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ORIGINAL RESEARCH

A Longitudinal Investigation on the Reciprocal Relationship of Problematic Smartphone Use with Bedtime Procrastination, Sleep Quality, and Mental Health Among University Students

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Background: Problematic smartphone use (PSU) is linked to various mental health issues, but the relationship between PSU, bedtime procrastination, and mental health symptoms is unclear. Sleep factors related to PSU and its mental health effects have been understudied. This study explores the longitudinal associations between PSU, bedtime procrastination, sleep quality, and mental health in university students.

Methods: In this study, a total of 683 university students participated by completing questionnaires on Smart Phone Addiction (SAS) scale, Bedtime Procrastination Scale (BPS), Pittsburgh Sleep Quality Index (PSQI), and Depression, Anxiety Stress Scales 21 (DASS-21) across two different time points with six-months interval between them. The participants were selected using a cluster sampling technique from Quaid-e-Azam University, Islamabad, Pakistan. A cross-lagged model was utilized to assess the longitudinal association between these variables.

Results: Statistically significant reciprocal associations were found between PSU, bedtime procrastination, and mental health symptoms. PSU at Time 1 significantly predicted PSU at Time 2, bedtime procrastination at Time 2, sleep quality at Time 2, and mental health symptoms at Time 2. Bedtime procrastination at Time 1 predicted PSU at Time 2, sleep quality at Time 2, and mental health symptoms at Time 2. Sleep quality at Time 1 predicted bedtime procrastination at Time 2 and mental health symptoms at Time 2. Mental health symptoms at Time 1 predicted PSU at Time 2 and sleep quality at Time 2.

Conclusion: The research findings have significantly advanced understanding of the longitudinal connections between PSU, bedtime procrastination, sleep quality, and mental health indicators. This enhanced comprehension is instrumental for psychological practitioners in devising targeted interventions to mitigate such issues among the university student demographic.

Keywords: bedtime procrastination, problematic smartphone use, depression, anxiety, stress symptoms, sleep quality

Introduction

The notion of problematic smartphone use (PSU) elicits a certain level of controversy due to its relationship with the primary purpose of smartphones being the execution of internet-oriented applications.[1] This relationship suggests that PSU shares several resemblances with internet-oriented addictions and might have reciprocal effects. Following earlier research, a significant association has been identified between internet addiction and PSU.[2] In contrast, previous scholarly investigations have also demonstrated variations among these two groups regarding risk factors, including gender and

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personality traits.[3] An instance of gender differentiation to internet addiction is observed, with men exhibiting a higher propensity towards this addictive behavior, in contrast to women who display a greater inclination towards PSU.[4] Nevertheless, it should be acknowledged that smartphones offer many features encompassing not only internet connectivity and gaming capabilities but also a diverse range of other administrations and capacities, including communication capabilities, camera functionality, interactive media playback, artistic expression, and electronic book reading capabilities. Hence, it is evident that specific indicators of PSU may vary distinctively from those associated with internet addiction. Hence, existing scholarly studies predominantly consider PSU as a distinct theoretical construct, thereby creating various dedicated evaluation instruments that have gained broad acceptance and acknowledgment within the academic community.[5–8] Nevertheless, it is essential to acknowledge that none of the currently available scales comprehensively account for the attributes of uncontrolled or excessive behavior, tolerance, and withdrawal when evaluating problematic smartphone use.[8] Consequently, the present investigation employed the Smartphone Addiction Scale (SAS), a tool derived from the theoretical underpinnings of the Internet addiction scale (IAS), while accommodating the distinguishing features intrinsic to smartphones.[6]

Several empirical investigations have demonstrated a direct correlation between PSU and an individual's overall health outcomes. PSU has been shown to not only result in physical symptoms[9,10] but also to be a potential catalyst for mental health complications.[11] Scholars have extensively investigated the symptoms of depression, anxiety, and stress to both mental and physical well-being associated with PSU.[11–14] For instance, an empirical investigation conducted on Australian adults revealed that high smartphone use had significantly higher depression, anxiety, and stress scores than those with lower use.[12] Similarly, a comprehensive meta-analysis assessed the link between PSU and mental health issues across various populations. The results uniformly showed that such use is connected to substantial depression and anxiety symptoms, affirming evidence from different geographical areas.[13] Another literature review incorporating a comprehensive meta-analysis conducted revealed a statistically significant and positive association between PSU and a diverse array of mental and somatic disorders.[11] A cross-sectional survey conducted in multiple regions among 4200 individuals revealed a strong association between PSU and adverse mental health levels. The survey also provided insights into the types of activities people engage in with their smart phones.[14] Furthermore, it is crucial to investigate the underlying mechanism that connects PSU and mental health symptoms and examine the immediate correlation between the two variables. Several scientific investigations have been conducted to scrutinize the mediators (resilience, neuroticism, reappraisal, borderline personality disorder) of the associations from self-regulation to personality characteristics.[15–17] Nevertheless, most of these studies utilized cross-sectional approaches, thus neglecting to establish the causal directionality between the assorted variables. Consequently, comprehending the intricacies of the interplay between PSU, mental health symptoms, and additional potential mediating aspects becomes arduous. Exploring potential mechanisms in a relationship for which directionality and causality have not been adequately ascertained appears premature. Hence, prior to delving into the intricacies of this association's mechanism, the expedient undertaking of longitudinal research is imperative to ascertain its directionality. Existing literature has centered on investigating the longitudinal associations between PSU and mental health symptoms.[18–20] However, the findings of these investigations have yielded inconsistent and contradicted outcomes, suggesting a lack of consensus regarding the directionality of this relationship. Given the variation observed in the findings above, it is imperative to conduct longitudinal studies to delve deeper into the relationship.

