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Research Paper

Digital overuse and sleep effects on adolescent wellbeing and academic performance

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ABSTRACT

Background: Overuse of digital media and insufficient sleep have commonly been suggested to adversely affect adolescent mental health and academic achievement, but evidence regarding time-based measures remains inconsistent.
Objective: To explore associations between digital overuse and sleep, and investigate sleep as a mediator between digital overuse and psycho-academic outcomes (stress, anxiety, addiction, GPA) among adolescents.
Methods: A quantitative correlational design used secondary data from a Kaggle dataset on adolescent mental health (ages 13–19, N = 1200). Variables included daily social media use, pre-bed screen time, sleep duration, GPA, stress, anxiety, and addiction scores. Hypothesized relationships and mediation pathways were tested using Pearson correlation, multiple linear regression, and structural equation modelling (SEM).
Results: Participants averaged 4.54 hours (SD = 2.03) on social media daily, 1.74 hours (SD = 0.72) viewing screens before bed, and 6.45 hours (SD = 1.44) sleeping—below the recommended 7–9 hours. Mean GPA was 2.99 (SD = 0.58), with moderate stress (M = 5.45), anxiety (M = 5.64), and addiction (M = 5.57) scores. Correlations between digital overuse and psychological outcomes were very weak ($r = 0.028–0.031$, $p > 0.05$). Regression models explained under 0.2% of variance, and sleep did not significantly predict GPA ($r = 0.022$, $p = 0.449$). SEM mediation effects ($\beta = -0.00001$ to 0.00002) were non-significant, though directionally consistent with theory.
Conclusion: No statistical support was found for the theorized digital overuse–sleep–wellbeing/academic pathway, suggesting duration-based measures inadequately capture compulsive-use and sleep-quality dimensions considered more clinically relevant. Screening and policy should shift toward validated tools assessing compulsive use and sleep quality, alongside continued emphasis on adolescent sleep health.

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1. INTRODUCTION

Digital engagement is becoming ubiquitous in ways that are having an impact on adolescent development around the globe. Smartphones, social media, and other networked devices are ubiquitous in communicating, entertaining, and learning, and have unanticipated psychological and academic consequences for youth [1]. There are decades of research supporting bibliometric evidence linking screen time and social media usage with poor sleep, increased psychological distress, and a decrease in academic performance [1]. Evidence of parallel relationships from university students reveals that smartphone addiction is common and is statistically associated with lowered academic performance, physical health, and mental wellbeing [2] electronic device addiction is associated directly with lowered sleep quality and academic performance in health-profession students [3].

Sleep as a key mediator of this link. Devices emit blue light that suppresses the production of melatonin and interferes with the regulation of circadian rhythms, and using media before sleep increases physiological arousal in ways that make it harder to fall and stay asleep and get restorative sleep [4]. In a recent study on modelling the relationship between screen time and sleep duration and executive function in school-age and adolescent children, [4] found a systematic relationship between higher screen time, with the caveat of the type of screen time content, and poorer downstream cognitive functioning, which was also moderated by the age of the child or adolescent. At the population level, however, the extent of these effects (measured through large secondary datasets) has proven to be much smaller than perhaps often believed: an influential specification-curve analysis of over 355,000 adolescents by [5] revealed that digital-technology use accounted for no more than 0.4% of the variance in adolescent wellbeing, which has in some ways shifted the methodological debate on whether these exposures are simply too coarse-grained to capture the compulsive and qualitative nature of problematic use.

This methodological tension is exacerbated by a second literature gap. [6] Revealed that the quality of the available evidence remains low, studies do not consistently distinguish interactive electronic-device types or contexts, and only a small proportion of the studies formally tested sleep as a pathway between interactive electronic-device overuse and downstream wellbeing or academic outcomes. Results have been mixed where mediation has been used: [7] found that problematic use was indirectly associated with lower wellbeing through poorer family-communication quality and not directly through a dose–response relationship; however, [8] found the link between smartphone addictions, sleep quality and academic performance to be more direct. Both indirect (quality mediated) and simpler dose-response pathways were found in the same general literature, which suggests the need to introduce further empirical clarification, especially in adolescent (not university) samples, where developmental vulnerabilities for sleep disruption and psychosocial stress are more pronounced.

Much of the existing evidence base, however, comes from homogeneous cross-sectional, clinical or single-institution university samples, with less generalisability of findings to the broader adolescent population and less certainty that pathways identified from smaller or clinical samples replicate in large secondary datasets representative of general populations. There are also relatively few studies that formally consider sleep as a mediator between digital overuse and both psychological wellbeing and academic outcomes, and not each of these outcomes in isolation from the other.

