The Triad of Smartphone Addiction, Sleep Deprivation, and Anxiety among Health Science Undergraduates: A Structural Equation Modeling Study

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Abstract

Objectives

Addictions to smartphones, sleep deprivation, and anxiety have become more common in college students. However, their mutual interaction has not been comprehensively studied within the realm of allied health science education. Being enrolled in health science programs young adults experience particular psychological and educational challenges which make them predisposed to maladaptive usage of technology and related negative outcomes in terms of mental health. In particular, the interaction of smartphone addiction, sleep deprivation, and anxiety is studied in order to understand the mediating role of smartphone addiction as an upstream risk factor of sleep insufficiency and anxiety during early stages of allied health science education. This is a quantitative study that will explore the triangular interaction of smartphone addiction, sleep deprivation, and anxiety among undergraduate students. It is especially important to explore whether sleep deprivation mediates the connection between smartphone addiction and anxiety.

Materials and Methods

366 undergraduate students (18-25) enrolled across allied health science courses in five universities participated in this cross-sectional study. Smartphone Addiction Scale-Short Version (SAS-SV), the Pittsburgh Sleep Quality Index (PSQI), and the Generalized Anxiety Order GAD-7, were completed by the Students alongside a socio-demographic questionnaire. Stratified random sampling was employed for participant recruitment. Data was analysed using descriptive statistics, Pearson correlation, subgroup comparisons, and Structural Equation Modeling (SEM) to examine direct, indirect, and mediating pathways among the three constructs.

Results

Significant positive correlations were found among all three constructs: smartphone addiction correlated with sleep deprivation and anxiety, while sleep deprivation correlated with anxiety. SEM confirmed partial mediation by sleep deprivation. Subgroup analyses revealed significantly higher mean scores on all three constructs among females and final-semester students, and hostellers demonstrated the most poor sleep quality compared to non-hostellers.

Conclusion

These findings confirm that smartphone addiction functions as a significant upstream factor driving both sleep deprivation and anxiety among allied health science undergraduates. The high comorbidity and subgroup disparities underscore the immediate need for university-level policy

development and targeted mental health interventions, particularly during the early stages, to promote adaptive technology use and overall psychological well-being.

Keywords: Smartphone addiction, Sleep deprivation, Anxiety, Health Science students, Structural Equation Modelling

Introduction

Although smartphones have a great potential for education and communications, their rampant misuse without any regulation has become a major public health problem especially among students attending universities.[1] Cross-cultural reinforces these concerns, showing that students exposed to high levels of helicopter parenting are more likely to exhibit problematic gaming and social media use than those experiencing lower parental over involvement.[2]

The very nature of course in medicine, nursing, physiotherapy, pharmacy, and other allied health sciences, with its long hours of studying, clinical placements, and exams, creates a state of chronic stress.[3] The health science students are thus prone to engage in unhealthy coping strategies, including overusing their smartphones. On the contrary, this group heading towards a noble profession of helping others achieve good health, could have problems with their own mental well-being.

Lack of sleep remains one of the most common yet largely overlooked health problems facing college students. There is a logical link between use of cell-phones and sleep disorders, since exposure to blue light from the screen disrupts melatonin production and affects circadian rhythm induction, while behavioural obsession with social networking sites prevents individuals from falling asleep.[4]

Anxiety is the most prevalent type among college students across the globe.[5] There has been emerging literature on the reciprocal and complex connection between the overuse of gadgets, disruption of sleep, and increased anxiety levels, but the exact structural linkages between the three variables have not been studies enough, especially among health science students in the Indian subcontinent.[6]

Regression technique was commonly used in earlier studies to investigate the linkage between the variables individually. This did not take into account the interconnectedness of the two phenomena. Structural Equation Modeling provides a framework for simultaneously modelling both direct and indirect linkages while also estimating mediation effects and taking into account errors of measurement.[7]

There are hardly any existing research in which the SEM technique was used to investigate the interrelationships among smartphone addiction, sleep deprivation, and anxiety as a structural system among undergraduates of health sciences in India.[8] The objective of the proposed study includes: 1) identifying the prevalence of smartphone addiction, sleep deprivation, and anxiety among health science undergraduate students; 2) investigating the direct structural relationships between the three variables; and 3) examining the mediation of sleep deprivation in the relationship between smartphone addiction and anxiety.