Sleep quality may significantly influence the manifestation of PSU and mental health symptoms due to emerging evidence suggesting plausible biological and psychological interdependencies among these parameters. A study revealed that individuals in the adolescent demographic who suffer from sleep disorders exhibit a higher propensity to engage with smartphones for extended durations, as they utilize these devices as a coping mechanism to alleviate anxiety and concerns.[21] This finding indirectly suggests that individuals who experience poor sleep quality may be at risk for developing PSU. Islam M. (2021) demonstrated that excessive smartphone use among South Korean adolescents is significantly associated with poor sleep quality, including delayed sleep onset, reduced sleep duration, and increased sleep disturbances.[22] Another investigation among Serbian medical students showed that PSU and excessive screen time are linked to poorer sleep quality and more sleep disturbances.[23] Prior research has examined the moderating influence of sleep quality in the relationship between PSU and mental health symptoms utilizing cross-sectional approaches across various populations from different regions.[24–26] Nevertheless, incongruous findings have emerged through previous

investigations, wherein mental health symptoms have served as a mediator between PSU and overall sleep quality.[27] Furthermore, it is essential to note the limitations of cross-sectional designs, as these investigations have not yet provided conclusive evidence regarding the causal relationship between these factors. Previous longitudinal investigations have discovered reciprocal associations between PSU and sleep quality. More specifically, sleep quality has been identified as a predictor of PSU, predicted by sleep quality. Furthermore, these investigations have demonstrated that insufficient sleep and suboptimal sleep quality are predictive of subsequent mental health symptoms.[28,29] However, it must be acknowledged that these pieces of evidence possess certain limitations, as their primary focus lies in examining the longitudinal association solely between the two variables, rather than delving into the intricate interplay among all three variables. The current body of literature regarding the correlation between PSU, sleep quality, and mental health symptoms remains inconclusive. Therefore, further longitudinal research is necessary to understand and comprehensively understand the relationship among these three variables.

The preceding literature has established that delaying bedtime, commonly called bedtime procrastination, mediates the constructive association between PSU and sleep quality among college and university students.[30,31] Moreover, scholarly investigations have also revealed a correlation between trait procrastination, general procrastination, and PSU.[32,33] The personality trait theory posits enduring characteristics or traits that can predict an individual's behavior. Applying this notion to the trait of bedtime procrastination, it can be hypothesized that it may also play a role in the phenomenon of PSU. However, limited empirical investigation has been dedicated to exploring this potential association. Based on the procrastination-health paradigm, individuals with persistent tendencies to procrastinate will encounter stress resulting from failing to meet designated timeframes or completing tasks only at the eleventh hour.[34] Consequently, they may engage in detrimental behaviors, such as utilizing their smartphones before bedtime, yielding instant gratification. Recently, there has been recognition of anxiety, stress, and unhealthy behaviors as significant determinants of reduced sleep duration and diminished sleep quality.[35] Previous research has documented a connection between bedtime procrastination and sleep quality;[30] however, it is worth noting that no prior studies have undertaken a longitudinal examination of the correlation between bedtime procrastination and sleep quality among college students with a comparatively more significant sample size in the Pakistani population.

In essence, it has been established that there are significant associations between PSU, bedtime procrastination, sleep quality, and mental health symptoms over time. Nevertheless, as mentioned earlier, prior research has primarily focused on conducting rudimentary correlation analyses involving a limited selection of two or three variables from the quartet. In addition, specific investigations solely encompassed systematic reviews without comprehensively systematically incorporating all four variables. Hence, the primary objective of this study is to investigate the longitudinal connections between PSU, bedtime procrastination, sleep quality, and mental health among university students in Pakistan.