This study aims to fill these gaps by using a large secondary data set of youth aged 13-19 years and a multi-method statistical approach (Pearson correlation, multiple linear regression, and structural equation modelling) to examine pathways by which digital overuse and sleep relate directly, indirectly, and in total to adolescent wellbeing and academic outcomes. Specific objectives were as follows: (1) to

investigate the relationship between digital overuse and psychological wellbeing in adolescents (assessed through stress, anxiety and addiction scores); (2) to determine if sleep duration was associated with academic performance (assessed through grade point average); and (3) to test the combined pathway of digital overuse and sleep on wellbeing and academic performance, with sleep as the hypothesized mediator. In doing so, the study will provide empirical evidence to inform digital-wellbeing policy for schools and families, and improve the understanding of how decisions around measurement affect the conclusions that quantitative research on adolescent digital-wellbeing can draw.

2. RELATED WORK

2.1. Conceptualizing Digital Overuse and Sleep Disruption

Digital overuse is generally defined as problematic excessive use of digital screens, in which there is a loss of control over one's behaviour, and dysfunction is measurable in one's daily life [1], [5]. Several conceptual framings are similar throughout the field: digital overuse as a psychological addiction with tolerance and withdrawal dynamics akin to substance dependence [8], digital overuse as a form of dependence on technology, in which a series of intermittent rewards are built into the design of apps [4]; or digital overuse as a coping strategy to real-life stressors that provide temporary relief from negative affect at the expense of further dysfunction [9]. Some commonly documented manifestations are: overuse of social media, multi-screen dependency, bedtime screen time and classroom digital distraction [10], [11].

Digital overload-induced sleep disturbances are physiological and behavioural. Screen time exposure to blue light inhibits melatonin production and delays the circadian phase, which delays sleep [4]. Pre-sleep media consumption also results in increased psychophysiological arousal (increased heart rate, cognitive activation and emotional reactivity to social content), which are all factors that disrupt the transition to deep sleep, separately from the light-exposure pathway [3]. Several other types of sleep disturbances are relevant to digital overuse: actual sleep deprivation (reduction in total sleep time), delayed sleep onset (increase in time to fall asleep), fragmented sleep (incursions of sleep during the night, typically based on a device alert) and daytime drowsiness (sleepiness persisting during the day, affecting learning and attention in classroom) [12], [13].

Adolescent wellbeing is, in turn, considered as a multidimensional concept that includes life satisfaction, emotional and behavioural regulation, and successful social and academic functioning [7]. Academic performance is often assessed using GPA, indicators of sustained attention, and task engagement, which are all sensitive to sleep architecture and sustained attention [10], [13].

2.2. Theoretical Framework

The current study was based on three major theories. Digital Displacement Theory posits that time is a finite resource: time spent using digital devices comes at a cost of time that is no longer dedicated to sleep, physical activity, or offline social engagement, and thus has downstream negative effects, not only by virtue of the time invested in digital engagement, but also because of the activities that are lost as a result of that displacement [14]. Experimental studies testing the displacement theory with structured social media abstinence protocols have revealed that this abstention allows for a selective increase in time spent on the social media activity being replaced in the case of the studies, sleep, work, and household work and that such displaced activities are themselves related to affective wellbeing, providing empirical support to the displacement mechanism although the ultimate link between social media and wellbeing is often small and strongly activity-dependent [14].

A complementary explanation is that excessive use of the internet is a coping response to pre-existing psychosocial stressors: people who feel stressed, lonely or under academic pressure may seek out digital media as a temporary coping mechanism, but this ends up just further contributing to the distress they were trying to manage, thus creating a vicious cycle of increasing internet use and increasing distress [9].

By contrast, the Goldilocks Hypothesis suggests that there is a non-linear, curvilinear association between digital use and wellbeing, with very low or very high levels of digital use linked to somewhat poorer outcomes than moderate levels of digital use [15]. A large-scale specification-curve test of this

hypothesis based on data from over 120,000 English adolescents revealed that the associations between screen time and wellbeing were quadratic rather than linear and that moderate digital-technology use was not invariably bad and was actually, if slightly, beneficial [15]. Within the context of the present study, this theoretical perspective suggests that the nature of the relationship between the variables of interest may be threshold-dependent, and that duration-only, linear-model analyses that are more commonly used to test digital-overuse hypotheses may be structurally insensitive to the true shape of the relationship.

