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Sleep Quality as a Partial Mediator Between Smartphone Addiction and Academic Performance in Moroccan Nursing Students: A PLS-SEM Analysis

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Abstract

Academic performance (AP) reflects a key dimension of achievement in nursing education, shaping both students' professional competence and the quality of future patient care. Although previous research links smartphone addiction (SA) and inadequate sleep quality (SQ) to reduced AP, the extent to which SQ mediates this relationship remains insufficiently explored, particularly in North African populations. This research examined whether SQ acts as a mediator between SA and AP among nursing students enrolled in Meknes, Morocco. A quantitative, cross-sectional survey design was used, including 451 nursing students selected via a census method at a public higher education institute in Meknes. Data collection occurred between January and July 2024. The Smartphone Addiction Scale–Short Version (SAS-SV) assessed SA, the Pittsburgh Sleep Quality Index (PSQI) measured SQ, and grade point average (GPA) represented AP. Structural relationships were analyzed using partial least squares structural equation modeling (PLS-SEM). A high proportion of participants exhibited SA (81.15%), and 86.467% reported poor SQ. PLS-SEM findings indicated that SA had a significant negative effect on AP ($\beta = -0.460$, $p < 0.001$) and a positive association with poorer SQ ($\beta = 0.587$, $p < 0.001$). In turn, SQ negatively predicted AP ($\beta = -0.227$, $p < 0.001$). SQ partially mediated the link between SA and AP, accounting for 22.4% of the total relationship. Results emphasize the necessity of integrating interventions addressing both smartphone dependency and healthy sleep routines to enhance nursing students' learning outcomes. Future studies are recommended to replicate and expand these findings within different sociocultural frameworks.

Keywords: Academic performance, Sleep quality, Smartphone addiction, Nursing students, Mediation, Structural equation modeling

Introduction

Academic performance (AP) represents a central measure of student progress, reflecting their mastery of learning objectives through grades, assessments, and active participation in coursework [1]. This is especially relevant in nursing education, where AP influences not only academic success but also the eventual quality of clinical practice [2]. A variety of internal and external factors affect AP—among them cognitive functioning, motivation, and mental well-being [3]—but smartphone addiction (SA) has recently received growing attention.

SA is characterized by excessive and uncontrolled phone use that often disrupts concentration, working memory, and time management, leading to procrastination and reduced academic engagement [4, 5].

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The Techno-Stress Theory explains this phenomenon by suggesting that prolonged exposure to digital technology can cause cognitive strain and distract from academic priorities [6]. Numerous international investigations have demonstrated a negative link between SA and AP [4, 5, 7, 8]. Within Morocco, recent findings indicate that 41.2% of nursing students show signs of problematic smartphone use, with 21% acknowledging its negative academic impact [9].

In addition to its academic consequences, SA also adversely affects sleep. Extended phone usage late at night disrupts the circadian cycle, delays falling asleep, and fragments sleep continuity due to both blue-light exposure and mental stimulation [10, 11]. According to the compensatory use theory, individuals tend to rely on technology to manage emotions or stress, extending their screen time and worsening sleep outcomes [12]. These behaviors are particularly prevalent among nursing students, who often face heavy workloads and clinical stress. A Moroccan study reported that 46.3% of students with high SA scores experienced impaired SQ [13].

Poor SQ, in turn, can severely impact learning. Insufficient or fragmented sleep compromises memory, focus, and cognitive integration—abilities essential for academic success [14, 15]. Neurocognitive models of sleep underscore its critical function in memory consolidation and neural adaptation [16]. Given the demanding schedules of nursing programs, involving lengthy study periods and clinical shifts, students are especially prone to poor sleep [5, 17, 18]. In Morocco, over 60% of nursing students report sleep-related problems [19], consistent with global data showing rates near 64.81% among university students [20].

Recent evidence suggests that SQ serves as an intermediary factor in the pathway linking SA to AP. Specifically, excessive smartphone use tends to impair SQ, which subsequently diminishes academic outcomes [21]. Disturbed sleep also mediates connections between overuse of digital technology and negative emotional states such as anxiety and depression, which further degrade learning performance [21-23]. Consequently, SQ integrates behavioral, emotional, and cognitive mechanisms explaining how SA leads to reduced AP [24, 25].