Methods

Participants and Procedure

The researchers employed the stratified cluster sampling technique to gather data from university students. The sample was derived from 30 classes in a university in Islamabad, Pakistan. This university encompasses a broad range of disciplines and majors, including but not limited to science and engineering, humanities, social sciences, and medicine. A questionnaire survey was then conducted among the selected individuals. Through their cooperation, we contacted the university administration and acquired a comprehensive roster encompassing all courses. A sample of ten classes comprising first-year students, sophomores, and juniors was randomly chosen to administer the survey.

The inclusion criteria for the participants encompassed individuals who were 18 years of age or older, possessed a smartphone, lacked any familial background of mental disorders (anxiety or depression), and had not received any formal diagnosis of addictive disorders, affective, substance dependence, or, as indicated through self-reporting. In September 2021 (P_1), 751 students were engaged in the initial assessment as part of the baseline study. In March 2022 (P_2), the study achieved a participant count of 683 individuals, with an average age of 18.83 years and a standard deviation of 0.19. A follow-up survey was conducted, during which 68 participants from the original population at P_1 were excluded due to their absence. The surveys were administered during classes within a designated timeframe of 30 minutes.

Ethics

Before conducting the survey, every student provided formal consent by signing an informed consent form. The study has received ethical approval from the Institutional Review Board of Quaid-e-Azam University (QAU/2021-May-0006712).

Questionnaire

Smartphone Addiction Scale- Short Version (SAS-SV)

The SAS is a 33-item scale with six distinct dimensions utilized to assess smartphone addiction;[36] however, we have utilized a revised and short version of the scale, which has already been validated in the Pakistani population.[37] The scale encompasses a range of options, extending from 1 to 6. Increased scores are indicative of an elevated susceptibility toward addiction to smartphones. The internal consistency test result for this scale in the present study was estimated to be 0.92 at P_1 and 0.94 at P_2.

Bedtime Procrastination Scale (BPS)

To assess the procrastination level among study participants, we employed a *9*-item BPS developed by Kroese et al,[38] a reliable and pre-validated instrument.[39,40] The scale consists of 4 positively worded and 5 negatively worded items rated on a 5-point Likert scale ranging from 1 (never) to 5 (always). Previous research has demonstrated a strong internal consistency of 0.79 for the BPS items.[40,41] The Cronbach's alpha coefficient for the present research study indicated a high level of internal consistency with a reliability coefficient of 0.94 at the baseline period (P_1) and 0.96 at period P_2 for the construct.

The Pittsburgh Sleep Quality Index (PSQI)

The PSQI was used to measure the quality of sleep, as it provides a thorough evaluation of sleep by analyzing 19 characteristics that are divided into seven main aspects consisting of subjective sleep disturbance, sleep quality, use of sleeping medication, sleep latency, sleep duration, sleep efficiency, and daytime dysfunction.[42] This investigation utilized a four-level Likert scale to allocate scores ranging from 0 to 3 for each dimension, yielding a cumulative score between 0–21. Participants with a higher score on the scale indicate poorer sleep quality. The measurement reliability of the scale was assessed using Cronbach's alpha, which yielded coefficients of 0.73 and 0.74 at the two distinct time points (P_1 and P_2), respectively.

Depression Anxiety Stress Scales 21 (DASS-21)

We utilized a set of 21 self-report measures designed to assess the severity of core symptoms related to depression, anxiety, and stress, which has undergone prior validation and is widely recognized within the academic community.[43] The response was recorded on a four-point Likert scale, with each participant's total score on the Depression, Anxiety, and Stress scales calculated by multiplying the aggregate score of seven specific items by two. Each scale is subsequently divided into subscales of two to five items each. The reliability coefficients, as measured by Cranach's alpha, indicate that the depression scale showed a score of *0.95 at* P_1 *and 0.94 at* P_2, the anxiety scale showed a score of *0.86 at* P_1 *and 0.89 at* P_2, whereas the stress scale showed a score of *0.94* at time P_1 and 0.93 at P_2.

Statistical Analyses

To obtain an objective evaluation of the data, we performed descriptive and Pearson correlation analysis by utilizing SPSS (*v25*), and the data is presented in the form of percentages for categorical variables. In contrast, numerical variables are represented using the mean value accompanied by the standard deviation (SD). The Mplus software (*v7.4*) was used to implement cross-lagged panel analysis. Initially, an assessment was made on the longitudinal measurement invariance of the four psychometric tools employed in this investigation, encompassing the evaluation of metric, scalar, and configural invariance.[44] After controlling for sex and age variables, we established a cross-lagged model to examine the longitudinal bilateral correlations between PSU, bedtime procrastination, sleep quality, and mental health symptoms among the study participants. The adequacy of the model fit was assessed through a comprehensive examination of the root mean square error of approximation (RMSEA), comparative fit index (CFI), standard root means square residual (SRMR), and Tucker–Lewis's index (TLI). Based on prior research, it has been determined that CFI and TLI exceeding

