

Caught in the web: a meta-analysis of Internet addiction, excessive daytime sleepiness and depressive symptoms in adolescents

Caught in
the web

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Abstract

Purpose – In response to growing concerns over the negative consequences of Internet addiction on adolescents' mental health, coupled with conflicting results in this literature stream, this meta-analysis sought to (1) examine the association between Internet addiction and depressive symptoms in adolescents, (2) examine the moderating role of Internet freedom across countries, and (3) examine the mediating role of excessive daytime sleepiness.

Design/methodology/approach – In total, 52 studies were analyzed using robust variance estimation and meta-analytic structural equation modeling.

Findings – There was a significant and moderate association between Internet addiction and depressive symptoms. Furthermore, Internet freedom did not explain heterogeneity in this literature stream before and after controlling for study quality and the percentage of female participants. In support of the displacement hypothesis, this study found that Internet addiction contributes to depressive symptoms through excessive daytime sleepiness (proportion mediated = 17.48%). As the evidence suggests, excessive daytime sleepiness displaces a host of activities beneficial for maintaining mental health. The results were subjected to a battery of robustness checks and the conclusions remain unchanged.

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Practical implications – The results underscore the negative consequences of Internet addiction in adolescents. Addressing this issue would involve interventions that promote sleep hygiene and greater offline engagement with peers to alleviate depressive symptoms.

Originality/value – This study utilizes robust meta-analytic techniques to provide the most comprehensive examination of the association between Internet addiction and depressive symptoms in adolescents. The implications intersect with the shared interests of social scientists, health practitioners, and policy makers.

Keywords Internet addiction, Web 2.0, Behavior change, Literature review, Structural equation modeling, Government policy

Paper type Research paper

1. Introduction

We are all now connected by the internet, like neurons in a giant brain - Stephen Hawking.

Like neurons in a giant brain, people connected through the Internet can communicate, collaborate, share knowledge, and achieve collective goals. Modern society depends on the Internet for unparalleled convenience in daily affairs. For researchers from varying fields, there is a growing interest to examine the impact of Internet usage, especially among adolescents. Key drivers of this inquisitiveness include adolescents' susceptibility to Internet addiction (Karacic and Oreskovic, 2017) and its subsequent impact on their mental health (Liu *et al.*, 2022; Van Rooij *et al.*, 2017), academic performance (Zhang *et al.*, 2018; Kubey *et al.*, 2001), and self-identity (Israelashvili *et al.*, 2012).

In literature, Internet addiction is also known as problematic Internet use, excessive Internet use, compulsive Internet use or pathological Internet use (Restrepo *et al.*, 2020). Internet addiction is a behavioral addiction spurring from human-machine interaction (Griffiths, 1996), which manifests in terms of physiological dependence, tolerance, and withdrawal symptoms (Yoo *et al.*, 2014). While Internet addiction has long been conceptualized as a generalized impulse control disorder (Young, 1996), however, there is a lack of a clear and coherent formal stylization of this condition (Pan *et al.*, 2020).

Regardless of how Internet addiction is formally codified, suffice to say, mental health implications of Internet addiction are a growing concern to parents and researchers alike (Cash *et al.*, 2012). Furthermore, despite extensive research on this literature stream, the results remain conflicting (Thom *et al.*, 2018) and this can stall efforts in designating Internet addiction as a mental disorder (Block, 2008; Cash *et al.*, 2012). For example, some evidence contends Internet addiction as a problematic condition, one which does not significantly contribute to depressive symptoms (Thom *et al.*, 2018; Yao and Zhong, 2014). Moreover, some studies have found that socially motivated excessive Internet usage may (Donnelly and Kuss, 2016; Sampasa-Kanyinga and Lewis, 2015) or may not (Jelenchick *et al.*, 2013; Fardouly *et al.*, 2020) contribute to depressive symptoms, suggesting a lack of consensus in this literature stream.

Second, the mechanisms through which Internet addiction contributes to depressive symptoms is not well understood. Insofar, studies grounded in the displacement hypothesis have primarily focused on displaced "time spent with existing friends" as the reason why Internet use may reduce quality of friendships and lead to depressive symptoms (Kraut *et al.*, 1998; Nie *et al.*, 2002; Kojima *et al.*, 2021). Some studies have suggested that excessive screen time displaces "physical activities", which may contribute to depressive symptoms (Twenge *et al.*, 2018; Huang *et al.*, 2020). Despite sound theoretical reasoning, these explanations have been contended (Hall *et al.*, 2019; Lee, 2009). For example, Valkenburg and Peter (2007) found support for the stimulation hypothesis as opposed to the displacement hypothesis whereby time spent online fosters greater quality of friendship which in turn enhances well-being.

More recently, studies have found sleep quality to mediate this association (Li *et al.*, 2017; Cheung and Wong, 2011) and there is scope to build on this line of consensus. While some healthy activities, such as social and physical activities, may not necessarily be displaced

by time spent on the Internet, however, the resultant displaced sleep may contribute to lack of engagement in activities beneficial to mental health and well-being. In other words, self-imposed sleep deprivation can perpetuate the displacement of activities beneficial to maintaining mental health by limiting one's ability to perform those activities altogether (Guilleminault and Brooks, 2001; Gandhi *et al.*, 2021). In accordance with the displacement hypothesis, there appears to be fragmented yet considerable evidence to indicate the potential mediating role of excessive daytime sleepiness. This study aims to reconcile conflicting accounts and offer a fresh perspective by incorporating excessive daytime sleepiness as a mediator in the relationship between Internet addiction and depressive symptoms. We review this evidence in greater detail in [Section 1.3](#).