2.3. Empirical Evidence Linking Digital Overuse, Sleep, and Adolescent Outcomes

There is a large empirical literature relating digital overuse to sleep disruption and to poor outcomes in adolescence, with varying degrees of strength and consistency across different age groups, samples, and measures. [7] Found an indirect relationship between problematic smartphone use and a decrease in adolescent wellbeing, with over 60% of the sample reporting more than 3 hours of daily smartphone use. There have been more consistent relationships between smartphone addiction and poor sleep quality and reduced academic performance among university students participating in cross-sectional studies [8] and with electronic-device addiction and reduced sleep quality and reduced GPA among healthcare students in Saudi Arabia [3]. Excessive use of digital devices, determined by device-specific weekly usage limits, was also reported to significantly correlate with poor sleep quality and psychological distress in the big cross-sectional study of university students in Thailand, while its association with academic performance was relatively weak [11].

Evidence supporting sleep as an outcome and mediator is presented with a focus on sleep. Adverse implications of device use (overuse, problematic use, telepressure, cyber-victimisation) were consistently linked to poorer sleep outcomes across the 28 studies included, although only a minority of studies explicitly included sleep as a potential mediator of downstream impacts on mental health and a generally poor methodological quality of the primary studies [6]. A second umbrella review on digital-device use and adolescent sleep also highlighted that the negative influence of smartphones and computers on sleep was stronger than the impact of TV, and that effects on sleep were most noticeable when participants engaged in social media and internet use, including going to bed later, sleeping less, and taking longer to fall asleep [13]. In previous research conducted with a large normative sample of adolescents in Australia, those who scored high on the pathological use of electronic media had significantly higher levels of sleep problems than those who did not score in that way, and approximately 20% of adolescents identified with a nightly bedtime delay specifically due to electronic-media use [16].

More specifically, the relationship between digital overuse and school-related outcomes was mediated by sleep disturbances, with longitudinal research performed in Taiwan revealing that sleep disturbances due to social-media use predicted school burnout in the next school term and school burnout predicted sleep disturbances in the following school term, thereby indicating a bi-directional pathway between these variables [17]. This was corroborated by the complementary cross-sectional evidence (N = 324 Brazilian medical students), in which an increase in mobile phone use at bedtime during the COVID-19 pandemic was related to a decrease in both sleep quality and academic performance self-reported by students [18]. Further adolescent-specific research indicates that problematic use of social-networking websites is associated with sleep disturbance and low sleep quality, which in turn leads to school-related outcomes indirectly; therefore, a mediation pathway similar to the one examined in the present study is supported by direct empirical evidence. The idea of displacement was previously supported in a small experimental study that tested digital "nude" interventions, which found that the more screen time was reduced, the better sleep quality was self-reported as a preliminary intervention-based study [19]. Finally, using a Stimulus-Organism-Response framework, [20] discovered that smartphone overuse was indirectly associated with lower academic performance through the mediation of organismic health states (insomnia and nomophobia) rather than behaving directly with the students' school performance, a finding that suggests the indirect or health-mediated logic that was tested through the structural equation model in the current study.

This literature, as a whole, leads to two conclusions that are the basis of the design of the present study. First, the relationship between digital overuse and adolescent harm is theoretically reasonable and has been supported in several well-designed studies, with reported effect sizes also widely divergent and

often small or non-existent when using measures of digital use only in large, general population studies [5]. Second, sleep disruption is consistently linked to wellbeing and academic outcomes as a proximal mechanism to digital overuse, but few studies test the entire mediated pathway from digital overuse, through sleep disruption, to wellbeing and academic outcomes in a single integrated statistical model using a large sample of adolescents. The current study was aimed at filling this gap.

3. METHODOLOGY

3.1. Research Design and Approach

Given the non-invasive nature suitable for research on adolescent behaviours in naturalistic settings, this study used a quantitative correlational design to determine the statistical relationship between digital overuse, sleep, wellbeing, and academic performance without intervening or manipulating variables [21]. This design decision enabled the primary independent (digital overuse) and dependent variables (wellbeing and academic performance) to be studied without the ethical issues associated with experimentally limiting or increasing sleep or digital device access of adolescents. A deductive approach was applied in the entire process: directional hypotheses were formulated based on the Stimulus-Organism-Response framework and time-displacement theory and then verified by empirical findings on the sample of data [20], [14]. Pearson correlation and multiple linear regression analyses examined the association between digital overuse and psychological outcomes, the association between sleep and academic performance, and structural equation modelling was used to test the complete integrated and mediated pathway between digital overuse, sleep and academic performance, with three distinct analytic objectives prespecified.