Despite existing research examining SA and SQ separately, limited attention has been paid to how SQ mediates their interaction, particularly in North African educational settings. Understanding this mechanism is essential for designing targeted strategies aimed at improving academic outcomes. Therefore, this study explores how SQ mediates the relationship between SA and AP among nursing students in Meknes, Morocco. The conceptual framework, based on theoretical and empirical evidence of digital overuse and sleep disturbance, proposes both direct and indirect effects among SA, SQ, and AP, as shown in **Figure 1**.

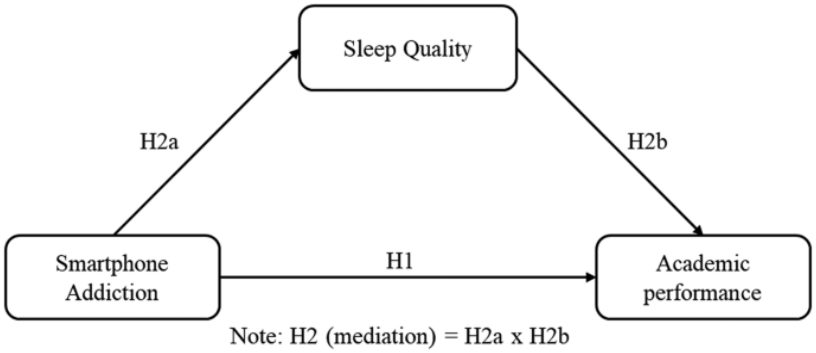

Figure 1. Hypothetical Model of the Study. Diagram depicting proposed direct and mediated links between SA, SQ, and AP, corresponding to hypotheses H1, H2a, and H2b

Research hypotheses

H1. Dependence on smartphones exerts a markedly negative influence on the academic outcomes of nursing students.

H2. The quality of sleep serves as an intermediary variable explaining how smartphone dependence impacts academic performance in nursing students.

H2a. Higher levels of smartphone dependence are expected to be associated with poorer sleep quality scores among nursing students.

H2b. Increased sleep quality scores are hypothesized to correspond with lower academic achievement among nursing students.

Materials and Methods

Study design

A descriptive, cross-sectional quantitative framework was applied to explore how smartphone addiction (SA), sleep quality (SQ), and academic performance (AP) interact among nursing students. The investigation was conducted within a public nursing institution in Meknes, Morocco, and encompassed all enrolled undergraduate students. In the analytic model, SA functioned as the independent predictor, SQ as the mediating construct, and AP as the dependent outcome variable.

Study context

Data collection occurred at the Higher Institute of Nursing and Health Techniques (HINHT) in Meknes—an establishment overseen by the Moroccan Ministry of Health and Social Protection. HINHT is distinctive in its focus on competency-based education and its alignment with the nation's health-sector modernization plan. It operates within a structured academic network that includes seven central institutions and sixteen regional branches across Morocco.

The Meknes branch contributes to regional healthcare advancement by prioritizing hands-on clinical preparation. It offers professionally oriented programs leading to bachelor's, master's, and doctoral degrees in nursing and allied health sciences. Educational activities follow nationally approved professional standards, ensuring harmony between academic instruction and healthcare practice.

Participants and sampling

Eligible participants were nursing students aged 18–23 years. Recruitment was carried out directly in classrooms using a census sampling approach, which invited all 472 students enrolled at HINHT Meknes, regardless of specialty or academic year. This comprehensive method enhanced representativeness and minimized recruitment bias. Students without smartphones (n = 8) and those declining participation (n = 13) were excluded, producing a final analytic sample of 451 individuals.

The resulting cohort mirrored the demographic diversity typical of Moroccan nursing programs, encompassing variations in gender, study level, and geographic origin. The sample size exceeded Cohen's (1988) minimum criterion for mediation analysis [26] and was comparable to or greater than those in previous PLS-SEM studies [27, 28]. However, as acknowledged in the limitations, the single-site focus and predominantly female population could restrict generalizability, especially to male cohorts.