Given the lack of consensus in this literature stream and the vested interest to safeguard adolescents from the negative consequences of Internet addiction, the present study sought to examine two research questions: Specifically, (1) what is the association between Internet addiction and depressive symptoms? Furthermore, (2) does excessive daytime sleepiness mediate the association between Internet addiction and depressive symptoms? We examine the mediating role of excessive daytime sleepiness through a meta-analytic structural equation modeling (MASEM) approach. Additionally, we examine whether Internet freedom across countries accounts for the diversity in this literature stream. We do not develop *a priori* hypothesis for this assessment and simply report the results as an exploratory pursuit.

1.1 The association between Internet addiction and depressive symptoms

In literature, the temporal directionality of the association between Internet addiction and depressive symptoms is contested. While the displacement hypothesis suggests a link from Internet addiction to depressive symptoms (Kraut *et al.*, 1998; Nie *et al.*, 2002; Kojima *et al.*, 2021; Twenge *et al.*, 2018; Huang *et al.*, 2020), the cognitive-behavior model implies a direction of causality from depressive symptoms to Internet addiction (Davis, 2001; Caplan, 2003, 2010). The premise of the latter argument lies in that adolescents with depressive symptoms use the Internet as a coping strategy which can eventually turn maladaptive (Caplan, 2002, 2003). Moreover, some researchers have found the association to be bidirectional (Stanković and Nešić, 2022). Kojima *et al.* (2021) suggest that these contradictions exist, in part, due to the methodological differences in studies. Researchers who have explicitly examined the temporal directionality of this association have overwhelmingly found Internet addiction to precede depressive symptoms and not the other way around (Kojima *et al.*, 2021; Zhou *et al.*, 2020; Ciarrochi *et al.*, 2016).

Based on the available evidence, we focus on the path from Internet addiction to depressive symptoms and hypothesize a significant association between the two constructs.

1.2 The mediating role of excessive daytime sleepiness

While the etiologies of excessive daytime sleepiness are diverse (Gandhi *et al.*, 2021), our primary focus is on self-imposed sleep deprivation. In this regard, researchers have suggested that Internet usage is one of the most common causes of self-imposed sleep deprivation (Schwartz *et al.*, 2009; Park *et al.*, 2018). Unremarkably, there is a well-established link in the literature between Internet addiction and excessive daytime sleepiness (Park *et al.*, 2018; Bener *et al.*, 2016). Consistent with the displacement hypothesis, excessive Internet usage, especially during bedtime, displaces sleep (Li *et al.*, 2017; Cheung and Wong, 2011) resulting in greater daytime sleepiness (Buysse *et al.*, 2008; Cleator *et al.*, 2013). From a physiological perspective, excessive screen use before bedtime suppresses the sleep-promoting hormone melatonin (Wood *et al.*, 2013) which can contribute to poor sleep quality (Fateme *et al.*, 2021) and excessive daytime sleepiness (Videnovic *et al.*, 2014).

Excessive daytime sleepiness in turn is associated with significant morbidity (Gandhi *et al.*, 2021). Specifically, studies have shown that excessive daytime sleepiness displaces

a host of daily activities necessitated for maintaining mental health (Ng *et al.*, 2020; Chen *et al.*, 2015), including physical (Maugeri *et al.*, 2018; Chasens *et al.*, 2007) and social activities (Reishtein *et al.*, 2006; Holding *et al.*, 2020), presumably due to low energy levels (Holfeld and Ruthig, 2014).

Based on the reviewed evidence, we hypothesize that excessive daytime sleepiness mediates the association between Internet addiction and depressive symptoms.

1.3 Contributions of the present meta-analysis

We craft our contributions based on the established guidelines outlined by Hollenbeck (2008) and focus on building consensus by providing a fresh perspective of the association between Internet addiction and depressive symptoms. We accomplish this through several ways. First, the use of a meta-analysis allows us to provide a more robust and precise estimate of the association between Internet addiction and depressive symptoms that exists in the population over and above any single included study (Schmidt and Hunter, 2014). A meta-analysis accomplishes this by enhancing statistical power to detect an effect of interest by synthesizing disparate findings (Stone and Rosopa, 2017). With a more precise estimate of the association between Internet addiction and depressive symptoms, we reduce uncertainty surrounding the detrimental effects of Internet addiction. This in turn, should facilitate scholarly efforts attempting to designate Internet addiction as a mental disorder. For example, Blum and Grant (2022) argue that for Internet addiction to be widely recognized as a distinct psychiatric condition, greater consensus among scholars is required regarding its nature.

Secondly, the present meta-analysis is the most comprehensive examination of the association between Internet addiction and depressive symptoms in adolescents. The most recent meta-analysis that examined this association (Cai *et al.*, 2023) includes studies with participants' age ranging upwards of 57 years (Caplan, 2002). The derived summary effect is an aggregation of effect sizes that incorporates characteristics of adolescent and non-adolescent participants, who naturally differ in terms of their depressive symptom trajectories (Ferro *et al.*, 2015). Furthermore, we explicitly model the dependence structure in the data by utilizing a correlated and hierarchical effects (CHE) model (Pustejovsky and Tipton, 2022). This allows us to include all available information (effect sizes) without relying on ad hoc techniques to deal with dependency (e.g. averaging). We further utilize robust variance estimation (RVE) to guard the statistical inferences (Pustejovsky and Tipton, 2022; Harrer *et al.*, 2021).