a threshold of 0.90, along with RMSEA and SRMR below 0.08, signify an acceptable fit for the model under consideration.[45] Due to the inherent sensitivity of X^2 analysis to sample size, we chose to refrain from using it to measure model adequacy.[46] In the interim, we estimated 95% confidence intervals (CI) employing a bias-corrected bootstrap technique that entailed 10,000 iterations. The estimated 95% CI reported herein does not encompass the value of zero, thereby illustrating the statistical significance of the observed effect at a p-value of less than 0.05. Furthermore, we employed ΔCFI and ΔRMSEA (Δ indicates the rate of change) values to assess the measurement invariance. The measurement invariance model was considered admissible when the difference in ΔCFI was less than or equal to 0.01, and the difference in ΔRMSEA was less than or equal to 0.015.[47]

Results

To examine the long-term measurement invariance of all the psychometric measures, we initially constructed configural invariance models. The findings demonstrated that the configural invariance models fit all four measures satisfactorily (Table 1). Following this, we ensured that the factor loadings remained consistent across time and implemented models for metric invariance. All of the models fit and exhibited satisfactory accuracy. The findings of the metric invariance models revealed that both ΔCFI and ΔRMSEA exhibited values ≤ 0.01, which suggests the preservation of factor loadings on each measure throughout the temporal dimension. According to the metric invariance model, we imposed additional constraints on threshold equality to evaluate scalar invariance. The changes in ΔCFI and ΔRMSEA remained within the permissible range. The findings of this study suggest that the four measures demonstrated consistency in their measurements across two separate periods.

The statistical summary of the study variables is presented in Table 2, which includes the means, standard deviations, and Pearson's correlations. The findings indicated the existence of statistically significant associations between the four psychometric measures, ie, PSU, bedtime procrastination, quality of sleep, and depression, anxiety, and stress symptoms, assessed at two distinct periods (P_1 and P_2).

Table 1 Measurement Invariance Over Time

	X^2/df	RMSEA	SRMR	CFI	TLI
	<3	**≤0.08**	**<0.08**	**≥0.90**	**≥0.90**
Configural invariance	1.71	0.06	0.05	0.94	0.93
Weak invariance	1.72	0.05	0.04	0.93	0.91
Strong invariance	1.72	0.05	0.04	0.94	0.93
Strict invariance	1.71	0.05	0.04	0.93	0.92

Abbreviations: CFI, comparative fit index; TLI, Ticker-Lewis's index; RMSEA, root mean square error of approximation; SRMR, root mean square residual.

Table 2 Descriptive and Correlational Analyses of the Selected Psychometric Measures in the Study

Variables	$\overline{X} \pm SD$	1	2	3	4	5	6	7	8
1 SAS_{P1}	22.41±9.23	1							
2 BPS_{P1}	19.83±7.01	0.506***	1						
3 $PSQI_{P1}$	15.81±1.44	0.231***	0.473***	1					
4 $DASS\text{-}21_{P1}$	7.23±3.12	0.501***	0.415***	0.614***	1				
5 SAS_{P2}	19.25±7.25	0.578***	0.103**	0.211**	0.353***	1			
6 BPS_{P2}	18.62±6.40	0.099**	0.536***	0.168**	0.296**	0.349***	1		
7 $PSQI_{P2}$	13.73±3.42	0.108**	0.185**	0.319***	0.228**	0.411***	0.483***	1	
8 $DASS\text{-}21_{P2}$	5.39±2.02	0.177**	0.305**	0.313***	0.322**	0.446***	0.343***	0.523***	1

Note: ***p<0.01, **p<0.05.