Variable measurement

Academic performance (AP)

Students' Grade Point Averages (GPAs) were obtained directly from the Examinations and Admissions Office of HINHT Meknes. Grades, based on a 20-point scale, provided an objective indicator of overall performance. Weighting adjustments were applied to correct for distributional differences among various programs and study levels, ensuring accurate population-level estimates of academic achievement.

Sleep quality (SQ)

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI) [29], a widely validated instrument measuring seven sleep domains: subjective quality, latency, duration, efficiency, disturbances, medication use, and daytime dysfunction. Total PSQI scores range from 0–21; scores below 5 indicate satisfactory sleep, whereas scores ≥5 denote poor sleep quality. The PSQI has strong psychometric support (Cronbach's $\alpha = 0.83$) [29]; in this study, internal consistency was similarly reliable (Cronbach's $\alpha = 0.70$).

Smartphone addiction (SA)

SA was quantified using the Smartphone Addiction Scale–Short Version (SAS-SV) [30], which consists of 10 items rated on a 6-point Likert scale (1 = strongly disagree; 6 = strongly agree). Aggregate scores range from 10 to 60. Cutoff values of 31 for males and 33 for females identified problematic smartphone use. The SAS-SV has demonstrated robust reliability in multiple populations (Cronbach's $\alpha = 0.91$) [30], and reliability in this study was similarly high (Cronbach's $\alpha = 0.88$).

Both the SAS-SV and PSQI were administered in English to avoid interpretive bias, as students possessed adequate English proficiency through their training. The researcher supervised administration, ensuring uniform understanding and data accuracy. Psychometric validation confirmed acceptable reliability, construct validity, and the absence of systematic measurement bias.

Data collection

All analyses were completed using SPSS (version 25). Descriptive statistics were generated to outline the participants' academic and demographic background—means and standard deviations were calculated for continuous measures, while counts and percentages described categorical variables. Spearman's rho was employed to examine the unadjusted associations among the principal study factors: SA, SQ, and AP.

To confirm the robustness of the structural model, assessments for multicollinearity and common method bias (CMB) were undertaken. Multicollinearity among predictor variables was tested through the Variance Inflation Factor (VIF) and tolerance metrics, following methodological standards [31]. Potential CMB was screened with Harman's one-factor procedure [32]. The measurement reliability and validity of the SAS-SV and PSQI scales were then tested using partial least squares confirmatory factor analysis. The evaluation considered outer loadings (indicator reliability), internal consistency indices (Cronbach's alpha, rho_A, and composite reliability [CR]), Average Variance Extracted (AVE) for convergent validity, and the Heterotrait–Monotrait ratio (HTMT) for discriminant validity. Outer VIF values were also examined for item-level collinearity. These measurement procedures were executed in SmartPLS 3.0, while SPSS 25 handled preliminary data screening, correlations, and construct-level diagnostics.

Partial Least Squares Structural Equation Modeling (PLS-SEM) was then applied to assess both direct and indirect links among the main constructs and to verify whether SQ mediated the association between SA and AP. The analytical framework **(Figure 1)** incorporated three main variables—two predictors (SA, SQ) and one outcome (AP). In addition, gender, study year, and place of origin were introduced as covariates to explore potential influences on AP. The mediating pathway of SQ was analyzed through bootstrapping with 2,000 samples in SmartPLS 3.0. Path estimates, t statistics, and p values were computed for significance testing, while R^2 and Q^2 represented overall model adequacy. Effect magnitude was further examined using f^2 and q^2 indices. A significance level of $p < 0.05$ was adopted.

Ethical considerations

All study procedures adhered to the ethical guidelines of the Declaration of Helsinki. Formal approval was obtained from the Biomedical Research Ethics Committee, Mohammed V University, Rabat, Morocco (CERB 62−23). Participants gave verbal informed consent before inclusion, and confidentiality, anonymity, and voluntary participation were maintained throughout the project.

Results and Discussion

Participant characteristics

The sample profile is shown in **Figure 2**. Most participants were female (68.7%), consistent with gender ratios typically seen in Moroccan paramedical education. A large majority lived in urban settings (77.6%) and possessed Moroccan nationality (97.8%). By academic level, first-year students represented the largest share (42.6%), with second-year and third-year students contributing 28.8% and 28.6%, respectively. Regarding training specialty, multi-skilled nursing was predominant (49%), followed by family health (23.1%), emergency care (21.1%), and midwifery (6.9%) **(Figure 2)**.