Thirdly, we examine whether Internet freedom modifies the association between Internet addiction and depressive symptoms in any way (see for example, arguments commonly made to impose Internet restrictions; Ververis *et al.*, 2020). We rule this possibility out even after controlling for study quality and the percentage of female participants. Specifically, meta-analyses results have been known to be influenced by study quality (Luchini *et al.*, 2021; Khan *et al.*, 1996). Moreover, gender variations in the association between Internet addiction and depressive symptoms are well documented in the literature (Ha and Hwang, 2014; Liang *et al.*, 2016). Finally, we harness the advantage of MASEM to provide a fresh perspective by examining the mediating role of excessive daytime sleepiness in the association between Internet addiction and depressive symptoms. MASEM allows researchers to examine a hypothesized mediation model for which, relevant correlation coefficients (or transformable data) are reported in the included studies, but the mediation model may not necessarily have been examined (Jak, 2015). By examining the mediating role of excessive daytime sleepiness, we incorporate a new interpretation of the displacement hypothesis. We reason that displacement does not necessarily occur in isolation. In other words, our examination aims to build consensus that Internet-induced excessive daytime sleepiness may lead to the displacement of other activities that may be deemed beneficial for well-being. As we detailed

earlier, past research has mostly focused on quality of friendship or physical activities as mediating variables and in such studies, both variables are assumed to be necessary for maintaining well-being and vulnerable to the displacement effect of Internet usage. Nonetheless, studies have shown that this is not necessarily the case (e.g. Valkenburg and Peter, 2007).

2. Methods

This meta-analysis was pre-registered. The PRISMA checklist, the study quality assessment tool, R codes, data relevant to the meta-analysis, and the coding manual can be found on the Open Science Framework's anonymized website link: https://osf.io/zgtj8/?view_only=01553a26addb4c5784bb4dffad9cc65a.

2.1 Literature search

The search process for studies initially commenced in April 2022. During this time, there was an exponential rise in studies relating to Internet addiction. To maximize the number of included studies, we halted the search and undertook the process on the 2nd of April 2023. Studies included in the present meta-analysis were retrieved through Scopus, PubMed, past meta-analyses (Cai *et al.*, 2023; Alimoradi *et al.*, 2019; O'Callaghan *et al.*, 2021), and Google Scholar (first 200 references). Studies were searched using a combination of different keywords such as, "internet addiction", "problematic internet use", "excessive internet use", "compulsive internet use", "pathological internet use", "daytime sleep", "daytime", "Epworth Sleepiness Scale", "ESS", "hypersomnia", "depression", "mental health", "teen", "adolescent", and "school". The search strings utilized to retrieve studies concerning each association are given in Table A.1 (supplementary material). We also pursued a snowball approach considering references of references by utilizing past meta-analyses (Cai *et al.*, 2023; Alimoradi *et al.*, 2019; O'Callaghan *et al.*, 2021) as a starting point. In total, 1,157 potential studies were retrieved.

2.2 Inclusion criteria

Studies that met the following criteria were included: (1) participants must be aged between 10 and 19 years, (2) participants must not be clinical patients or those diagnosed with major depression disorder, (3) studies must have examined at least one of the hypothesized relationships (Internet addiction and depressive symptoms; Internet addiction and excessive daytime sleepiness; excessive daytime sleepiness and depressive symptoms), (4) studies must be cross-sectional, (4) there must be enough statistics reported to enable effect size extraction, (5) studies must not be published in a predatory journal, and (6) studies must be published in English.

We followed the World Health Organization's definition of adolescence as individuals aged between 10 and 19 years and this definition is also consistent with that of the Canadian Paediatric Society and the Adolescent Health Committee (Sacks *et al.*, 2003). Like a past meta-analysis (Kauhanen *et al.*, 2022), we did not rely on the reported mean age of participants for study eligibility purposes. Instead, studies were deemed eligible if participants' age range was reported (i.e. between 10 and 19 years of age) since the age range of participants can extend far beyond the reported mean age (e.g. Caplan, 2002). In this way, we eliminate potential confounding emerging from the characteristics of non-adolescent participants. Furthermore, we excluded studies that utilized single items. For example, one study measured depression using a single question "during the past year, have you ever felt depressed or sad for 2 weeks continuously?" (Ha and Hwang, 2014, p. 662). Some studies

measured Internet use per day as opposed to generalized Internet addiction (Akgun Kostak *et al.*, 2019). Such studies were excluded.

Among the 1,157 potentially relevant studies, there were a total of 128 duplicates. The remaining 1,029 studies were subjected to abstract and title screening against the inclusion criteria and a further 725 studies were removed. The remaining 304 studies were subjected to full text screening. In total, 52 studies met the inclusion criteria, and these studies were included in the meta-analysis. Specifically, 44 studies examined the relationship between Internet addiction and depressive symptoms, 4 studies examined the relationship between Internet addiction and excessive daytime sleepiness, and 6 studies examined the relationship between excessive daytime sleepiness and depressive symptoms. Figures A.1–A.3 (Appendix A) (supplementary material) summarize the literature search process. None of the included studies was published in a journal listed on the now defunct Beall's List of predatory journals.

2.3 Data extraction and coding

Data extraction and coding was conducted by two authors (except for effect size coding) and all disagreements were resolved through discussion (inter-coder agreement = 98.2%). Zero-order correlations were extracted for the hypothesized associations. In instances where zero-order correlations were not reported, we extracted other reported statistics that could be transformed into Pearson correlation coefficients.