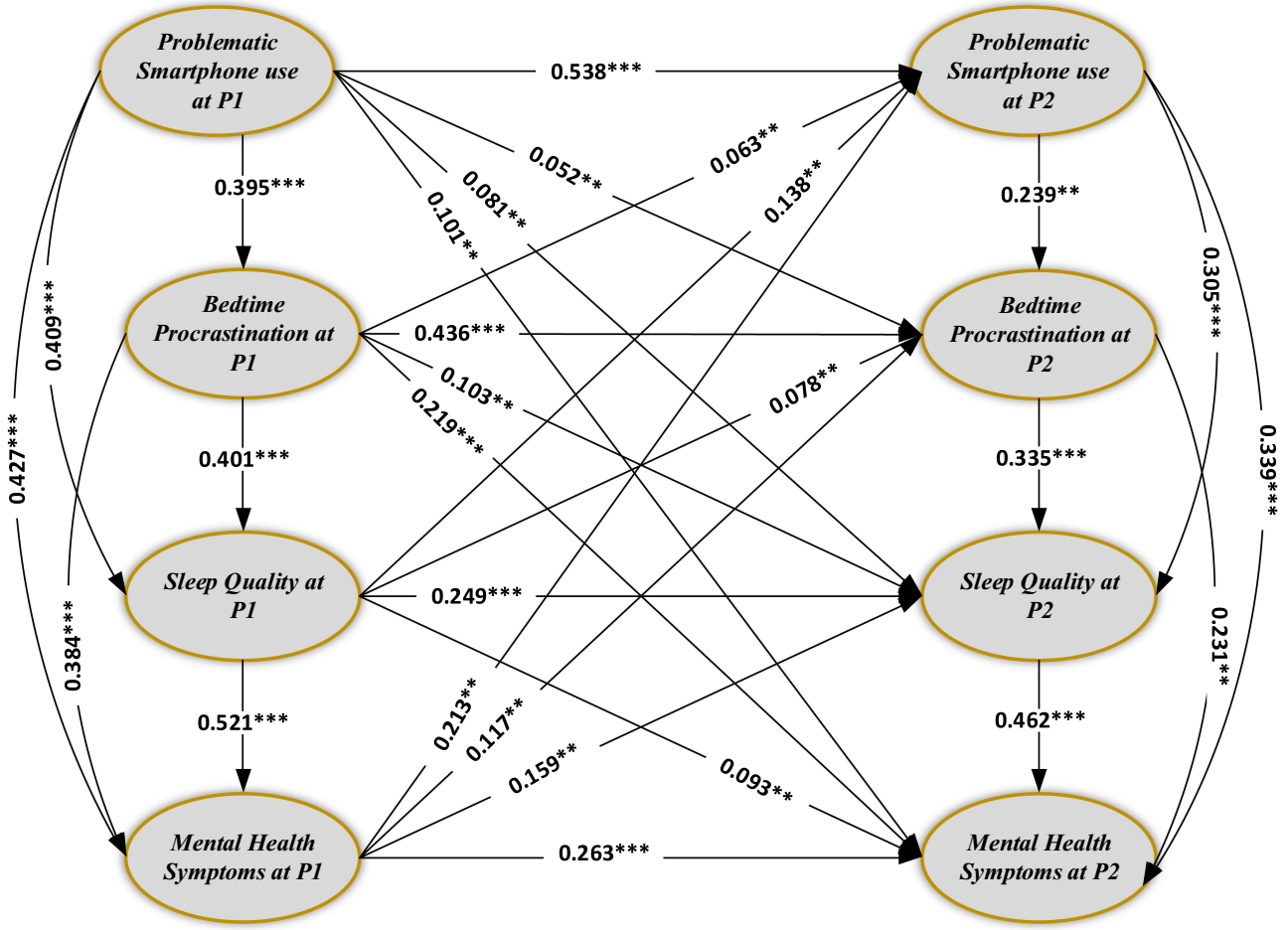

Figure 1 A longitudinal cross-lagged path model among study variables across two-time frames ie P_1 & P_2. **Significant at 0.01. ***Significant at 0.001.

The results of the adopted cross-lagged model in the current investigation are presented in Figure 1 and Table 3. The findings highlight a positive correlation between PSU and bedtime procrastination at P_1 and reciprocal associations between PSU and mental health symptoms at time point P_2. In contrast, sleep quality demonstrated significant predictive

Table 3 Cross-Lagged Analysis Results

Path	Effects	Bootstrap Standard Error	Bootstrap 95% CI	Outcome
$SAS_{P1} \rightarrow SAS_{P2}$	0.538	0.019	0.245–0.625	Significant
$SAS_{P1} \rightarrow BPS_{P2}$	0.052	0.031	0.023–0.135	Significant
$SAS_{P1} \rightarrow PSQI_{P2}$	0.081	0.022	0.010–0.169	Significant
$SAS_{P1} \rightarrow DASS\text{-}21_{P2}$	0.101	0.030	0.032–0.228	Significant
$BPS_{P1} \rightarrow BPS_{P2}$	0.436	0.021	0.245–0.610	Significant
$BPS_{P1} \rightarrow SAS_{P2}$	0.063	0.029	0.013–0.141	Significant
$BPS_{P1} \rightarrow PSQI_{P2}$	0.103	0.021	0.014–0.283	Significant
$BPS_{P1} \rightarrow DASS\text{-}21_{P2}$	0.219	0.028	0.110–0.478	Significant
$PSQI_{P1} \rightarrow PSQI_{P2}$	0.249	0.031	0.113–0.526	Significant
$PSQI_{P1} \rightarrow BPS_{P2}$	0.078	0.028	0.032–0.134	Significant
$PSQI_{P1} \rightarrow DASS\text{-}21_{P2}$	0.093	0.026	0.021–0.110	Significant

(*Continued*)

Table 3 (Continued).