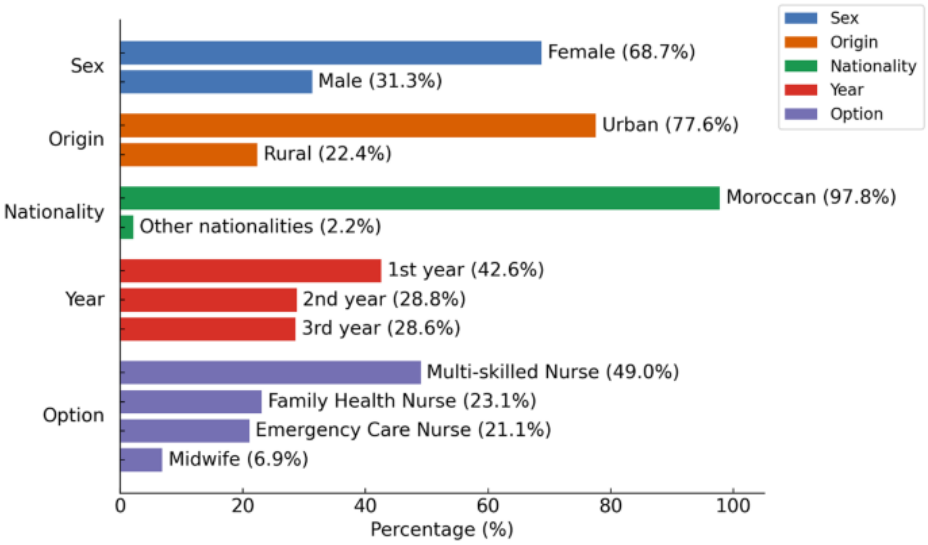

Figure 2. Sociodemographic overview of the study group (**N = 451**)

Associations among smartphone addiction, sleep quality, and academic outcomes

The Spearman correlation coefficients **(Table 1)** indicated that the three constructs were significantly interrelated at the 0.01 level (two-tailed). SA showed a negative association with AP ($r_s = −0.627$; $p < 0.01$), implying that stronger smartphone dependency corresponds to poorer academic results. Meanwhile, SA was positively related to SQ ($r_s = 0.597$; $p < 0.01$), signifying that increased phone use is accompanied by reduced sleep quality. A

further negative correlation emerged between SQ and AP ($r_s = -0.502$; $p < 0.01$), indicating that sleep disturbances are linked with diminished academic performance.

Table 1. Correlations among smartphone addiction, sleep quality, and academic performance (r_s).

Variables	M ± SD	Academic Performance	Sleep Quality Score	Smartphone Addiction Score
Academic Performance	13.90 ± 2.26	1	–0.502**	–0.627**
Sleep Quality Score	7.23 ± 2.34	–0.502**	1	0.597**
Smartphone Addiction Score	40.87 ± 8.467	–0.627**	0.597**	1

Note: All values are significant at $p < 0.01$ (two-tailed)

Measurement model evaluation

Reliability and convergent validity

Both SAS-SV and PSQI instruments exhibited high reliability, with Cronbach's alpha and Composite Reliability (CR) values above the 0.70 benchmark. The rho_A values reinforced this internal consistency. Average Variance Extracted (AVE) values between 0.50 and 0.56 satisfied Fornell and Larcker's validity standards [33]. Factor loadings ranged from 0.58 to 0.84, confirming that the retained items were reliable indicators. Although some loadings were under 0.70, methodological precedent supports their retention when overall reliability indices are acceptable. VIF diagnostics confirmed the absence of multicollinearity, as all outer VIFs were below 3.3. Since both tools are reflective constructs, VIF values were interpreted solely as supportive checks. Taken together, these results affirm the psychometric soundness of the measures and confirm that the measurement model fulfills standard evaluation criteria **(Table 2)**.

Table 2. Summary of reliability and validity statistics for the SAS-SV and PSQI scales.