To examine potential heterogeneity in effect sizes, several variables were coded, namely, (1) Internet freedom, (2) study quality, and (3) the percentage of female participants. Moreover, to provide a descriptive overview of the included studies (Appendix B; Table B.1 [supplementary material]), we further coded (4) the study context (i.e. country), (5) measures of Internet addiction, (6) measures of excessive daytime sleepiness, and (7) measures of depressive symptoms. Based on the study context (i.e. country) we coded the degree of Internet freedom by utilizing data provided by Freedom House (2022). Internet freedom scores are rated from a scale of 0–100 (0–39 = not free, 40–69 = partly free, and 70–100 free) which provide a measure of: obstacles to access, limits on content, and violation of user rights (Freedom House, 2022). Internet freedom data was matched with the year of data collection given in the included studies. When the year of data collection was not reported, the year of article submission was taken as a proxy. When this was not reported, the publication year was taken as a proxy. One author undertook the study quality assessment, and another author confirmed the coded study quality assessment. Study quality assessment was undertaken using the *Quality Assessment Tool for Quantitative Studies* (Thomas *et al.*, 2004). Specifically, we adopted the modified version utilized by Marker *et al.* (2022) which was more appropriate for the present meta-analysis. The modified tool assesses study quality across three domains, namely, selection bias, disclosure of the study's purpose, and data collection methods (Marker *et al.*, 2022). Studies are assigned a rating (1 = high quality, 2 = medium quality, and 3 = low quality) across all three domains and the final study quality score is the mean value of the assigned ratings.

2.4 Meta-analytic procedures

The present meta-analysis followed the recommended guidelines and procedures of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Moher *et al.*, 2015).

2.4.1 Effect size. The present study utilized the Pearson product-moment correlation coefficient (r) as an effect size measure. Like Marker *et al.* (2022), we only included zero-order relationships and excluded second-order relationships (e.g. adjusted odds ratios). Pearson correlation coefficients were reported across 31 studies. The remainder of the studies reported

Spearman's correlation coefficient ($k = 5$), Student's t -test ($k = 4$), mean values ($k = 5$), crude odds ratios ($k = 2$), the Kruskal–Wallis test ($k = 1$), standardized beta weights ($k = 2$), one-way ANOVA ($k = 2$), and chi-square test ($k = 2$). These results were transformed into Pearson correlation coefficients.

2.4.2 Meta-analytic models. For the association between Internet addiction and depressive symptoms, one study (Sesar *et al.*, 2018) reported the results separately for each subdomain of the problematic Internet use scale. In this instance, multiple effect sizes were extracted. There were two other studies (Kim *et al.*, 2006; Lai *et al.*, 2015) from which multiple effect sizes were extracted, however, the effect sizes from these studies emerged from independent samples. We accounted for the dependence structure by utilizing a CHE model with RVE (Pustejovsky and Tipton, 2022).

The CHE working model combines a correlated effects model and a hierarchical effects model. The hierarchical effects model is like a three-level meta-analysis in the sense that participants (level 1) are nested within effect sizes (level 2) and effect sizes are nested within studies (level 3) (Van den Noorgate *et al.*, 2013). In this way, the model captures within-study heterogeneity on level 2 and between-study heterogeneity on level 3. Nonetheless, the hierarchical effects model assumes that within studies, the effect size estimates are independent, and this is not the case in the present meta-analysis. The hierarchical effects model can therefore be combined with a correlated effects model that considers the correlation between sampling errors (Pustejovsky and Tipton, 2022). We chose $\rho = 0.5$ as the default within-study correlation of estimates and we further undertook sensitivity analysis (Table C.1 [supplementary material]) to note changes in the summary effect size by varying the degree of correlation between estimates for $\rho = [0, 0.9]$. We utilized RVE since it does not require precise knowledge of the dependence structure and only requires a working model (CHE) to approximate the dependence structure (Tipton, 2013; Pustejovsky and Tipton, 2022). In this way, RVE can guard inferences (p -values and confidence intervals) against any misspecification of the model (Harrer *et al.*, 2021). Estimates were obtained via Restricted Maximum Likelihood (REML) by utilizing the “metafor” package (version 3.4-0; Viechtbauer, 2010) and the “clubSandwich” package (version 0.5.8; Pustejovsky, 2020) in R (version 4.2.1; R Core Team, 2022).

The associations between Internet addiction and excessive daytime sleepiness as well as excessive daytime sleepiness and depressive symptoms were examined using a traditional two-level meta-analysis. This is equivalent to a conventional random-effects model, where study participants (level 1) are nested within studies (level 2) (Hedges and Olkin, 1985). We utilized a conventional approach to examine these associations since the effect sizes were overwhelmingly independent (i.e. one effect size per study was extracted). Summary effect sizes for these associations were derived using a random-effects model via REML by utilizing the “metafor” package (version 2.1-0; Viechtbauer, 2010) in R (version 4.2.1; R Core Team, 2022).

2.4.3 Moderation analysis. Sources of heterogeneity in the association between Internet addiction and depressive symptoms were examined by developing univariate models for each predictor (Internet freedom, study quality, and the percentage of female participants). Next, a multivariate model was developed that simultaneously included all the predictors which were, the moderating variable (Internet freedom) as well as the covariates (study quality and the percentage of female participants). In this way, we highlight the potential moderating effect of Internet freedom with and without accounting for study quality and the percentage of female participants. Moreover, we probe the robustness of the findings by excluding potential outliers and refitting the univariate models as well as the multivariate model to note if the exclusion of potential outliers leads to considerable changes in the results (e.g. Viechtbauer and Cheung, 2010) (Table C.2 and Table C.3 [supplementary material]). Potential outliers were identified by computing Cook's distances associated with effect size

estimates and values exceeding the 50th percentile of a chi-square distribution with 1 degree of freedom (i.e. $\chi^2_{1;0.5} = 0.45$) were considered influential (Cook and Weisberg, 1982).

2.4.4 Publication bias assessment. We assessed potential publication bias by generating a funnel plot and noting its asymmetry both, subjectively and objectively. In the absence of publication bias, effect size estimates from studies with lower standard error would approach the true effect size estimate while effect size estimates from studies with high standard error would be evenly distributed on either side of the true effect size (i.e. a symmetrical funnel plot) (Simmonds, 2015). There is an indication of publication bias if low-precision studies with non-significant results are absent (Simmonds, 2015). Objectively, funnel plot asymmetry was assessed through Egger's regression test which regresses the observed effect sizes on the corresponding standard error (Egger *et al.*, 1997). Publication bias is indicated when the regression weight for the studies' standard error is significant.

