., 2024). Because temporal precedence was not possible as a result of cross-sectional data, the relationships in time were interpreted as theoretically specified relationships and not causal. All participants had given informed consent, and ethical approval was gained from the relevant institutional review board prior to data collection.

Population and Sample

The target population included the students of Higher Education Commission-recognized public and private universities of Pakistan, both at undergraduate and graduate levels. The subjects who participated were selected if they were at least 18 years old and enrolled in a university degree program, and used a smartphone at least once a week, and had been using it for a minimum of six months. To increase sample heterogeneity and population coverage, students from various disciplines and study levels were included. Students with a history of recent trauma or surgery to the neck and those who had been diagnosed with nervous or inflammatory disorders of the neck or had severe congenital spinal problems were excluded from the study to reduce the impact of alternative clinical explanations of the neck-related symptoms. The sampling frame consisted of selected universities from both major geographical regions of Pakistan, both public and private universities. The analytical sample included only respondents who gave informed consent, met the eligibility criteria, and filled out the primary measures of the study. Demographic and control data included age, sex, academic level, field of study, physical activity status, and other musculoskeletal factors.

Sample Size and Sampling Technique

The sample was determined as adequate considering both the survey-sampling and the statistical-power approach of PLS-SEM. First, Cochran's (1977) sample-size formula was used for the large number of university students in Pakistan. The minimum number of respondents necessary at a 95% confidence level, 5% margin of error, and maximum population variability ($p = .50$) was about 384 respondents. A complementary statistical-power analysis was done with G*Power 3.1. With four predictors in the most complex endogenous equation, $\alpha = .05$, $\beta = .8$, and assuming a medium effect size ($f^2 = .15$), a sample size of 85 observations was necessary, which is significantly larger than the minimum power requirement (Faul et al., 2009). Therefore, the study aimed to collect at least 400 valid responses, with an estimated 450 responses to include incomplete or unusable questionnaires.

A multistage stratified sampling method was used. Universities were first divided on the basis of geographical region, and then the public/private sector, and then the institutions were selected within each of these strata. Students were then proportionately sampled within faculties and for each academic level. If student lists were available, then random selection was used; otherwise, randomly selected classes were used as sampling clusters.

Measurement Instrument

The data were obtained with the help of a structured bilingual English – Urdu questionnaire. Smartphone Use Intensity was defined as a formative composite of four theoretically distinct behavioral indicators: Average Daily Smartphone Use Duration, frequency of smartphone use, night-time smartphone usage, and non-ergonomic smartphone usage. The same behavioural markers have been used in recent studies of smartphone use among university students (John et al., 2026). Forward Head Posture was evaluated by using a pictorial self-perception tool that showed increasing degrees of cervical flexion, which has been shown to have acceptable test–retest reliability in previous smartphone studies (Damasceno et al., 2018). The higher the coded value, the more forward the head position.

MSD was measured by modified items from both the Cornell Musculoskeletal Discomfort Questionnaire neck and shoulder subscales for symptom frequency, discomfort severity, and interference (Hedge et al., 1999). The 11-point Numerical Rating Scale (NRS) was obtained for Neck Pain and related to the mean severity of neck pain in the last 7 days. Ergonomic Awareness was measured with multi-item statements comprising neutral neck posture, adequate height of the smartphone, physical support, taking frequent breaks, and changing posture, all of which have been adopted from the latest research on smartphone-posture awareness (Akodu et al., 2024). The adapted items were expert content validated, bilingual validated, and pilot tested with around 30-50 students who were not included in the final study.

Data Analysis Techniques

First, the data were screened for demographic characteristics, missing data, responses to questions that were not clearly understood, and outliers, with the data then being used to estimate the model via SmartPLS 4 (Ringle et al., 2024). Indicator loadings, Cronbach's alpha, rho_A, composite reliability, average variance extracted (AVE), and the heterotrait–monotrait ratio (HTMT) were used to assess the measurement model for reflective constructs. The loadings of the indicators were around 0.708 or higher, the reliability values were in the range 0.70–0.95, the AVE values were 0.50 or higher, and the HTMT values were acceptable (Hair et al., 2022; Henseler et al., 2015). Indicator collinearity and the significance and relevance of the outer weights were checked for the formative Smartphone Use Intensity construct.