Construct	Item	Loading	Cronbach's α	rho_A	Composite Reliability (CR)	AVE	VIF
SAS-SV	SAS1	0.78	0.88	0.89	0.91	0.56	2.10
	SAS2	0.81					2.05
	SAS3	0.74					1.88
	SAS4	0.69					2.12
	SAS5	0.82					2.30
	SAS6	0.76					1.95
	SAS7	0.71					2.21
	SAS8	0.84					2.18
	SAS9	0.73					1.97
	SAS10	0.65					2.25
PSQI	PSQI1 (Subjective quality)	0.72	0.70	0.73	0.82	0.50	1.66
	PSQI2 (Latency)	0.79					1.84
	PSQI3 (Duration)	0.68					1.72
	PSQI4 (Efficiency)	0.66					1.69
	PSQI5 (Disturbances)	0.70					1.81
	PSQI6 (Medication use)	0.58					1.55
	PSQI7 (Daytime dysfunction)	0.73					1.90

Discriminant validity

To verify discriminant validity among the latent constructs, the Heterotrait–Monotrait Ratio (HTMT) was employed. Values ranged from 0.54 to 0.75, remaining below the conservative limit of 0.85, confirming satisfactory distinction between factors. This outcome supports that SA and SQ represent empirically separate dimensions. The results collectively affirm the adequacy of the measurement framework **(Table 3)**.

Table 3. HTMT ratios confirming the discriminant validity of the model.

Constructs	SAS-SV	PSQI
SAS-SV	—	0.62
PSQI	0.62	—

Assessment of multicollinearity and common method bias

To ensure the model's stability, multicollinearity among predictors was examined using VIF and tolerance indices. The SAS-SV measure showed a VIF of 1.091 with tolerance = 0.917, and the PSQI score yielded a VIF of 1.112 with tolerance = 0.899. As all VIF values were far below 5, multicollinearity was deemed negligible.

A Harman's single-factor test further assessed common method bias (CMB). An unrotated factor analysis revealed that the primary factor explained 34.02% of the total variance—well under the 50% threshold—indicating that a single factor did not dominate the data structure, and thus CMB was unlikely to threaten validity.

Structural model estimation

To evaluate the proposed model, PLS bootstrapping with 2,000 resamples was applied to test the three hypothesized paths. All hypothesized effects were statistically significant.

SA → SQ: positive and significant (β=0.587; t= 20.050; p<0.001)-indicating that greater smartphone dependency relates to poorer sleep quality.

SA → AP: negative and significant (β =−0.460; t = 11.777; p<0.001)-showing SA detrimentally influences academic outcomes.

SQ → AP: negative and significant (β= −0.227; t = 5.733; p<0.001)-revealing that lower sleep quality corresponds with reduced performance.

Mediation analysis confirmed that SQ mediates the SA–AP association. Both indirect paths (SA → SQ and SQ → AP) were significant. The indirect effect was β = 0.587 × (−0.227) = −0.133, giving a total effect of β = −0.460 − 0.133 = −0.593. Thus, a one-point increase in SAS-SV corresponds to an estimated 0.593-point decrease in average grades. The results reflect partial mediation, as both direct and indirect paths contribute to AP reduction **(Figure 3; Table 4)**.

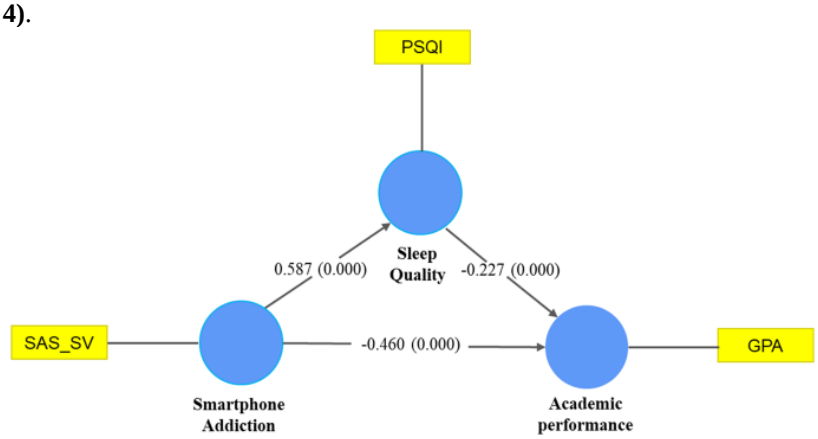

Figure 3. Structural model displaying the mediating effect of sleep quality between smartphone addiction and academic outcomes among nursing students

Table 4. Hypotheses testing results for structural paths.