To obtain bias-corrected pooled effect size, the precision-effect test (PET) and the precision-effect estimate with standard error (PEESE) (Stanley, 2017; Stanley and Doucouliagos, 2014) were utilized. The PET model controls for the effect of small studies by including standard error as the predictor. In this way, the intercept, or the limit effect (β_0) represents the true effect size in the absence of sampling error. Similarly, the PEESE model controls for the effect of small studies by including effect size variance as the predictor. The PET model is preferred to the PEESE model when the true effect represented by β_{PET} is not statistically distinguishable from zero ($p > 0.05$) and the PEESE model is preferred to the PET model when the true effect size represented by β_{PET} is significant ($p < 0.05$) (Stanley and Doucouliagos, 2014). Publication bias assessment was undertaken by utilizing the "metafor" package (version 2.1-0; Viechtbauer 2010) in R (version 4.2.1; R Core Team, 2022).

2.4.5 Meta-analytic structural equation modeling (MASEM). We employed MASEM to examine the potential mediating role of excessive daytime sleepiness. The analysis was undertaken in two stages. In the first stage, correlation matrices were pooled based on the meta-analytic models described above. This approach differs from the standard first stage of the two-stage structural equation modeling (TSSEM) approach (Cheung and Chan, 2005; Cheung, 2014, 2015) which assumes that each study contributes one correlation matrix (Wilson *et al.*, 2016). This would necessarily entail an ad hoc procedure to synthetically yield one effect size per study (see for example Schutte *et al.*, 2021). In the second stage, the pooled correlation matrix was subjected to a path analysis to test the hypothesized mediation model by utilizing weighted least squares (WLS) estimation (Cheung, 2014). Following Cheung and Chan's (2005) approach, the inverse of the asymptotic covariance matrix was used as the weight matrix. The model was specified with excessive daytime sleepiness as a mediator in the relationship between Internet addiction and depressive symptoms. The significance of the indirect effect of excessive daytime sleepiness was evaluated using likelihood-based confidence intervals. The analysis was undertaken by utilizing the "metaSEM" package (version 1.3.0; Cheung, 2015) in R (version 4.2.1; R Core Team, 2022).

3. Results

Characteristics of the included studies are summarized in Table B.1 (supplementary material). We followed Cohen's (2013) categorization for the interpretation of effect sizes (0.10 = small, 0.30 = moderate, 0.50 = large).

3.1 Association between Internet addiction and depressive symptoms

The CHE model (working model) yielded a significant and moderate association between Internet addiction and depressive symptoms ($r = 0.324$, $SE = 0.018$, $p < 0.001$, $CI_{95} = 0.288$, 0.360). The estimated heterogeneity was significant ($Q [52] = 1085.727$, $p < 0.001$) and the

estimated variance components were $\tau_{Level3}^2 = 0.012$ (between-study heterogeneity) and $\tau_{Level2}^2 = 0.02$ (within-study heterogeneity). The application of RVE to the working model yielded a similar inference ($r = 0.324$, $SE = 0.018$, $p < 0.001$, $CI_{95} = 0.288, 0.361$).

Sensitivity analysis conducted in [Appendix C \(supplementary material\)](#) demonstrates that the summary effect size remains practically unchanged when we include the study ([Ha and Hwang, 2014](#)) that assessed depressive symptoms with a single question. The result from the Egger's regression test was not significant ($t = -0.826$, $p = 0.478$, $CI_{95} = -5.580, 3.445$), which suggested a symmetrical funnel plot as shown in [Figure C.1 \(supplementary material\)](#). Thus, there was no indication of publication bias. Since the PET estimate was significantly different from zero ($\beta_{0PET} = 0.358$, $SE = 0.051$, $p < 0.01$, $CI_{95} = 0.221, 0.496$), the PEESE estimate ($\beta_{0PEESE} = 0.325$, $SE = 0.023$, $p < 0.001$, $CI_{95} = 0.278, 0.372$) was taken as the true effect size (with an infinite sample size and a standard error of zero). This estimate was almost identical to the derived summary effect size of $r = 0.324$. Moreover, the summary effect size remains unchanged when the degree of correlation between effect size estimates is varied for $\rho = [0, 0.9]$ in increments of 0.1 ([Table C.1 \[supplementary material\]](#)). Thus, the findings are robust to publication bias and to the values of correlation between sampling errors of the effect sizes.

Based on the univariate assessment of moderators ([Table 1](#)), Internet freedom did not moderate the association between Internet addiction and depressive symptoms ($\beta_{Internet\ freedom} = 0.000$, $SE = 0.001$, $p = 0.679$, $CI_{95} = -0.002, 0.001$). Moreover, none of the covariates moderated this association. The lack of the moderating effect of Internet freedom was also evidenced in the multivariate model that incorporated all the predictors simultaneously ([Table 2](#)). Specifically, after controlling for the effects of study quality and the percentage of female participants, the moderating effect of Internet freedom remained insignificant ($F[3, 4.26] = 0.429$, $p = 0.743$). These results are robust to potential outliers ([Table C.2 and Table C.3 \[supplementary material\]](#)).