The model was assessed in terms of inner VIF, standardized path coefficient, R2, f2, and bootstrapped confidence intervals and 10,000 resamples. The relationship between being exposed to smartphones and FHPs and MSD and neck pain was explored through serial mediation, where smartphone use intensity mediated between FHPs and MSD and neck pain, and moderation was tested by the interaction between smartphone use intensity and ergonomic awareness.

An omission distance, such as seven, was used to evaluate the traditional Stone–Geisser Q^2 predictive relevance of the models in the blindfolding procedure (Stone, 1974; Geisser, 1974). Since SmartPLS 4 has abandoned the blindfolding approach, the most recent methods of evaluating predictive performance, PLSpredict and CVPAT, were adopted instead.

Results

Measurement Model

The measurement-model results showed reasonable reliability and convergent validity for the Ergonomic Awareness (EA), Forward Head Posture (FHP), Musculoskeletal Strain (MS), and Neck Pain (NP). The loadings of these reflective constructs ranged from 0.753 to 0.912, surpassing the recommended value of 0.708, and the indicators were considered to be reliable. Cronbach’s alpha values were 0.893 for EA, 0.879 for FHP, 0.874 for MS, and 0.882 for NP, while composite reliability values ranged from 0.914 to 0.927. Internal consistency is good, as confirmed by these values. Likewise, AVE scores were between 0.696 and 0.809, which was higher than the minimum value of 0.50, indicating convergent validity.

Multicollinearity was not a problem as the VIF values for EA, FHP, MS and NP were between 1.935 and 2.840. The indicator values for Smartphone Use Intensity (SUI) were between 1.035 and 1.050, indicating that there was no collinearity between the four indicators. However, SUI produced comparatively low loadings (0.539–0.630), Cronbach’s alpha (0.373), composite reliability (0.676), and AVE (0.344). These statistics would show poor reliability if SUI were reflectedively modelled. However, in the proposed study, SUI is considered as an emerging composite, which is composed of four individual dimensions: daily duration, frequency, night-time use, and non-ergonomic use. Thus, the evaluation criteria of alpha, composite reliability, AVE, and conventional loading criteria are not suitable for SUI. Rather, a measure of its quality should be based on indicator VIFs and the significance and relevance of formative outer weights. The overall results of the reflective measurement model are satisfactory in terms of reliability, convergent validity and the degree of collinearity.

Table 1: Reliability and validity

Indicator	Loading	Construct	Cronbach’s Alpha	CR	AVE	VIF
EA1	0.895	EA	0.893	0.919	0.696	2.840
EA2	0.821	EA				2.280
EA3	0.871	EA				2.349
EA4	0.825	EA				2.023

Indicator	**Loading**	**Construct**	**Cronbach's Alpha**	**CR**	**AVE**	**VIF**
EA5	0.753	EA				1.935
FHP1	0.891	FHP	0.879	0.917	0.735	2.638
FHP2	0.842	FHP				2.078
FHP3	0.872	FHP				2.376
FHP4	0.822	FHP				1.971
MS1	0.851	MS	0.874	0.914	0.726	2.156
MS2	0.868	MS				2.309
MS3	0.859	MS				2.169
MS4	0.829	MS				2.021
NP1	0.911	NP	0.882	0.927	0.809	2.591
NP2	0.912	NP				2.702
NP3	0.876	NP				2.237
SUI1	0.539	SUI	0.373	0.676	0.344	1.050
SUI2	0.545	SUI				1.049
SUI3	0.626	SUI				1.035
SUI4	0.630	SUI				1.041