	Original Sample (O)	M	SD	T	p-value
Smartphone Addiction → Academic Performance	-0.460	-0.460	0.039	11.777	0.001
Smartphone Addiction → Sleep Quality	0.587	0.586	0.029	20.050	0.001
Sleep Quality → Academic Performance	-0.227	-0.227	0.040	5.733	0.001

Note: "Original Sample" denotes coefficients before bootstrap resampling.

Control variables analysis

Control variables were incorporated to determine whether demographic factors influenced AP. Using the same bootstrapping procedure, effects were tested individually **(Table 5)**.

Results revealed that study level had a small yet significant negative impact (β = −0.080; p = 0.037), implying that academic progression may coincide with rising workload and slightly reduced grades. Conversely, gender (β = −0.025; p = 0.518) and residence origin (β = −0.090; p = 0.059) were nonsignificant, though the latter showed a marginal trend nearing significance. Thus, only the study level contributed meaningfully, while gender and origin did not explain AP variations. The findings indicate that the model's primary variables account for most of the variance, maintaining robustness regardless of control inclusion.

Table 5. Significance of control variable effects within the model.

Variable	Original Sample (O)	M	SD	t	P-Value
Year of education → Academic Performance	-0.080	-0.081	0.038	2.083	0.037
Sex → Academic Performance	-0.025	-0.023	0.039	0.647	0.518
Origin → Academic Performance	-0.090	-0.088	0.048	1.887	0.059

Model fit quality

Model adequacy was evaluated via multiple PLS-SEM indices. The model exhibited $R^2 = 0.383$ and $Q^2 = 0.380$, signifying moderate explanatory and predictive capacity. Effect size comparisons showed SA ($f^2 = 0.226$) exerted

a stronger influence than SQ ($f^2 = 0.183$) on the dependent construct, whereas SQ presented higher predictive relevance ($q^2 = 0.219$) compared to SA ($q^2 = 0.175$). Together, these results emphasize the complementary predictive roles of SA and SQ in explaining AP.

Importance–performance map analysis (IPMA) for the mediation model

To extend the findings from the mediation analysis, an Importance–Performance Map Analysis was carried out using academic performance (AP) as the focal outcome. The data indicated that smartphone addiction (SA) exerted the greatest overall negative impact on AP ($|\beta| = 0.593$), while sleep quality (SQ) also contributed meaningfully ($|\beta| = 0.227$). Nevertheless, the performance score for SQ (54.3) was lower than that of SA (61.0), suggesting that improving sleep-related factors could offer considerable room for academic enhancement. These results imply that programs designed to foster healthier sleep behaviors may lead to substantial academic benefits, although reducing problematic smartphone engagement continues to be crucial **(Table 6)**.

Table 6. Importance–Performance matrix of the mediation model (criterion variable: academic performance).

Predictor (construct)	Importance (total standardized effect on AP)	Performance IPMA (0-100)
Smartphone Addiction (SA)	−0.593	61.046
Sleep Quality (SQ)	−0.227	54.298

Notes. The importance metrics represent standardized cumulative effects, which include both direct and mediated relationships. For SA, the overall influence integrates its direct path on AP ($\beta = -0.460$) and its indirect pathway through SQ ($\beta = -0.133$). All performance indicators were normalized on a 0–100 scale within SmartPLS.

Summary of hypothesis verification

The empirical model confirmed all proposed assumptions, supporting the integrity of the conceptual structure.

H1, predicting a direct link between SA and AP, was validated ($\beta = -0.460$; $t = 11.777$; $p < 0.001$). The negative direction signifies that higher dependency on smartphones is associated with poorer academic outcomes.

H2, which proposed the intermediating influence of SQ, was also upheld. The indirect coefficient ($\beta = -0.133$) indicated a partial mediation, consistent with modern mediation frameworks. Two subordinate relationships were distinguished:

H2-a: A significant positive path between SA and SQ **(**$\beta = 0.587$; $t = 20.050$; $p < 0.001$**),** evidencing that heavier smartphone reliance predicts reduced sleep quality.