Variables	Estimate	SE	t	p	CI ₉₅		k ₁ /k ₂
					LB	UB	
β_0 Internet freedom	0.337	0.027	12.332	0.000	0.277	0.398	32/36
β Internet freedom	0.000	0.001	-0.436	0.679	-0.002	0.001	
β_0 Percentage of females	0.386	0.097	4.003	0.015	0.123	0.650	44/53
β Percentage of females	-0.001	0.002	-0.620	0.570	-0.007	0.004	
β_0 Study quality	0.440	0.121	3.652	0.002	0.184	0.697	44/53
β Study quality	-0.061	0.062	-0.980	0.341	-0.191	0.070	

Note(s): LB: lower bound, UB: upper bound; k₁: number of studies, k₂: number of effect sizes; study quality coding: 1: strong quality, 2: moderate quality, 3: weak quality

Source(s): Authors' own work

Table 1.
Moderator analyses
(univariate)

Variables	Estimate	SE	t	p	CI ₉₅		k ₁ /k ₂
					LB	UB	
β_0	0.524	0.230	2.278	0.057	-0.020	1.068	32/36
β_1 Internet freedom	0.000	0.001	-0.135	0.898	-0.002	0.002	
β_2 Percentage of females	-0.001	0.003	-0.245	0.822	-0.010	0.009	
β_3 Study quality	-0.081	0.073	-1.114	0.290	-0.241	0.080	

Note(s): LB: lower bound, UB: upper bound; k₁: number of studies, k₂: number of effect sizes; study quality coding: 1: strong quality, 2: moderate quality, 3: weak quality; test of moderators: $F(3, 4.26) = 0.429$, $p = 0.743$

Source(s): Authors' own work

Table 2.
Moderator analysis
(multivariate)

3.2 Association between Internet addiction and excessive daytime sleepiness

The results from the random-effects model indicated a significant and a small association between Internet addiction and excessive daytime sleepiness ($r = 0.226$, $SE = 0.082$, $p < 0.01$, $CI_{95} = 0.066, 0.386$). Furthermore, the estimated heterogeneity was significant ($Q[3] = 193.451$, $p < 0.001$). The number of included studies ($k = 4$) assessing the relationship between Internet addiction and excessive daytime sleepiness were too few to meaningfully detect publication bias (see for example, [Sterne et al., 2011](#); [Simmonds, 2015](#)). Nonetheless, the non-significant Egger's regression test result suggested that there was no publication bias since there was no indication of an asymmetrical funnel plot ($z = -1.372$, $p = 0.170$). We did not undertake the PET-PEESE procedure as it performs poorly when there are few included studies ([Stanley, 2017](#)).

3.3 Association between excessive daytime sleepiness and depressive symptoms

Based on the random-effects model, there was a significant and moderate association between excessive daytime sleepiness and depressive symptoms ($r = 0.311$, $SE = 0.049$, $p < 0.001$, $CI_{95} = 0.215, 0.407$) and the estimated heterogeneity was significant ($Q[5] = 60.831$, $p < 0.001$). Since there were only 6 studies that assessed the relationship between excessive daytime sleepiness and depressive symptoms, publication bias would not be meaningfully detected. Nonetheless, results from the Egger's regression test indicated the absence of publication bias via a symmetrical funnel plot ($z = -0.607$, $p = 1.859$). Since there were only a few included studies, we did not undertake the PET-PEESE procedure.

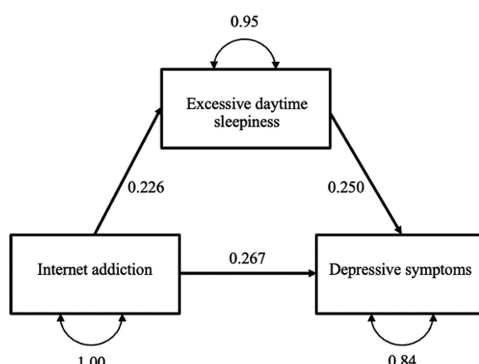
3.4 The mediating role of excessive daytime sleepiness in the relationship between Internet addiction and depressive symptoms

Given that the fitted structural equation model was saturated with zero degrees of freedom, there were no fit indices. As shown by the 95% likelihood-based confidence intervals, the estimated path coefficients from Internet addiction to depressive symptoms (direct effect; $\beta = 0.267$, $CI_{95} = 0.207, 0.320$), Internet addiction to excessive daytime sleepiness ($\beta = 0.226$, $CI_{95} = 0.067, 0.386$) and excessive daytime sleepiness to depressive symptoms ($\beta = 0.250$, $CI_{95} = 0.140, 0.356$) were all statistically significant. The estimated indirect effect was $\beta = 0.057$ ($CI_{95} = 0.019, 0.099$) indicating that 17.48% of the association between Internet addiction and depressive symptoms was mediated through excessive daytime sleepiness. The estimated mediation model is presented in [Figure 1](#).

To demonstrate the robustness of the MASEM results, we additionally undertook the standard TSSEM approach ([Cheung and Chan, 2005](#); [Cheung, 2014, 2015](#)) to examine the mediation model. Since there was one study that reported multiple effect sizes that emerged from non-independent samples, we aggregated the effect size (see for example, [Schutte et al., 2021](#)). In this way, we conform to the assumptions of the TSSEM approach (i.e. one effect size per study). Missing correlations were managed using full information maximum likelihood (FIML) ([Jak and Cheung, 2020](#)) and in the second stage of the analysis, the WLS estimation was utilized to obtain parameter estimates. We report the results in full in [Appendix D](#) (the average correlation matrix is given in [Table D.1](#)) (supplementary material). The path coefficients from the TSSEM approach are almost identical to the ones reported above. Moreover, through this approach, the proportion mediated by excessive daytime sleepiness was 16.98%. Collectively, these results suggest a modest mediating effect of excessive daytime sleepiness which is robust to varying MASEM approaches.

4. Discussion

In this study, we examined the association between Internet addiction and depressive symptoms in adolescents through a meta-analysis. Our examination was a response to



Note(s): Standardised regression coefficients are shown to the nearest three decimal places and residual variances are shown to the nearest two decimal places

Source(s): Authors' own creation

Figure 1.
Meta-analytic
structural equation
model (MASEM)

growing concerns about the mental health implications of Internet addiction as well as a lack of consensus in this literature stream. Our examination yielded three important findings.