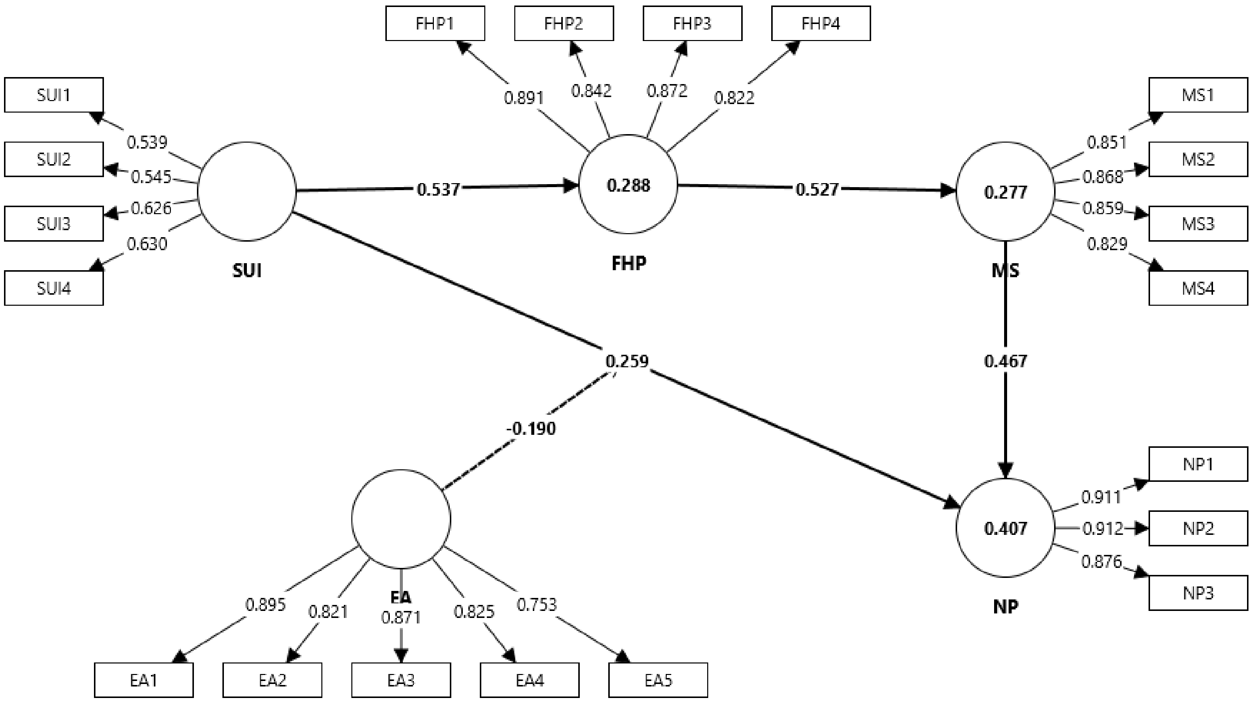


Figure 2: Measurement Model

Discriminant Validity

According to the results of the HTMT, the validity of the constructs was generally acceptable with regard to the reflective constructs. The HTMT values of EA–FHP (0.069), EA–MS (0.064), EA–NP (0.080), FHP–MS (0.598), FHP–NP (0.466), and MS–NP (0.620) were lower than the typical value of 0.85 and lower than the more lenient value of 0.90, which indicated that these constructs were empirically separate. The correlations of Smartphone Use Intensity (SUI) with EA (0.091), MS (0.632), and NP (0.729) were also acceptable. Between SUI and FHP, however, the HTMT was 0.920, which is above the threshold of 0.90, and indicates that there may be discriminant-validity issues if SUI were considered a reflective item. However, in this study, SUI was used as a formative composite, and conventional HTMT assessment cannot be a suitable criterion to consider its discriminant validity. Therefore, the discriminant validity among reflective constructs was validated, and for the formative SUI construct, the collinearity and the outer-weight significance were used for validation.

Table 2: HTMT Criteria

Construct	EA	FHP	MS	NP	SUI
EA					
FHP	0.069				
MS	0.064	0.598			
NP	0.080	0.466	0.620		
SUI	0.091	0.920	0.632	0.729	

Structural model

All hypothesized relationships were supported by the results of the structural model. The Forward Head Posture (FHP) was significantly positively correlated with Smartphone Use Intensity (SUI) ($\beta = 0.537$, $t = 15.318$, $p < 0.001$), suggesting that the higher students' SUI, the worse their FHP. FHP significantly increased Musculoskeletal Strain (MS) ($\beta = 0.527$, $t = 15.052$, $p < 0.001$), while MS significantly predicted Neck Pain (NP) ($\beta = 0.467$, $t = 12.563$, $p < 0.001$). Furthermore, SUI showed a strong partial mediation effect on NP ($\beta = 0.259$, $t = 6.406$, $p < 0.001$). The serial indirect effect via FHP and MS was significant ($\beta = 0.132$, $t = 7.367$, $p < .001$), thus supporting the proposed sequential mediation pathway. Also, the interaction between Ergonomic Awareness and SUI was negative and significant ($\beta = -0.190$, $t = 4.135$, $p < 0.001$), meaning that the positive relationship between SMI and NCP was weakened by increasing Ergonomic Awareness.