Materials and Methods

Participants

Inclusion Criteria

- Current undergraduate students registered in any health science program, in the university.
- At least 18 years old
- Owning a smartphone used daily for at least six months
- Readiness to sign an informed consent.

Exclusion Criteria

- Irregular/students of other stream
- Students having been previously diagnosed with a mental health condition.
- Questionnaires with incomplete data (more than 10% of missing data on any questionnaire)

Data Collection Instruments

1. **Sociodemographic Proforma:** Included questions about age, sex, stream of study, year of study, hostel/dayscholar status, family income/month, parental education level, and time spent on smartphones daily in hours.
2. **Smartphone Addiction Scale Short Form (SAS-SV):** Consists of 10 questions rated on a 6-point Likert scale ranging from 1("strongly disagree") to 6("strongly agree"). It is specifically validated for college students.[9] The cut-off score ≥31 for male respondents and ≥33 for female respondents was used as criteria for smartphone addiction. Good internal consistency was found in this study (Cronbach's α=0.87).
3. **Pittsburgh Sleep Quality Index (PSQI):** Consists of 19 questions and evaluates sleep quality of the past month in seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction.[10] Cut-off score for PSQI score>5 was taken as poor sleep quality or sleep deprivation. Satisfactory internal consistency (Cronbach's α=0.79) was found in this study.
4. **Generalized Anxiety Disorder-**7 Scale (GAD-7): consists of 7 items and utilizes a four-point Likert scale 0("not at all") to 3("nearly every day"). Possible scores vary from 0 to 21; 5, 10, and 15 indicated mild, moderate, and severe anxiety, respectively.[11] The cut-off score ≥10 was set as clinically significant anxiety in this study. Cronbach's α=0.88 in this study.

Statistical Analysis

The data collection process involved using Microsoft Excel 2019 for entering and validation; data analysis used IBM SPSS (version 23). Descriptive statistics (mean, standard deviation, skewness, kurtosis) was calculated for all continuous variables. Prevalence estimates were reported with 95% Confidence Intervals (CI), using the Wilson scores method. Comparing groups on scale score was performed by using Independent sample t-test (for two group comparisons: gender, residence status) and One-way Analysis of Variance (ANOVA) together with post-hoc Tukey's Honestly Significant Difference (HSD) test (for year of study). Pearson's correlation coefficients with 95% CIs was computed to assess bivariate associations among the three primary constructs.

Structural Equational Modeling (SEM): Performed in two sequential stages.

1. **Confirmatory Factor Analysis (CFA): E**ach latent construct (smartphone addiction, sleep deprivation, and anxiety) was assessed individually for factorial validity. Standardized factor loadings, average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's α were calculated to measure convergent validity. Discriminant validity was calculated using Fornell-Larcker criteria, by comparing AVE values with the squares of inter-construct correlation coefficients.
2. **Structural Model Testing:** Smartphone addiction was considered an exogenous latent variable; sleep deprivation was considered a mediating latent variable, while anxiety was taken as an endogenous latent variable. Direct, indirect, and total effects were measured. Mediation analysis was performed using the bootstrapping technique with 5,000 resamples and a bias-corrected 95% confidence intervals (95% BCa CI). The proportion of the toatal effect mediated by sleep deprivation was also computed.

Model fit was calculated: using $\chi^2/df < 3.0$; Goodness-of-Fit Index (GFI) >0.90; Comparative Fit Index (CFI≥0.95), Tucker-Lewis Index (TLI≥0.90); Standardized Root Mean Square Residual (SRMR≤0.08); Root Mean Square Error of Approximation (RMSEA) ≤0.08, with 90% CI reported. Statistical significance was determined at $P<0.05$.

Results

Table 1 shows the demographic details of 366 participants. Most of them were from hostels (64.5%, n=236. Female students constituted the majority 58.1% (n=213).). The average self-reporting of daily usage of smartphones was 6.4±2.3 hours, with 18.1% reporting use exceeding eight hours per day.