First, we found a moderate association between Internet addiction and depressive symptoms. The moderate association was derived from a meta-analytic model that included all available information (effect sizes), while accounting for dependency between effect sizes as well as correlation between sampling errors. We further subjected this result to a battery of robustness checks. Specifically, there was no indication of publication bias, the limit effect size was identical to the derived summary effect size, and the summary effect size remained unchanged when the values of correlation between sampling errors were varied.

The derived summary effect size is strikingly similar to a past meta-analysis (Cai *et al.*, 2023) that also found a moderate association between Internet addiction and depressive symptoms. Nonetheless, this similarity is a consequence of statistical aggregation of effect sizes from varying age ranges. The considerable participant age range in Cai *et al.*'s (2023) meta-analysis permitted a subgroup analysis which suggested a smaller summary effect size for secondary school participants and a relatively greater summary effect size for undergraduate participants. In this way, their derived summary effect size is like ours but only in aggregate. Additionally, our finding is in stark contrast to some of the included studies that found the association to be small (Lee *et al.*, 2018) and large (Van Rooij *et al.*, 2017).

Our second finding suggests that the degree of Internet freedom across countries does not account for this statistical heterogeneity. Our analysis offers a clear-cut conclusion that obstacles to access, limits on content and the like neither dampens nor exacerbates the negative consequences of Internet addiction. This result is quite robust since it holds before and after accounting for study quality and the percentage of female participants. Moreover, the result remains unchanged even after accounting for potential influential outliers. One potential explanation for the lack of the moderating effect of Internet freedom may be that Internet users regularly circumvent Internet restrictions with the aid of virtual private networks, web proxies, and the like (Ververis *et al.*, 2020). Nonetheless, we refrain from making substantial claims about this line of reasoning since we did not hypothesize the moderating role of Internet freedom as *a priori*.

Our third finding indicates that adolescents prone to Internet addiction experience excessive daytime sleepiness which leads to greater depressive symptoms. Furthermore, this result is robust to varying MASEM approaches and strongly supports studies grounded in the displacement hypothesis (Kraut *et al.*, 1998; Nie *et al.*, 2002; Kojima *et al.*, 2021; Li *et al.*, 2017; Cheung and Wong, 2011).

4.1 Theoretical implications

Valkenburg and Peter (2007) suggest that studies that have assessed the relationship between Internet usage and well-being have been met with mixed evidence because research efforts have primarily treated this relationship as a simple stimulus-response process. Conceptualizing a direct linear relationship between Internet usage and well-being inherently ignores the complex mechanisms through which excessive Internet usage might be detrimental for well-being. In this study, we incorporate one such mechanism underlying the Internet usage and well-being relationship by grounding our study in the displacement hypothesis. While several notable studies have done so in the past, the focus has been on quality of friendship or physical activities as mediating variables that explain the displacement effect of Internet usage on well-being. In this way, the mediating variables are assumed to be both, necessary for maintaining well-being and vulnerable to the displacement effect of Internet usage. In this study, we incorporate a new interpretation of the displacement hypothesis by postulating that displacement does not necessarily occur in isolation and therein lies our primary theoretical contribution. Specifically, we offer a fresh perspective by providing empirical support to the notion that self-imposed sleep deprivation attributed to excessive Internet usage perpetuates the displacement of other activities that are deemed beneficial for well-being (Guilleminault and Brooks, 2001; Gandhi *et al.*, 2021). These results additionally align with studies that link excessive day time sleepiness to significant morbidity such as reduced socialization, reduced physical activities and reduced participation in activities of daily living (Gandhi *et al.*, 2021; Ng *et al.*, 2020; Maugeri *et al.*, 2018; Chasens *et al.*, 2007; Reishtein *et al.*, 2006; Holding *et al.*, 2020; Holfeld and Ruthig, 2014). Our findings therefore reconcile conflicting findings within this literature stream by highlighting an alternate mechanism through which Internet addiction may displace activities beneficial for maintaining mental well-being.

Neuman (1988) initially conceptualized the displacement hypothesis such that the detrimental effects of technology are directly proportional to exposure to such technologies. Instead, our results suggest a more nonlinear relationship in the sense that displacement of activities beneficial for well-being may not be proportional to time spent on the Internet (or screen time) since the displacement of one activity may in turn displace other activities. In our case, we reasoned that Internet-induced excessive daytime sleepiness displaces a host of other activities. Additionally, these results may potentially explain why moderate use of technology may not be intrinsically harmful particularly if moderate users do not experience daytime sleepiness and subsequently do not limit their participation in healthy activities. In such instances, moderate use of technology may in fact facilitate technology-driven peer pursuits (i.e. digital Goldilocks hypothesis; Przybylski and Weinstein, 2017).

4.2 Practical implications

Our results unambiguously underscore the importance of promoting sleep hygiene among Internet dependent adolescents to alleviate their depressive symptoms. This can be accomplished through several ways. First, Internet usage through digital devices such as computers and handheld phones should be limited nearer to bedtime. Exposure to blue light emitted from digital devices suppresses the secretion of the hormone melatonin, which in turn disrupts the circadian rhythm and negatively impacts sleep quality (Wood *et al.*, 2013).

Internet dependent adolescents should therefore actively utilize screen filters on their digital devices. Furthermore, most handheld devices offer a “night mode” that limits the amount of blue light emitted from the screen and this should be actively utilized. If either of these options is unavailable, blue light filter glasses may be worn. A recent study has indicated that evening wear of blue light filter glasses can improve overall sleep quality and latency (Hester *et al.*, 2021). Another promising intervention known as mindfulness meditation has been amply documented to improve sleep quality (e.g. Rusch *et al.*, 2019). This practice simply focuses on breathing and creating an awareness of the present moment.