Table 3 Path co-efficient

Path	Beta	Sample Mean (M)	STDEV	T Value	P Value
FHP → MS	0.527	0.528	0.035	15.052	0.000
MS → NP	0.467	0.465	0.037	12.563	0.000
SUI → FHP	0.537	0.539	0.035	15.318	0.000
SUI → NP	0.259	0.259	0.040	6.406	0.000
EA × SUI → NP	-0.190	-0.177	0.046	4.135	0.000
SUI → FHP → MS → NP	0.132	0.133	0.018	7.367	0.000

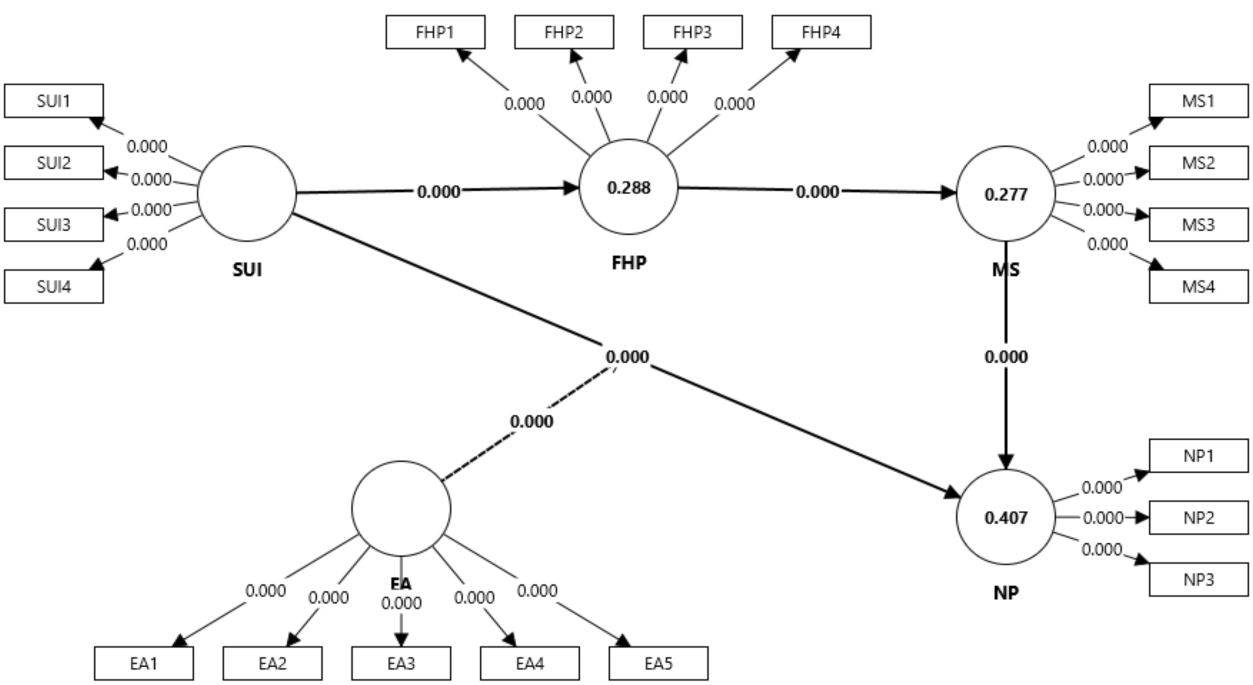


Figure 3: Structural Model

Variance and effect size

The structural model explained moderate amounts of variance. The smartphone use intensity accounted for 28.8% of the variance in Forward Head Posture ($R^2 = 0.288$), and Forward Head Posture accounted for 27.7% of the variance in Musculoskeletal Strain ($R^2 = 0.277$). The Neck Pain model had an R2 value of 0.407 and was able to explain a significant proportion of the variance in this variable. Effect-size results showed that SUI → FHP ($f^2 = 0.404$) and FHP → MS ($f^2 = 0.384$) had large effects, while MS → NP ($f^2 = 0.315$) had a moderate-to-large effect. SUI → NP ($f^2 = 0.097$) and the moderation effect ($f^2 = 0.067$) were small but meaningful.