Table 1: Socio-demographic Characteristics of Study participants (N=366)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	153	41.9
	Female	213	58.1

Age Group (years)	18-20	172	47.1
	21-23	152	41.4
	24-26	42	11.4
Programme	BSc. Nursing	124	34.0
	B.Pharma	95	26.0
	BPT	82	22.4
	Allied Health Sciences	65	17.6
Year of Study	First	103	28.1
	Second	98	26.7
	Third	92	25.2
	Final	73	20.0
Residence	Hostel	236	64.5
	Day Scholar	130	35.5
Daily smartphone use	< 4 hours	68	18.6
	4-6 hours	124	33.8
	6-8 hours	108	29.5
	>8 hours	66	18.1

Table 2 presents descriptive statistics and prevalence estimates for all three primary study variables. Smartphone addiction was identified in 47.3% of participants (95% CI: 42.2-52.5%). Poor sleep quality (PSQI > 5) was present in 61.8% (95% CI: 56.7-66.6%). Clinically significant anxiety (GAD ≥ 10) was identified in 38.4% of participants (95% CI: 33.4-43.7%). Score distributions exhibited acceptable normality, with skewness and kurtosis values within conventional bounds (|skewness| <2.0, |kurtosis| <7.0).

Table 2: Descriptive Statistics and Prevalence of Key Study Variables (N = 366)

Variable	Mean	SD	Skewness	Kurtosis	Prevalence (%, n)	95% CI
SAS-SV score	30.41	8.73	0.42	–0.31	Addiction:47.3% (173)	42.2–52.5%
PSQI Global score	7.18	3.09	0.18	0.18	Poor sleep (>5): 61.8% (226)	56.7–66.6%
GAD-7 score	9.12	4.57	0.55	–0.22	Clinical anxiety (≥10): 38.4% (n=141)	33.4–43.7%

Table 3 depicts Pearson correlation coefficients with 95% CIs for all pairwise associations. Moderate positive correlations were observed among all three constructs. The strongest association was between sleep deprivation and anxiety (r=0.52, 95% CI: 0.44–0.59, P<0.001). Smartphone addiction was moderately correlated with poor sleep quality (r=0.41, 95% CI: 0.33–0.49, P<0.001), explaining approximately 17% of their shared variance, and anxiety (r=0.38, 95% CI: 0.29–0.46, P<0.001)

Table 3: Pearson Correlation Coefficients among study variables (N=366)

Variable	Mean	SD	1	2	3
SAS-SV	30.41	8.73	–		
PSQI	7.18	3.09	0.41***[0.33, 0.49]	1	
GAD-7	9.12	4.57	0.38***[0.29, 0.46]	0.52***[0.44,0.59]	1

Note: Values in brackets denote 95% confidence intervals. ***P <0.001.

Confirmatory Factor Analysis was conducted separately for each of the three latent constructs. Table 4 presents factors loadings, Composite Reliability (CR), AVE, and Cronbach's α for each construct.

Table 4: Measurement Model– Factor Loadings, Composite Reliability, AVE, and Internal Consistency (N=366)

Constructs	Indicator	Standardized Factor Loading	CR	AVE	Cronbach's α

Smartphone Addiction (SAS-SV)	Item 1	0.71	0.89	0.52	0.88
	Item 2	0.74			
	Item 3	0.68			
	Item 4	0.76			
	Item 5	0.70			
	Item 6-10	0.65-0.79			
Sleep Deprivation (PSQI)	Component 1	0.69	0.86	0.48	0.79
	Component 2	0.72			
	Component 3	0.74			
	Component 4	0.67			
	Component 5-7	0.63-0.71			
Anxiety (GAD-7)	Item 1	0.78			
	Item 2	0.81			
	Item 3	0.76			
	Item 4	0.79			
	Item 5-7	0.73-0.82	0.92	0.57	0.91

Note: All standardized factor loadings were statistically significant at P<0.001. CFA model fit: SAS-SV–χ^2/df=2.61, CFI=0.94, RMSEA=0.058; PSQI–CFI=0.96, RMSEA=0.047; GAD-7–χ^2/df=2.09, CFI=0.97, RMSEA=0.042. CR=Composite Reliability, AVE=Average Variance Extracted.

Table 5 presents the Fornell-Larcker matrix. The square root of each construct's AVE (diagonal values) exceed the inter-construct correlations in the corresponding row and column, supporting discriminant validity.