Path	Effects	Bootstrap Standard Error	Bootstrap 95% CI	Outcome
$PSQI_{P1} \rightarrow SAS_{P2}$	0.063	0.032	0.009–0.205	Significant
$DASS\text{-}21_{P1} \rightarrow DASS\text{-}21_{P2}$	0.263	0.022	0.193–0.519	Significant
$DASS\text{-}21_{P1} \rightarrow SAS_{P2}$	0.213	0.018	0.134–0.406	Significant
$DASS\text{-}21_{P1} \rightarrow PSQI_{P2}$	0.159	0.022	0.048–0.323	Significant
$DASS\text{-}21_{P1} \rightarrow SAS_{P2}$	0.117	0.039	0.101–0.347	Significant

power in only one direction. The present study found that baseline bedtime procrastination at P_1 was positively associated with sleep quality at P_2. Conversely, sleep quality at P_1 was positively associated with bedtime procrastination at P_2. Additionally, bedtime procrastination was found to significantly and positively predict depression, anxiety, and stress symptoms in one direction. Furthermore, it was found that the quality of sleep observed at P_1 showed a positive association with depression, anxiety, and stress symptoms noted at P_2, and similarly, depression, anxiety, and stress symptoms at P_1 were also predictive of sleep quality at P_2.

Discussion

In the present investigation, a two-wave longitudinal design was employed to examine the reciprocal relationships between PSU, bedtime procrastination, sleep quality, and mental health symptoms. Additionally, a cross-lagged model was constructed to analyze these connections. These findings contribute to comprehending the longitudinal associations and causal relationships among the aforementioned psychometric measures. The findings indicated several longitudinal associations in both directions. Firstly, there is a significant relationship between PSU and both bedtime procrastination and mental health symptoms. Secondly, sleep quality is associated with bedtime procrastination and mental health symptoms. This study represents the initial examination in which bedtime procrastination has been linked with PSU and sleep quality. Additionally, specific unidirectional associations were observed in the study outcomes. Specifically, PSU demonstrated a predictive relationship with sleep quality, while bedtime procrastination exhibited a predictive relationship with mental health symptoms.

The findings of this study indicate a bidirectional relationship between PSU, sleep quality, and mental health symptoms, which aligns with several prior research findings.[48–51] Nevertheless, a recent investigation conducted in Pakistan spanning six months revealed that the presence of anxiety and stress symptoms at the initial assessment was indicative of subsequent psychological well-being issues, in contrast to the inverse relationship.[48] One potential explanation arises from the divergent lengths of follow-up periods, which may contribute to disparate manifestations of effects among PSU and mental health symptoms. Two preceding longitudinal investigations, lasting more than one year each, revealed a reciprocal connection between PSU and mental health symptoms.[52,53] Nonetheless, a short-term longitudinal investigation conducted among American students over three months revealed a unidirectional correlation, wherein baseline PSU was found to be predictive of subsequent depression, anxiety, and stress symptoms. This hypothesis suggests that discerning the reciprocal connection between the two variables may necessitate a lengthier period. Longitudinal investigations over a year have uncovered a unidirectional relationship.[54,55] Hence, it is imperative to undertake additional longitudinal research endeavors, incorporating extended follow-up durations, to elucidate the enduring correlation between PSU and mental health symptoms. Our findings strongly indicate the significance of developing efficacious interventions to mitigate PSU and mental health symptoms, underscoring the pressing need for immediate attention. Furthermore, there is substantial evidence that supports the association between sleep disorders and mental health symptoms. In the study conducted by Breslau et al, it was observed that sleep disruption served as a significant predictor for symptoms associated with mental health among individuals in the young adult population.[56]

Interestingly, many research investigations have established significant biological associations between these variables.[57,58] Furthermore, several empirical investigations have uncovered that sleep quality is a mediating factor in

the relationship between PSU and physical health.[59–61] These findings support the assertion that a significant correlation exists between sleep quality and mental health symptoms. Our investigation additionally ascertained that PSU demonstrated the capability to predict sleep quality solely in unidirectional, thus corroborating the findings of prior longitudinal investigations.[62] Previous research has established a connection between PSU and various sleep-related issues. For instance, a three-year longitudinal survey on Korean adults unveiled a link between PSU and sleep quality.[62] Moreover, a cross-sectional study demonstrated that utilizing smartphones for over 5 hours regularly correlated with inadequate sleeping duration and increased prevalence of insomnia among high school students.[63] The present research findings do not support the hypothesis that sleep quality at P_1 can predict PSU at P_2. This finding contrasts prior evidence that reported a bidirectional association.[55] Existing evidence has demonstrated a significant association between suboptimal nocturnal sleep quality and the manifestation of excessive tiredness and somnolence during the daytime.[64–66] The findings suggest that college students exhibiting suboptimal sleep quality may potentially encounter feelings of daytime fatigue and somnolence, manifesting in limited availability of temporal and cognitive resources for engaging with mobile devices. This subsequently contributes to reducing both the prevalence and duration of smartphone usage, thereby attenuating the likelihood of PSU.