H2-b: A significant negative path between SQ and AP **(**$\beta = -0.227$; $t = 5.733$; $p < 0.001$**),** emphasizing the detrimental effect of poor sleep on academic achievement.

Together, these findings establish the mediating mechanism of SQ between SA and AP **(Table 7)**.

Table 7. Validation of hypotheses.

Hypothesis	Type of link	Coefficient	t	p-value	Decision
H1: Smartphone addiction → Academic performance	Effect	-0.460	11.777	0.001	Supported
H2: Smartphone addiction → Academic performance	Mediation	-0.133	-	-	Supported
H2-a: Smartphone addiction → Sleep quality	Effect	0.587	20.050	0.001	Supported
H2-b: Sleep quality → Academic performance	Effect	-0.227	5.733	0.001	Supported

The principal objective of this research was to determine how sleep quality mediates the relationship between smartphone dependency and academic achievement among nursing students in Morocco. To examine this framework, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed. The analysis revealed that SA has a strong direct negative association with AP, and that SQ partially transmits this effect, indicating the complex interplay between behavioral habits and learning outcomes.

A notably high rate of smartphone addiction was observed, with 81.15% (366 of 451) participants categorized as addicted under SAS-SV criteria. This prevalence far surpasses a prior Moroccan report (46.3% [13]), reflecting the rapid escalation of this issue in healthcare education. Comparable or higher rates have been documented across similar contexts—78% in Saudi Arabia [7], 87.8% in Egypt [34], 80.15% in Turkey [35], and 87.8% in Sudan [36]. Such disparities between studies may result from differences in measurement thresholds, diagnostic tools, or sociocultural conditions influencing mobile technology use, underscoring the contextual value of local evidence.

Results further indicated that academic level exerted a modest but significant negative effect on AP ($\beta = -0.080$; $p = 0.037$). This suggests that as students' progress through successive years, performance may slightly deteriorate—possibly due to heavier academic loads, increased clinical obligations, and accumulated stress. Similar patterns are consistently reported within medical and health science disciplines, where later years correlate with heightened fatigue and diminished efficiency [37, 38]. Comparable findings in secondary and tertiary education also link greater academic expectations to reduced grades when coping strategies and institutional support are insufficient [39, 40]. Hence, the program year should be considered an important contextual factor when analyzing determinants of student outcomes.

From an analytical standpoint, SA emerged as a major negative determinant of AP. The technostress framework provides a plausible explanation—continuous exposure to digital stimuli can overload cognition, reduce working memory function, and impair time regulation, thereby compromising academic productivity [6]. Previous research echoes this association, documenting that excessive smartphone use correlates with lower GPA and reduced study efficiency [5, 41]. Moreover, behaviors such as checking phones immediately after waking, prolonged daily engagement, or high message frequency have all been linked to diminished academic attainment [42]. These patterns suggest that the consequences of SA stem not merely from usage duration but from deeper cognitive and attentional disruptions.

Nonetheless, the literature presents mixed perspectives. Some research reports positive or neutral associations, indicating that smartphones, when utilized purposefully for educational communication or digital learning, may enhance access to materials and peer interaction [43]. Other findings suggest that frequent but strategic users may outperform peers due to productive academic engagement [44]. Conversely, several studies found no significant relationship between smartphone dependence and academic achievement [45]. These inconsistencies highlight the necessity of distinguishing constructive academic use from compulsive or entertainment-driven behaviors to accurately interpret smartphone-related effects on learning.

Mediating role of sleep quality

The assessment of sleep quality (SQ) as a mediator illustrates an indirect mechanism through which smartphone addiction (SA) influences academic performance (AP). Our data indicate that higher levels of SA are strongly associated with poorer SQ outcomes, confirming that excessive device use leads to reduced sleep quality. This pattern aligns with previous research linking nighttime smartphone engagement to disruptions in circadian rhythms, delayed sleep initiation, and fragmented rest [11, 46, 47]. According to compensatory use theory, individuals may rely on smartphones to cope with stress or regulate emotions, fulfilling unmet psychological needs but heightening mental stimulation before sleep and postponing rest onset [48]. Such tendencies may be intensified among nursing students, who experience elevated stress due to academic rigor, emotional demands, and clinical workloads [49]. Supporting this, [50] reported that over 78% of students engaging in late-night phone use exhibited poor SQ, reflecting the pervasive nature of this compensatory behavior.