Table 5: Discriminant Validity

Construct	Smartphone Addiction	Sleep Deprivation	Anxiety
Smartphone Addiction	**0.72**		
Sleep Deprivation	0.41	**0.69**	
Anxiety	0.38	0.52	**0.75**

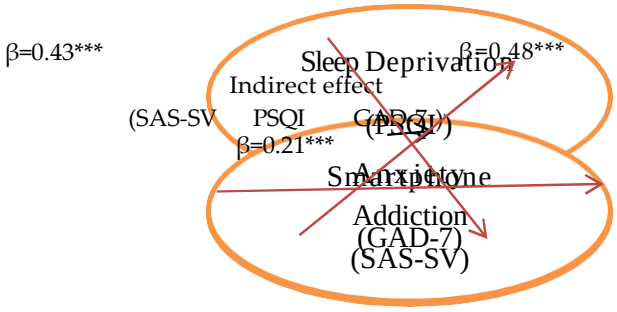
Note: Diagonal values (bold) represent the square root of AVE for each construct. Off-diagonal values are inter-construct Pearson correlations.

The structural model demonstrated acceptable to good fit across all six fit indices (Table 6) Smartphone addiction was specified as the exogenous variable, sleep deprivation as the mediator, and anxiety as the outcome variable.

Table 6: Structural Model Fit Indices

Fit Index	Obtained Value	Acceptable Threshold
X2/df	2.47	<3.0
GFI	0.92	>0.90
CFI	0.96	≥0.95
TLI	0.94	≥0.90
SRMR	0.052	≤0.08
RMSEA (90% CI)	0.053 (0.041-0.065)	≤0.08

Figure 1: Structural equation model (SEM) of the Relationship among Smartphone addiction, Sleep deprivation, and Anxiety



β=0.31***

Structural Equation Model demonstrating the direct and indirect associations of smartphone addiction, sleep deprivation, and anxiety of the participants. standardized path coefficients (β) have been shown for all paths. Sleep partially mediated the association between smartphone addiction and anxiety. All paths were significant ($p<0.001$). Model fit indices were found to have good model fit (χ^2 /df=2.47, GFI=0.92, CFI=0.96, TLI=0.94, SRMR=0.052, RMSEA=0.053)

Table 7 presents full structural path coefficients with standard errors, critical ratios, and significant values.

Table 7: Structural Path Coefficient (N=366)

Path	β	SE	Critical Ratio (CR)	P
Smartphone Addiction →Sleep Deprivation	0.43	0.05	8.14	<0.001
Sleep Deprivation →Anxiety	0.48	0.06	8.73	<0.001
Smartphone Addiction →Anxiety (direct)	0.31	0.05	5.92	<0.001

Note: β =standardized path coefficient; SE =standard error, CR =critical ratio (z-equivalent). R^2 for Anxiety= 0.437

Table 8 presents the results of the bootstrapped mediation analysis (5000 resamples).

Table 8: Mediation Analysis – Direct, Indirect, and Total Effects

Effect	β	95% BCa CI	P	Proportion Mediated
Direct Smartphone Addiction →Anxiety	0.31	[0.21, 0.41]	< 0.001	–
Indirect (via Sleep Deprivation)	0.21	[0.14, 0.29]	< 0.001	40.4%
Total Effect	0.52	[0.43, 0.61]	< 0.001	–
R^2 for Anxiety	0.437	–	–	–

Note: Based on 5000bootstrap resamples with bias-corrected and accelerated (BCa) 95% confidence intervals. Significance of the indirect effect is indicated by a 95 % BCa CI that excludes zero.

Discussion

The study explored the triad between smartphone addiction, sleep deprivation, and anxiety among 366 undergraduates enrolled in different programs in allied health sciences using SEM approach. Findings reveal nearly half of the subjects were smartphone addicts (47.3%), more than two-thirds were deprived of good-quality sleep (61.8%), and over a third had high anxiety symptoms (38.4%). All three concepts are associated in a statistically significant and positive manner. Most significantly, however, the SEM model found that sleep deprivation was a partial mediator of the relationship between smartphone addiction and anxiety with the model collectively accounting for approximately 44% of the variance in anxiety symptom. The frequency of smartphone addiction identified herein belongs to the spectrum of 15.6% to 81.1%, which has been reported in various healthcare student groups globally.[12, 13] This is due to the great variation caused by differences in criteria for defining smartphone addiction, cultural background and educational settings. An average duration of smartphone usage of 6.8 hours matches other studies, which found that a large portion of health science students use them for at least four hours daily, and a small portion uses it for more than ten hours daily.[14] Poor qualities of sleep identified among participants of this study has already been described in the literature and can be explained both by specific demands of education of health science students (irregular schedule, clinical rotations, exam stress) and motivation to spend time in the evening using social media.[15, 16] A high prevalence of clinically significant anxiety of 38.4% is also consistent with the literature and indicates the existence of these three conditions as a triad.[17, 18]