Our findings revealed a bidirectional association between bedtime procrastination and PSU and sleep quality. This finding further substantiates the perspective put forth by Sirois et al, positing that bedtime procrastination heightens the health hazards individuals face.[67] Despite the absence of any existing reports in academic literature, a cross-sectional study conducted a preliminary examination of the causal relationships involved using a mediation model. The findings suggest that PSU indirectly influences sleep quality by affecting bedtime procrastination.[68] Steel's Temporary Motivation Theory (TMT) posits that the tendency for procrastination in individuals is contingent upon their perception of the utility of the task. Furthermore, this multifaceted variable is intricately linked to value, expectation, and delay.[69] Individuals with PSU demonstrated an extended duration for acquiring health advantages derived from sleep compared to the timeframe during which immediate psychological satisfaction and pleasure were gained through smartphone usage. Consequently, the former option was significantly less appealing to individuals than the latter alternative. This can be attributed to the fact that individuals who are addicted to smartphones tend to postpone sleep-related activities in favor of activities that are perceived to offer comparatively greater utility, ultimately leading to the phenomenon known as bedtime procrastination. Conversely, adopting bedtime procrastination as a habitual practice signifies that individuals are afforded a greater allocation of time and avail themselves of additional prospects for participating in alternative pursuits. For instance, individuals who procrastinate at bedtime may predominantly opt for smartphone usage, as it offers high accessibility and a range of powerful features. Smartphones increase the likelihood of experiencing PSU 71 by obtaining instantaneous gratification and contentment.

Furthermore, a comprehensive longitudinal investigation has further demonstrated that academic procrastination is a precursor to PSU among middle school students.[70] The present findings suggest that a reciprocal causal relationship may exist between PSU and bedtime procrastination, leading to a cyclic pattern of detriment—the statement above held validity about the correlation between bedtime procrastination and sleep quality. Bedtime procrastination has the potential to induce sleep disturbances and decrease subjective sleep duration. Simultaneously, individuals who procrastinate are compelled to voluntarily endure the stress of retiring to bed at the final moment and subsequently achieving prompt sleep onset, decreasing sleep quality. Prior research has also identified that individuals with low self-control can deplete their energy and capacity for self-regulation, leading to a heightened risk of inadequate self-regulation in the workplace. Consequently, this deficiency may contribute to the propensity for work procrastination.[71] The predictive relationship between sleep quality at P_1 and bedtime procrastination at P_2 can potentially be accounted for by the association between procrastination and the inadequacy of self-regulatory efforts elucidated by the self-regulation perspective on procrastination.[72] Hence, individuals exhibiting suboptimal sleep quality may encounter difficulties in maintaining self-regulation. This can manifest in their susceptibility to being enticed by alternative stimuli or engagements before their sleeping routine, thereby contributing to bedtime procrastination.[71]

Moreover, our findings indicate that the presence of bedtime procrastination at P_1 is a significant predictor of the subsequent manifestation of mental health symptoms at P_2. Previous evidence has yielded substantial evidence indicating a noteworthy bidirectional association between the engagement of adolescents in self-harming behaviors, known as

bedtime procrastination, and the subsequent development of mental health symptoms in the subsequent year.[73] Nevertheless, the correlation between mental health symptoms and the subsequent development of bedtime procrastination did not yield statistically significant results. This discrepancy is potentially attributed to the dissimilarities observed in using bedtime procrastination evaluation instruments across the two investigations. Prior research primarily relied on self-report measures to assess bedtime procrastination; however, in this current study, a specialized scale was utilized to measure this phenomenon. Hence, additional investigation is warranted to investigate the longitudinal correlation between bedtime procrastination and mental health symptoms. Procrastination has been identified as a phenomenon described by the prioritization of one's immediate self-interest over future-oriented considerations and the prioritization of short-term emotional regulation over long-haul objectives and benefits, as observed along the unidirectional trajectory from bedtime procrastination to mental health symptoms.[74]