3.2. Population and Data Source

The target population was secondary school adolescents aged between 13 and 19 years. The data were obtained from the Kaggle 'Teen Mental Health Dataset', which is a de-identified, structured dataset collected for the purpose of public-health and digital well-being modelling studies. For the analytic sample, records were only included when all core variables; academic performance and lifestyle-habit indicators contained no missing data and appeared to be free of obvious data-entry corruption; records with missing core metrics were excluded listwise. The data were collected by a safe programmatic download of the dataset file Teen_Mental_Health_Dataset.csv, resulting in a final analytic sample of 1,200 adolescents.

Digital overuse was measured using two variables: daily_social_media_hours and screen_time_before_sleep. One physiological indicator was used for sleep, namely sleep_hours. The two outcome domains were operationalised as: academic performance (self-reported grade point average [GPA] on a 10-point scale) and psychological wellbeing (stress_level, anxiety_level and addiction_level all on a 10-point scale). All continuous variables were examined for out-of-range values and implausible outliers before analysis; no cases were excluded on these grounds beyond the listwise exclusion of cases with missing core variables described above, and all variables used for analysis were within their expected ranges of values, lending credibility to the final analytic data set.

It is important to note upfront that this operationalisation represents a duration-only measurement strategy; digital overuse is measured as hours of use, instead of using a validated instrument of compulsive use that measures loss of control, tolerance or withdrawal; and sleep is measured as total hours, instead of using sleep-quality or sleep-fragmentation instruments such as the Pittsburgh Sleep Quality Index. This choice of measurement units, typical of large secondary data sets of this nature, has direct implications for the interpretation of the results of the study and is revisited in the Results and Discussion and Conclusion sections that follow.

3.3. Data Analysis

Thereafter, all statistical procedures were done using standard general-purpose statistical software, and the data were tested for normality, linearity, and homoscedasticity before regression and structural equation modelling to ensure that the conditions for each technique were reasonably met. Data analysis was in three phases, which are in line with the three research objectives. First, descriptive statistics

were calculated for all major variables to describe the sample and determine if sleep and screen use levels differed from recommendations for adolescents. Second, Pearson correlation and multiple linear regression were used to assess Objective 1, the relationship between two digital-overuse indicators and three psychological-distress outcomes (stress, anxiety, and addiction). Third, simple linear regression was used to test Objective 2, the association between sleep hours and GPA. Last, to test Objective 3, the integrated and hypothesized mediated pathway from digital overuse to sleep hours to wellbeing and academic-performance outcomes simultaneously was tested, along with direct pathways from digital overuse to each outcome, using path analysis and structural equation modelling (SEM). All path coefficients and their corresponding p-values for the SEM were reported using standardization, and indirect (mediated) effects were estimated for the digital-overuse-to-sleep-to-outcome pathways. Throughout, statistical significance was evaluated at the standard 0.05 level and all analyses were based on the full analytic sample of 1,200 adolescents with complete data.

3.4. Ethical Consideration

The study posed only low ethical risk since it was based on secondary, non-manipulated, de-identified data without personally identifiable data. None of the participants underwent sleep deprivation or any manipulation involving the use of these devices at any point, and all analytic procedures were carried out in a way that respected principles of beneficence and non-maleficence [2], [6].

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

As shown in Table 1 , the results indicate that participants spent a mean of 4.54 hours per day on SM (SD = 2.03), a mean of 1.74 hours per day on screen time before sleep (SD = 0.72), with a median of 6.50 hours of sleep per day (average sleep time = 6.45 hours per day, SD = 1.44), which is below the 7-9 hour recommended sleep time for adolescents. Mean GPA was 2.99 (SD = 0.58). Each of these subscales (stress, anxiety, and addiction) was rated on a 10-point scale and revealed moderate levels of psychological distress at baseline for the sample. The combination of these descriptive figures represents a sample with relatively high daily digital-exposure, a chronic sleep deficit (compared to clinical recommendations) and moderate psychological distress, a profile broadly similar to the one reported in other studies of the digital wellbeing of adolescents [7], [2]. Importantly, the deficit in sleep, averaging 0.5-2.5 hours less than the recommended amount, was not confined to a small proportion of the heavy sleepers in the sample, which also indicates that the sleep restriction observed in this study would extend across the entire distribution of the population, and is consistent with the population level framing of adolescent sleep restriction found in previous large scale surveys [16].