The structural relationships discovered by the model were mechanistically consistent with existing physiology and psychology literature.[19] The highest weight path was from sleep deprivation to anxiety (β=0.48), followed by that from smartphone addiction to sleep deprivation (β=0.43), mechanism behind this relationship being multifactorial and that from smartphone addiction to anxiety (β=0.31). Photo-biologically, blue light in the wavelength 460-480 nm range causes activation

of retinal gland ganglion cells containing melanopsin, which signals suprachiasmatic nucleus and inhibit melatonin secretion in the pineal gland causing phase shift and increased sleep onset latency.[20, 21] Dopamine-driven reward pathways are activated due to social media activity, which prolongs wakefulness and increase sleep onset latency. Decreased sleep duration, onset delay, and disturbed sleep architecture is caused.[22, 23] The pathway from sleep deprivation to anxiety is well established in the neuroscientific literature. Lack of sleep leads to a dysfunction in prefrontal cortex regulation of the amygdala activity resulting in increased activation of the threat detection systems and emotional hyper-sensitivity, which is quite similar to the cognitive-emotional state seen in cases of generalized anxiety disorder.[24] Moreover, sleep deprivation results in an elevated level of cortisol.[25]

The significant indirect effect of smartphone addiction on anxiety via sleep deprivation (β=0.21, 95% BCa CI: 0.14-0.29) adds mechanistic precision to existing literature by demonstrating that a meaningful portion of smartphone addiction's contribution to anxiety is transmitted through sleep disruption rather than exclusively through direct psychological pathways. The direct pathway between them remained significant after accounting for sleep deprivation (β=0.31) confirms partial mediation indicating that smartphone overuse also promotes anxiety independently-through social comparison, fear of missing out, academic procrastination, and attention dysregulation-alongside its sleep-mediated effects.

Subgroup findings demand particular attention. Significantly higher scores across all three constructs among female students are consistent with prior studies.[26] Final-semester students exhibiting highest scores across all constructs likely reflects cumulative burden of clinical placements, semester examination preparation, and transition related uncertainty. The significantly poorer sleep quality among hostel residents compared to day scholars may reflect environmental determinants of sleep– shared accommodation, ambient noise, disrupted light exposure– that are amenable to institutional intervention.

The health sciences student population warrants particular attention because these individuals are simultaneously among the most informed about the health consequences of smartphone overuse and among the most structurally vulnerable to its effects. The paradox of future healthcare professionals experiencing high rates of the very conditions they are being trained to manage carries clear pedagogical implications. Digital wellness literacy should be incorporated as a core curricular competency rather than an elective concern. Institutional scheduling practices that structurally deprive students of sleep-consecutive night shifts, early ward rounds combined with evening assignments-should be critically reviewed. Routine screening using brief validated tools at academic welfare check-ins, particularly at clinical placement transitions, represent a low-burden, evidence-supported response that institutions can implement without delay.

Conclusion

This study shows smartphone addiction, sleep deprivation and anxiety as an interconnected structural triad for health sciences students. Using SEM it was found that smartphone addiction influences anxiety both directly and indirectly by means of sleep deprivation, where the model accounts for about 44% of anxiety variance, sleep deprivation is shown to be the strongest predictor and partial predictor. The results have special necessity because the studied group consists of the healthcare workforce of the future. Universities are encouraged to integrate digital wellness education and sleep hygiene initiatives into health sciences programs and providing mental health screening options.

There are several limitations; cross-sectional, single-region university design restricts causal inference and generalizability. Moreover, relying solely on self-report data might lead to biases in the results. Unmeasured confounders-including workload, physical activity, and caffeine use-may further qualify the observed associations. Future research must prioritise longitudinal and experience-sampling designs to establish temporal precedence, alongside intervention trials aiming screen-time reduction and sleep improvement. Cross-disciplinary comparative studies will reveal whether these patterns are unique to health sciences context or reflect a broader higher education phenomenon.

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Ethical approval
The study was approved by the Institutional Ethical Committee of host institution prior to the study

Declaration of Patient consent
The authors confirm that appropriate participant consent forms have been obtained prior to the study. The participant agrees to publication of clinical data in the journal and is aware that names will not be published. Due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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The authors have no conflict of interest.

Use of artificial intelligence AI-assisted technology for manuscript preparation
The authors confirm that no artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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