Given that our results also indicate a direct relationship and of moderate strength between Internet addiction and depressive symptoms, a collective effort by parents, educational institutions and counselors is required to understand the motivations underlying adolescents’ excessive Internet usage. Where excessive Internet usage is socially motivated, emphasis should be placed on physical interactions and relationships with people beyond those that are made online, and this may help attenuate Internet addiction (Wang and Wang, 2013). In fact, studies have unambiguously underscored the importance of physical interactions in improving mental health above and beyond technology-mediated communication (e.g. Stieger *et al.*, 2023). Communicating these benefits to adolescents is key since abstinence from time spent on the Internet for social reasons is not automatically replaced with offline socialization (Przybylski *et al.*, 2021). Finally, the finding that Internet addiction leads to depressive symptoms is particularly concerning due to the recent COVID-19 pandemic, which resulted in increased Internet usage, making users susceptible to Internet addiction (Jahan *et al.*, 2021). Resultantly, educational institutes should make every effort where possible to ensure that adolescents participate in face-to-face learning that enables greater interaction with their peers.

4.3 Limitations and directions for future research

The present meta-analysis has several limitations. Considering the inclusion criteria, we did not include studies that measured depressive symptoms using a single-item question. Our rationale for this is grounded in that it is questionable whether single-item questions offer a valid and reliable assessment of depressive symptoms (Skoogh *et al.*, 2010; Allen *et al.*, 2022). Nonetheless, we demonstrated in Appendix C (supplementary material) that inclusion of such studies (Ha and Hwang, 2014) does not change the summary effect size, nor the inferences drawn. Furthermore, we only included studies that measured generalized Internet addiction and we excluded studies that measured other addictions on the Internet, such as excessive social media usage and Internet gaming disorder. Our rationale for this criterion was grounded in that it remains to be seen whether generalized Internet addiction is synonymous to social media addiction, Internet gaming disorder etc. Some researchers suggest that they are not the same and that there are fundamental differences in addictions on the Internet (Pontes and Griffiths, 2014). Considering the moderating factors, none of the included predictors (Internet freedom, study quality, and the percentage of female participants) explained the significant heterogeneity in the association between Internet addiction and depressive symptoms. We strongly recommend future researchers to examine sources of heterogeneity in this literature stream as it would aid in nuancing guiding practices and improving our understanding of the association between Internet addiction and depressive symptoms.

Considering the mediation model, the pooled correlation matrix was derived from a small number of studies that assessed the association between Internet addiction and excessive daytime sleepiness and the association between excessive daytime sleepiness and depressive symptoms. Given this, there is scope to improve the precision of the parameter estimates of the mediation model, one which would be possible as more studies assess these associations.

Our meta-analysis demonstrates a need for this. Finally, we only included cross-sectional studies from which causal claims cannot be drawn. In other words, our findings cannot suggest whether Internet addiction precedes depressive symptoms or the other way around. The empirical and theoretical evidence presented in this study strongly supports a path from Internet addiction to depressive symptoms. In fact, in [Appendix E \(supplementary material\)](#), we purposefully specify an erroneous path from depressive symptoms to Internet addiction via excessive daytime sleepiness, one which is inconsistent with empirical and theoretical evidence presented within this study. Unremarkably, this path leads to a non-significant indirect effect of excessive daytime sleepiness. Thus, while we cannot strictly make causal claims based on the cross-sectional nature of the included studies, the MASEM approach is suggestive of a “potentially” causal path ([Bollen and Pearl, 2013](#)) which future longitudinal studies can assess.

Finally, while we found evidence that Internet addiction contributes to excessive daytime sleepiness and consequently, depressive symptoms, however, we did not explicitly examine activities that are likely to be restricted due to Internet-induced excessive daytime sleepiness. We therefore propose that future studies examine the type of activities that are likely to be restricted and that further contribute to adolescent depression. As we elaborated earlier, reduced socialization, reduced physical activities and reduced participation in activities of daily living are some examples of activities that may be restricted. Nonetheless, it remains to be seen which restricted activity contributes to depressive symptoms the most. Our examination highlighted that the relationship between Internet addiction and adolescent depression is more complex than a simplified stimulus-response process. Thus, a better understanding of the nature of the displaced activities attributed to Internet-induced excessive daytime sleepiness will improve guiding practices in terms of screening and identification of symptoms specific to adolescent Internet addiction (see for example, [Starcevic and Aboujaoude, 2017](#)). Moreover, such an examination would also address a common criticism of the displacement hypothesis, i.e. its “poor fit for predicting what people will do when they forgo digital opportunities” ([Przybylski et al., 2021](#), p. 513). In all likelihood, these forgone digital opportunities would potentially include those activities that are displaced from Internet-induced excessive daytime sleepiness.

5. Conclusion

The present meta-analysis found that Internet addiction moderately contributes to depressive symptoms in adolescents and that the diversity in this literature stream is not explained by variations in Internet freedom across countries. In support of the displacement hypothesis, this study found that Internet addiction contributes to depressive symptoms through excessive daytime sleepiness. As the evidence suggests, excessive daytime sleepiness displaces a host of activities beneficial for maintaining mental health by restricting adolescents’ ability to perform those activities. Given this, our primary theoretical contribution lies in that we incorporate a new interpretation of the displacement hypothesis by postulating that displacement does not necessarily occur in isolation. Collectively, these results underscore the negative consequences of Internet addiction in adolescents. Addressing this issue would involve interventions that promote sleep hygiene and greater offline engagement with peers to alleviate depressive symptoms.

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Further reading

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Appendix

The supplementary material for this article can be found online.

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