Similarly, the current findings show that diminished SQ exerts a significant negative influence on AP, with students who sleep poorly achieving lower academic results. This outcome corresponds with existing literature describing how sleep deprivation impairs attention, working memory, and learning retention — functions critical to demanding disciplines such as nursing [51-53]. Neurocognitive theories of sleep emphasize its role in neural plasticity and memory integration during REM and deep-sleep phases [54]. When sleep becomes irregular, the consolidation of learned material and knowledge organization is compromised, lowering learning efficiency [55]. Poor sleep also contributes to fatigue, reduced vigilance, and concentration deficits, which collectively impair AP [16]. These challenges are particularly acute for nursing students, whose training often involves unpredictable schedules and substantial cognitive load.

Overall, the results point to a sequential relationship in which SA indirectly affects AP via impaired SQ. This framework enriches conventional academic performance models by integrating psychological and technological variables often overlooked in educational analysis. It further highlights the necessity of multidisciplinary strategies grounded in theories of academic engagement, techno-stress, and circadian balance to address these interrelated factors.

Strengths and limitations

This investigation benefits from a substantial sample (N = 451), a focus on nursing students (a group rarely examined in Moroccan contexts), and the use of globally standardized tools (SAS-SV, PSQI), ensuring methodological validity. Structural equation modeling enabled a comprehensive exploration of both direct and mediating effects between smartphone use, SQ, and AP. The study's robustness was reinforced through thorough tests of reliability, construct validity, multicollinearity, and common method variance.

Nevertheless, some constraints exist. The predominance of women (68.7%) and data from a single training institute may limit the representativeness of the results. The cross-sectional nature of the study precludes causal interpretation, allowing for the possibility that poor academic results could themselves promote greater phone use. Potential confounders such as stress, workload, and financial background were not included, and only SQ was analyzed as a mediator. Furthermore, AP was evaluated solely by GPA, which might not fully reflect practical or clinical competence.

The absence of qualitative insights is also noted; however, given that the goal was to quantitatively test mediation through PLS-SEM, this does not diminish the study's integrity. Future research employing longitudinal or mixed-method designs could provide a deeper contextual understanding of students' behaviors and experiences.

Implications

This research advances understanding of how SA, SQ, and AP interact within nursing education. Theoretically, it extends behavioral health and addiction frameworks by demonstrating how excessive smartphone use disrupts biological timing and cognitive processes. Identifying SQ as a mediator clarifies the pathway linking digital dependency to academic deficits, supporting perspectives from self-regulation and cognitive overload theories. It also contributes to techno-stress and compensatory use models, explaining how maladaptive phone behaviors indirectly weaken learning outcomes through disturbed sleep.

Practically, the findings suggest that academic institutions should adopt strategies that promote responsible smartphone habits, particularly before bedtime, and develop programs aimed at improving sleep hygiene via workshops or coaching sessions. The IPMA analysis suggests that enhancing SQ could yield greater academic benefits than focusing solely on reducing smartphone use, highlighting the importance of targeted interventions. By strengthening SQ, schools may indirectly boost student achievement while informing policy and mental health services related to digital wellness.

Ultimately, the study offers valuable theoretical and actionable guidance for integrating behavioral, cognitive, and technological considerations into educational planning and student well-being initiatives.

Conclusion

The study confirms that smartphone addiction detrimentally affects nursing students' academic performance, primarily through its negative impact on sleep quality. Using PLS-SEM, a partial mediating effect of SQ was identified, underscoring the significance of managing digital habits as part of strategies to enhance learning outcomes.

The prevalence of risky smartphone behaviors highlights the urgent need for comprehensive interventions combining digital literacy, sleep education, and psychosocial support. This research provides direction for adapting nursing curricula to current digital-era challenges and sets a foundation for longitudinal inquiries to better elucidate causal mechanisms.

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