Table 1. Descriptive Statistics of Key Variables (N = 1,200)

Variable	Mean	SD	Min	Max
Daily social media hours	4.54	2.03	1.00	8.00
Screen time before sleep (hrs)	1.74	0.72	0.50	3.00
Sleep hours	6.45	1.44	4.00	9.00
Academic performance (GPA)	2.99	0.58	2.00	4.00
Stress level (1-10)	5.45	2.90	1.00	10.00
Anxiety level (1-10)	5.64	2.86	1.00	10.00
Addiction level (1-10)	5.57	2.83	1.00	10.00

As Shown in Figure 1, the respondents were more or less equally split with 615 males (51.2%) and 585 females (48.8%). The gap of 2.4 percentage points (or 30 respondents) is also considered to be negligible, suggesting a well-balanced sample. Such a balance is methodologically desirable because it helps to make comparisons between the scores of the gender group with a higher and the one with a lower

number of participants, for stress, anxiety, and addiction, without allowing one gender group to dominate the estimates.

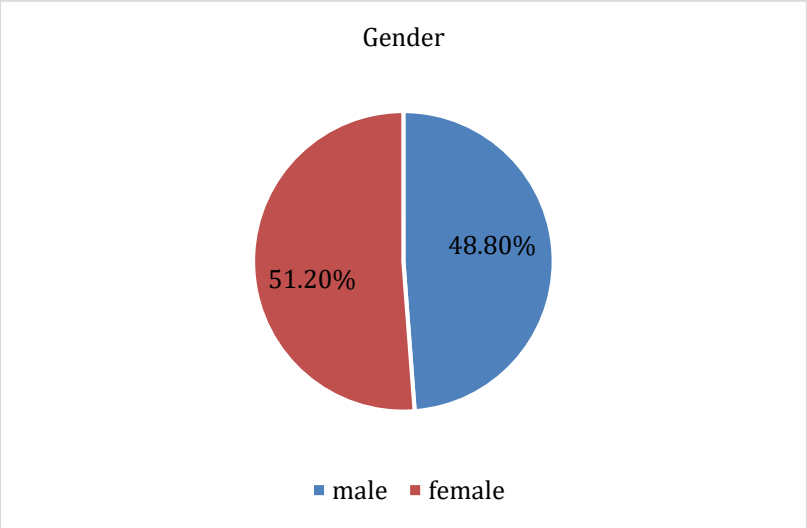

Figure 1. Gender

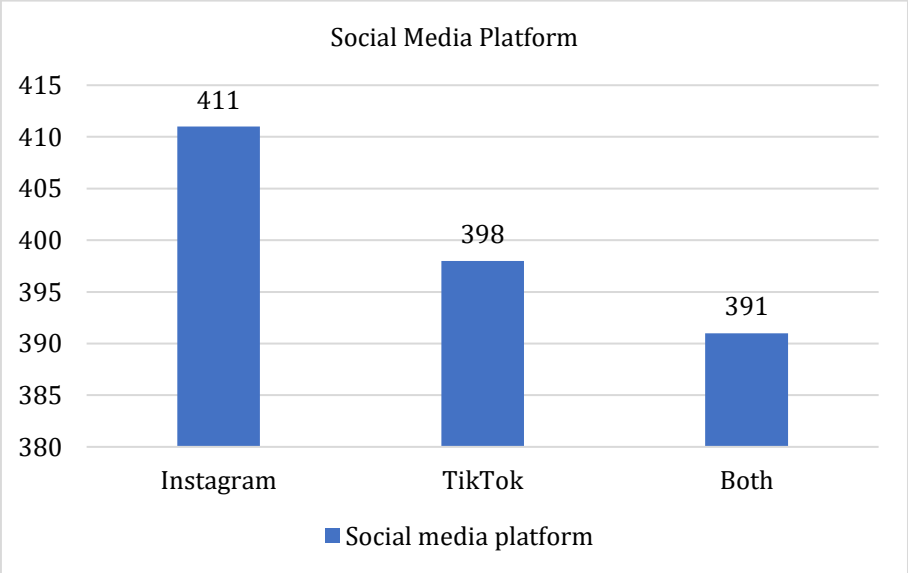

Figure 2. Social Media Platform Used

As shown in Figure 2, the spread throughout the social media channels was similarly extremely even. Instagram users were the largest group at 411 (34.2%), and TikTok users were right behind at 398 (33.2%), and those who used both platforms were at 391 (32.6%). The range between the highest and lowest is narrow at 1.6 percentage points, indicating that no one platform has a strong commanding lead in adolescent platform usage in this sample. Significantly, about a third of the respondents were actively using both platforms, suggesting that there was significant cross-platform usage instead of loyalty to one app.