Table 4 R- Square and f- Square

Construct	R-square	R-square adjusted	Path	f-square
FHP	0.288	0.286	EA → NP	0.022
MS	0.277	0.276	FHP → MS	0.384
NP	0.407	0.402	MS → NP	0.315
			SUI → FHP	0.404
			SUI → NP	0.097
			EA × SUI → NP	0.067

CVPAT Analysis

The main findings of the CVPAT results showed that the PLS-SEM model performed better in predicting than the indicator-average (IA) model. The average loss differences showed that PLS had lower prediction errors compared to the benchmark model for the cases of FHP (−0.310), MS (−0.137), and NP (−0.661). These differences were statistically significant for FHP ($t = 6.136$, $p < 0.001$), MS ($t = 4.781$, $p < 0.001$), and NP ($t = 5.027$, $p < 0.001$). The model's overall (mean) loss difference also was negative and significant, indicating that the model has robust out-of-sample predictive performance (−0.343, $t = 6.705$, $p < 0.001$).

Table 5 CVPAT Results

Construct	PLS loss	IA loss	Average loss difference	t value	p value
FHP	1.204	1.514	-0.310	6.136	0.000
MS	1.356	1.493	-0.137	4.781	0.000
NP	3.368	4.029	-0.661	5.027	0.000
Overall	1.849	2.192	-0.343	6.705	0.000

Discussion

The results offer a solid empirical basis for the hypothesized biomechanical mechanism between smartphone use intensity and neck pain in university students. The use intensity of the smartphone significantly predicted the FHP (β = 0.537) and the musculoskeletal strain (β = 0.527); the musculoskeletal strain significantly predicted the neck pain (β = 0.467). The findings were consistent with the evidence that long-term use of the smartphone leads to cervical flexion, distorted cervical muscle activation, and decreased muscular endurance (Chen et al., 2024; Elvan et al., 2024; Kim et al., 2024). The direct association of smartphone use intensity with neck pain (β = 0.259) also suggests that the intensity of smartphone exposure might have effects on neck pain other than the ones indicated here.

Importantly, the significant serial indirect effect (β = 0.132) indicates that the effect of smartphone use intensity on neck pain is mediated by forward head posture and musculoskeletal strain. This corroborates the theoretically postulated exposure → posture → strain → pain sequence. The discovery builds upon past studies that associate long periods of head-down posture and engagement with electronic devices with neck pain among students at universities (Gao et al., 2023; Szeto et al., 2020). Additionally, the smartphone use – neck pain relationship was negatively associated with ergonomic awareness (β = −0.190), highlighting its protective effect. This is consistent with the evidence of ergonomic interventions, which showed that the improvement of support and posture management, along with behavioral feedback, can both reduce the loading of the cervical spine and reduce fatigue (Tapanya et al., 2021; Lindegård et al., 2024). The model also had a meaningful explanatory and predictive performance with an explanation level of 40.7% and outperformed the indicator-average benchmark.

Theoretical Implications

This study adds to the biomechanical exposure–response paradigm, showing that a direct exposure–outcome relationship is insufficient to explain the occurrence of smartphone-related neck pain. Rather, the results present a sequential process wherein the intensity of using the smartphone is a risk factor for forward head posture, which in turn elevates musculoskeletal strain and leads to the development of neck pain. The key to the important serial mediation is to combine behavioral exposure, postural deviation, muscular response, and pain in a single explanatory framework. It builds on previous research, which mostly studied one of the three aspects of smartphone exposure, posture, or neck pain separately (Maayah et al., 2023; Torkamani et al., 2023). Furthermore, ergonomic awareness plays an important role in the biomechanical model as a moderating factor, making ergonomic awareness an important behavioral boundary variable. The results illustrate that the biomechanical outcomes are not always the same when users are different, partly due to the individual's knowledge and practices in relation to their ergonomics. Theoretically, the study adds to the current literature because it integrates the mechanisms of biomechanics with a behaviorally modifiable protective factor in understanding the musculoskeletal outcomes of smartphone-related activities.