Individuals experiencing bedtime procrastination may realize that failing to adhere to proper sleeping schedules can negatively impact their health. As a result, they may impose self-inflicted pressure on themselves, subsequently leading to the manifestation of symptoms associated with mental health. Prior research indicates a potential link between bedtime procrastination and the onset of detrimental psychological outcomes.[31,40] These adverse psychological effects may ultimately manifest in the emergence of mental health symptoms. Furthermore, it should be noted that bedtime procrastination has the potential to exert an indirect influence on the manifestation of mental health symptoms via its impact on the individual's sleep quality. Specifically, bedtime procrastination is liable to diminish the overall sleep quality experienced by the individual, thereby exacerbating the likelihood of mental health emergence. This suggests that there may be a prospective mediating role of sleep quality in the relationship between behavioral and psychological symptoms and daily activity functioning. However, additional rigorous multi-level longitudinal investigations are needed to confirm this hypothesis.

Limitations and Future Directions

Despite the valuable insights provided by this study on the longitudinal associations between PSU, bedtime procrastination, sleep quality, and mental health symptoms among university students, it is imperative to acknowledge its limitations and delineate future research directions. Firstly, the sample was derived from a single institution, which may limit the generalizability of the findings to other educational contexts or demographic groups. Future studies could benefit from a more diverse participant pool, including varied age groups, occupations, and cultural backgrounds, to ascertain the universality of these relationships. Secondly, self-report measures were employed in this research, which could introduce response biases such as social desirability or recall inaccuracies. Objective measures of smartphone usage patterns and sleep quality (eg, actigraphy) could complement self-report data in future investigations, offering a more holistic understanding of these behaviors.

Moreover, the study's design does not allow for causal inferences; while associations are identified, the directionality and underlying mechanisms remain unclear. Experimental or longitudinal studies with multiple waves of data collection could elucidate the causal pathways between these variables. Lastly, this study focused on adverse outcomes associated with problematic smartphone use and bedtime procrastination but did not explore potential moderating or mediating factors that could mitigate these effects. Future research could examine protective factors such as resilience, mindfulness, or social support, which might buffer against the adverse consequences of these behaviors on mental health.

Conclusion

This research contributes significantly to the body of knowledge regarding the longitudinal and reciprocal associations between PSU, bedtime procrastination, sleep quality, and mental health symptoms among university students. Our study provides a more refined understanding of the complex interplay between these factors by employing a robust methodology that assesses these variables across two-time points. The findings underscore the importance of PSU as a salient factor influencing both sleep quality and mental health outcomes. They highlight that the relationship between PSU and these variables is not unidirectional but demonstrates persistent reciprocal influences over time. This insight is crucial for mental health professionals, particularly those working within educational settings, as it enables them to develop more targeted and timely interventions.

Moreover, the study emphasizes the need to address bedtime procrastination as a significant concern linked to PSU and adverse mental health symptoms. The recognition of this behavior's impact on sleep quality and mental well-being adds a new dimension to the discussion on health outcomes related to technology use. Furthermore, while our study acknowledges the ongoing debate regarding classifying PSU as a disorder, it provides empirical evidence supporting the notion that excessive smartphone use correlates with psychological and physical impairments. This correlation, however, may not be directly proportional, suggesting a more nuanced relationship that warrants further exploration. In addition, our research supplements the dimensional methodology employed in investigating PSU. By considering multiple dimensions of mental health—including depression, anxiety, and stress—our study provides a broader perspective on the mental health implications of PSU and associated behaviors. Finally, the insights gained from this research will aid educational professionals specializing in mental health within schools in formulating precise interventions aimed at mitigating problematic patterns of PSU, sleep difficulties, and symptoms of depression, anxiety, and stress within the university student population. Such interventions could include but are not limited to, digital wellness workshops, cognitive-behavioral therapy for technology-related issues, and promoting healthy sleep habits.

In conclusion, our study not only enhances the existing knowledge in the field but also paves the way for future research to explore potential moderating or mediating factors that could further elucidate the complexities of the relationships identified. We hope this line of inquiry will continue to evolve, shedding light on the intricate ways technology use affects the academic, psychological, and physical well-being of university students.

Data Sharing Statement

The original data used to support the findings of this study are available from the corresponding author upon reasonable request. (Shazia Rehman: rehmanshazia.malik@gmail.com).

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the Research Ethics Board of the Quaid-e-Azam University and with the 1964 helsinki Declaration and its later amendments or comparable ethical standards (QAU/2021-May-0006712).

Informed Consent

Informed consent was obtained from all participants in the study.

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Disclosure

Dr Shyamkumar Sriram is affiliated with Department of Rehabilitation and Health Services, College of Health and Public Service, University of North Texas, Denton, 76201, Texas, USA since August 16, 2024. The authors declare that they have no conflicts of interest in this work.

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