As shown in Figure 3, age was placed into three developmental bands. Early adolescents (13-15 years old; 533, 44.4%) were the largest, followed by middle adolescents (16-17; 333, 27.8%) and late adolescents (18-19; 334, 27.8%) in almost equal numbers. The sample is, therefore, slightly younger, with nearly half of the sample being in early adolescence. This concentration is important for the interpretation of the following results, as younger adolescents may systematically differ in terms of sleep patterns, parental supervision, and predisposition to social media problems.

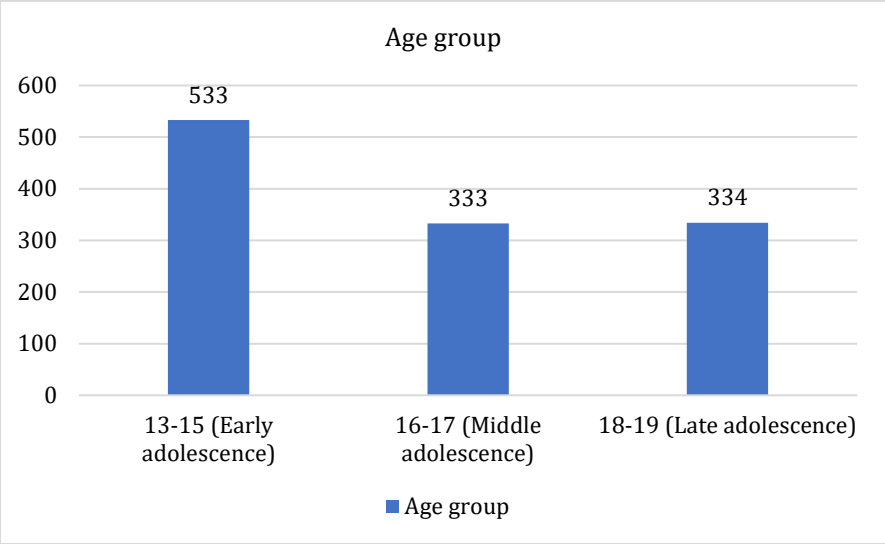

Figure 3. Age Group

4.2. Digital Overuse and Psychological Wellbeing

As shown in Table 2, the results indicate that all correlations between digital-overuse indicators and psychological outcomes were weak, and statistically non-significant. Hours spent on social media daily were negligibly associated with stress ($r = 0.031$, $p = 0.288$), anxiety ($r = 0.028$, $p = 0.335$), and addiction ($r = -0.025$, $p = 0.388$); time on digital devices before bed showed similarly negligible associations with stress ($r = -0.009$, $p = 0.765$), anxiety ($r = -0.010$, $p = 0.720$), and addiction ($r = 0.029$, $p = 0.317$). Multiple regression confirmed these null results: predictor variables explained under 0.2% of variance in stress ($R^2 = 0.001$, $F = 0.622$, $p = 0.537$), anxiety ($R^2 = 0.001$, $F = 0.541$, $p = 0.582$), and addiction ($R^2 = 0.002$, $F = 0.906$, $p = 0.405$).

The null results are at odds with earlier studies indicating that digital overuse is associated with high levels of psychological distress [1], [8] likely due to different methodologies in measuring digital overuse. Much of the previous research on the association between device dependency and psychological harm has used validated addiction scales to assess the presence of tolerance, withdrawal, and loss of control [2], [7] instead of looking at hours of device use, and the overuse of digital screen time study of Thai university students also revealed that mental-health associations were much more robust when device-specific compulsive-use thresholds were used as opposed to raw hours of use [11]. Furthermore, [7] discovered there was no direct relationship between problematic smartphone use and distress scores, but rather an indirect impact on wellbeing through reduced family-communication quality. The current dataset, in contrast, recorded only the amount of time spent and not the compulsive and dysregulated aspect of the use that the literature suggests is most harmful. An alternative explanation is provided by the Goldilocks Hypothesis (GH), which states that negative effects only appear when the use of a substance crosses a critical threshold, such that linear correlation and regression models are not structurally sensitive to curvilinear or threshold-dependent effects [15], [5].

Table 2. Pearson Correlation Analysis: Daily Social Media Hours, Screen Time before Sleep, and Stress Level, Anxiety Level, and Addiction Level

Predictor Variable	Dependent Variable	r	r^2	p-value
Daily social media Hours	Stress Level	0.031	0.001	0.288
Daily social media Hours	Anxiety Level	0.028	0.001	0.335
Daily social media Hours	Addiction Level	-0.025	0.001	0.388
Screen Time Before Sleep	Stress Level	-0.009	0.000	0.765
Screen Time Before Sleep	Anxiety Level	-0.010	0.000	0.720
Screen Time Before Sleep	Addiction Level	0.029	0.001	0.317