Practical Implications

The results indicate that restricting smartphone usage could be ineffective in the management of neck pain in university students. Smartphone-use intensity, cervical posture, muscular strain and ergonomic behavior should all be addressed at once in prevention programs. Institutions can offer short educational interventions focusing on optimal smartphone use, neutral cervical posture, supported postures, posture changes and frequent micro-breaks. Evidence indicates that ergonomic support during smartphone use can help to minimize the loading and fatigue of neck and shoulder muscles (Tapanya et al., 2021). Students should also be reminded not to have continuous long periods of smartphone use, especially when studying or at night time. Digital reminders or apps on mobile phones may remind people to change their posture, take a break, or change the position of their devices. Screening programs could also be used to detect pupils who are complaining of recurrent neck pain and/or muscle fatigue and/or forward head posture to ensure that early advice and/or referral is made before the symptoms escalate into a more chronic musculoskeletal disability.

Managerial Implications

The findings can be used by university administration, student-affairs units, occupational-health units and campus health services to create structured policies for digital-wellbeing and ergonomics. The model accounted for 40.7% of the variance in neck pain and had good predictive power, so smartphone ergonomic behaviour is a relevant domain for institutional action. Smartphone ergonomics could be introduced into the orientation programmes, health-awareness campaigns, and digital-learning guidelines of universities to be considered. Campus managers can also increase the comfort of study using furniture that can be adjusted to fit the desk user, as well as appropriate desk configurations and device supports that promote a neutral cervical position. Faculty might use brief breaks in the midst of long digital learning sessions and discourage needless, non-classroom cell phone use. Periodic evaluation of musculoskeletal complaints and posture training workshops may be offered to students by student health departments. Importantly, ergonomic awareness was an important moderating variable, implying that modestly priced education programs might be used to lessen the negative effects of heavy smartphone use. Thus, institutional solutions need to be thoughtfully designed around the interests of not only limiting the use of smartphones but also encouraging more positive technology interactions.

Limitations and Future Research

The limitations of the findings should be noted: First, the cross-sectional design does not allow for definitive causal inference or confirmation of the temporal ordering of smartphone use intensity, forward head posture, musculoskeletal strain, and neck pain. Thus, the manuscript itself does not give any final guarantees of the causal effects in question, but only mentions the possible paths that are assumed as theoretically specified associations. Longitudinal or experimental design should be used for future studies to determine temporal relationships. Second, the study was mostly self-reported, which could result in recall bias, common-method variance, and subjectively determined measurement error. Objective smartphone screen-time measurements, accelerometers, posture sensors, electromyography, or photographic craniovertebral-angle measurements could be integrated in future studies. Thirdly, the approach of the sampling was representative of public and private universities, but the findings may not be equally applicable for all regions and socioeconomic groups of Pakistan. In the future, nationally representative samples and multigroup comparisons by gender, academic field, region, and sector of the university should be used. Last but not least, other mechanisms like sleep quality, stress, physical activity, psychological distress, and sedentary behavior can be added to enhance the explanatory power of the model.

Conclusion

This study offers a comprehensive explanation for the association between intensive use of the smartphone and neck pain in university students in Pakistan. The results show that using a smartphone intensifies forward head posture, which leads to musculoskeletal strain and finally to neck pain. The findings of this significant serial indirect effect support the idea that both the postural and muscular mechanisms account for an important component of the smartphone use-neck pain association, and the direct effect suggests that other pathways may be at play. Ergonomic awareness was shown to be an important moderating protective factor that reduced the undesirable association between the intensity of smartphone use and neck pain. The model was also shown to be meaningfully explanatory and to have better out-of-sample predictive performance. Taken together, the results highlight the need for dual intervention of the behavioral and biomechanical aspects when dealing with neck pain related to the smartphone. Use of mobile devices, posture, and appropriate breaks should be encouraged among students through the awareness of ergonomics in universities. The proposed framework thus provides a measure for the understanding of the musculoskeletal risks associated with smartphones as well as a basis for preventive interventions in the university context.

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