4.3. Sleep Deprivation and Academic Performance

As shown in Table 3, the results indicate that there was a positive but not statistically significant relationship between sleep hours *and* GPA (b = 0.0087; r = 0.022; R^2 = 0.0005; F = 0.575, p = 0.449). In this study, participants' average sleep was 6.45 hours per night, which was less than the sleep recommended for adolescents and similar to widely reported patterns of sleep loss observed in adolescents [16]. The null finding is in contrast to studies that have found a strong relationship between sleep and academic performance. [8] Found that poor sleep quality and smartphone addiction were significantly associated in university students, and [3] found that the use of electronic devices was significantly associated with sleep quality and academic achievement in healthcare students. [12] Also reported that combined screen time, daytime sleepiness, and sleep duration are robust predictors of school failure in school-aged adolescents.

This discrepancy with the vast literature pointing to statistically significant relationships between sleep duration and academic outcomes might reasonably be attributed to measurement differences: the current study used a single measurement of sleep duration when reported by the students, while the literature generally indicates that sleep quality, timing and daytime sleepiness have a stronger and more consistent association with academic outcomes than sleep duration alone [4], [13]. Another explanation is that GPA is a general, quite coarse-grained summary index of academic achievement that may not be as sensitive to sleep restriction as measures of cognition that are more closely tied to sleep, like attention or working memory, or to same-day test performance, which previous experimental and quasi-experimental studies suggest may be more responsive to sleep restriction than are end-of-term grade averages.

Table 3. Simple Linear Regression: Sleep Hours and GPA

Parameter	Value
Regression Coefficient (slope)	0.0087
Intercept	2.934
Pearson r	0.022
R^2 (Coefficient of Determination)	0.0005
F-statistic	0.575
p-value	0.449
Standard Error (slope)	0.012

4.4. Integrated Systemic Pathways

As shown in Table 4, the results indicate that the structural equation modelling showed that none of the paths from digital overuse to sleep hours, sleep hours to wellbeing, nor from wellbeing to academic performance were statistically significant. The path from digital overuse to sleep hours was negligible (β = 0.001, p =0 .985); downstream paths from sleep hours to stress (β = -0.011, p = 0.704), anxiety (β = -0.012, p =0 .681), and GPA (β = 0.022, p = 0.449) were similarly weak, as were direct paths from digital overuse to stress (β = 0.021, p = 0.596), anxiety (β = 0.017, p =0.674), GPA (β = -0.021, p = 0.605), and addiction (β = 0.004, p = 0.925). Indirect effects via sleep were very small (ranging from -0.00001 to 0.00002) and not statistically significant.

Table 4. Standardized Path Coefficients among Digital Overuse, Sleep, Wellbeing and Academic Performance

Path	β (Std.)	p-value
Digital overuse to Sleep hours	0.001	0.985
Sleep hours to Stress level	-0.011	0.704
Sleep hours to Anxiety level	-0.012	0.681
Sleep hours to Academic performance (GPA)	0.022	0.449
Digital overuse to Stress level (direct)	0.021	0.596
Digital overuse to Anxiety level (direct)	0.017	0.674
Digital overuse to Academic performance (direct)	-0.021	0.605
Digital overuse to Addiction level	0.004	0.925

Theory and similar published studies predict a different result from these null results. An indirect link between the effects of smartphone overuse on academic performance was found using the Stimulus-Organism-Response framework by [20] and between sleep disturbance and social media and later school burnout and lower academic performance in a two-wave longitudinal approach by [17]. The present cross-sectional, single-metric design would not support the multi-wave design with validated measurements of sleep used in [6], who found that sleep mediation could only be reliably determined in prospective studies using repeated, validated measurements of sleep and not a single self-reported duration figure. In an umbrella review, [13] also found that the magnitude of the impact on sleep from digital devices varied widely by the type of device and type of content; parameters not measured by the present dataset's general hours-based measure [13]. While none of the estimated coefficients were statistically significant, all estimated paths were in the direction expected in theory and the descriptive profile observed here of heavier social-media use, a chronic sleep deficit, and moderate psychological distress are very similar to what is reported elsewhere in the literature [7], [2], implying that the hypothesised cascade from digital overuse through sleep disruption to reduced wellbeing and academic performance is plausible in principle but was simply not statistically detectable using this cross-sectional, duration-only, single-metric design.

4.5. Practical and Theoretical Implications

All of these results have two practical implications. First, a small experimental study of digital "nudge" interventions has found that reductions in tracked screen time were directly correlated with increased sleep quality [19], suggesting that school- and family-level interventions focused on decreasing screen time before sleep, rather than on a general limitation of screen time, may be more likely to have a practical impact than blanket time caps. Second, the pattern of null results observed here with duration-only measures, however, compared with the large number of significant results from the use of validated measures of compulsive use and sleep quality [2], [7], [8] suggests that, at least in the field of digital overuse in adolescents, research and screening tools should prioritise the use of validated instruments over duration measures, an argument that aligns with the theory discussed above (the Goldilocks Hypothesis and Compensatory Internet Use Theory) [15], [9].

5. CONCLUSION

This study aimed to examine the relationship between digital overuse and sleep, wellbeing and academic performance in adolescents and employed a large secondary data set, which was analyzed in three ways to offer a complementary perspective on this relationship. Although none of these relationships were significant, this does not mean that there is no effect of digital overuse and sleep loss. Rather, they propose that duration-only screen-exposure measures and single-item sleep-duration measures are not fine-grained enough to account for the compulsive, qualitative, and architectural aspects of digital and sleep behaviour that are consistently associated with psychological and academic outcomes in the wider literature.

Regarding digital overuse, the results suggest a need to move away from hours of use and towards validated compulsive use measurement that could differentiate the subgroup of adolescents who are truly at higher risk, per the Compensatory Internet Use Theory and Goldilocks Hypothesis studied in this paper. The chronic sleep deprivation experienced by the entire sample, significantly below the recommended sleep range of 7-9 hours a night, is itself a public-health concern and is not a straightforward linear relationship between sleep duration and GPA, but rather sleep quality, timing, and fragmentation are more closely related to academic outcomes. This hypothesised pathway, from digital overuse to sleep disruption, to reduced wellbeing, to reduced academic performance, is conceptually sensible and several well-designed studies support it, but this pathway needs to be examined longitudinally, using multi-dimensional and validated measures, before it can be considered confirmed or disconfirmed. The descriptive profile found in this adolescent sample highlights high levels of digital consumption, chronic sleep shortfall and moderate psychological distress that are similar to what has been reported in other samples in similar studies, even if not statistically significant in the current study. This gap between a troubling descriptive picture and a non-significant statistical picture in itself is an important finding and suggests that policy and practice

should not be held back by the absence of statistically significant coefficients in secondary data based on time spent using a device before taking action on the wellbeing risks that digital overuse and sleep deprivation plausibly pose to adolescents. Interventions that could be considered on this basis are evidence-aligned, low-risk and include later school start times, mandatory digital-wellbeing curricula integrated in existing health education, and community-based education programmes for parents that specifically target pre-bedtime device use, but not screen time more broadly.

Several limitations to this study warrant consideration when interpreting the results and highlight specific areas for future studies. The cross-sectional design does not allow for any causal conclusions to be drawn, and the use of self-report, duration-only measures of digital use and sleep (as opposed to validated compulsive-use scales and validated objective sleep-tracking measures) most likely accounts for the smaller effect sizes found in comparison to the broader literature. Additionally, the secondary data did not allow for the control of potentially important confounding and/or moderating variables, including socioeconomic status, school context, parental monitoring practices, and the type of content on the device, each of which has been identified as a moderator of the digital-overuse-to-sleep pathway in other studies.

Future studies should focus on longitudinal multi-wave studies that include validated compulsive-use and sleep-quality measures, including the Pittsburgh Sleep Quality Index, and should formally test gender, socioeconomic status, and school context as potential moderators to better establish pathways between digital overuse, sleep, and the development of adolescents. However, if this is the case, then the findings of the present study, while perhaps not inferential, might provide a sound foundation from which to take cautious, low-risk policy action related to adolescent digital wellbeing and sleep health, until such evidence is found. More fundamentally, the importance of this study is not so much in the specific high-value coefficient as in the fact that the use of duration-only measurement choices, in this instance, can mask associations that are theoretically meaningful and practically relevant for adolescent development, albeit only to an extent.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Michael Nyamekye Kusi	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

The author states no conflict of interest.

Informed Consent

Not applicable. This study used a fully anonymized, publicly available secondary dataset containing no personally identifiable information.

Ethical Approval

The research relied exclusively on secondary, de-identified, open-access data and did not involve direct interaction with human participants.

Data Availability

The data that support the findings of this study are openly available in the Kaggle repository "Teen Mental Health Dataset" at https://www.kaggle.com/datasets/sebz0206/teen-mental-health-dataset.

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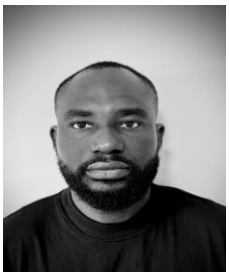

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