Adolescents' technology and face-to-face time use predict objective sleep outcomes

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ABSTRACT

Objectives: The present study examined both within- and between-person associations between adolescents' time use (technology-based activities and face-to-face interactions with friends and family) and sleep behaviors. We also assessed whether age moderated associations between adolescents' time use with friends and family and sleep.
Design: Adolescents wore an actigraph monitor and completed brief evening surveys daily for 3 consecutive days.
Participants: Adolescents ($N = 71$; *mean age* = 14.50 years old, SD = 1.84; 43.7% female) were recruited from 3 public high schools in the Midwest.
Measures: We assessed 8 technology-based activities (eg, texting, working on a computer), as well as time spent engaged in face-to-face interactions with friends and family, via questions on adolescents' evening surveys. Actigraph monitors assessed 3 sleep behaviors: sleep latency, sleep hours, and sleep efficiency.
Results: Hierarchical linear models indicated that texting and working on the computer were associated with shorter sleep, whereas time spent talking on the phone predicted longer sleep. Time spent with friends predicted shorter sleep latencies, while family time predicted longer sleep latencies. Age moderated the association between time spent with friends and sleep efficiency, as well as between family time and sleep efficiency. Specifically, longer time spent interacting with friends was associated with higher sleep efficiency but only among younger adolescents. Furthermore, longer family time was associated with higher sleep efficiency but only for older adolescents.
Conclusion: Findings are discussed in terms of the importance of regulating adolescents' technology use and improving opportunities for face-to-face interactions with friends, particularly for younger adolescents.

Advancements in technology have led to an increase in the availability of mobile devices, such as smartphones, which provide constant opportunities to connect with others via mobile screens.[1] In the United States, over 90% of 13- to 17-year olds report daily online activity and 24% report being constantly connected to some form of technology.[2] Adolescents' technology use may facilitate the accomplishment of developmental tasks by providing opportunities for identity development and social interactions.[3] However, despite these benefits, there is concern over the implications of widespread technology use on adolescent functioning. Specifically, researchers

have proposed 3 important domains of adolescent development that may be implicated in adolescents' technology use: identity, intimacy and sexual development.[4] Another domain of adolescent development that researchers believe may be associated with technology use is sleep.[5] There is increased concern regarding the potential negative impact of technology use on adolescent sleep–wake patterns,[5–7] particularly because of the important developmental changes in sleep that take place during the transition from childhood to adolescence.[8] The present study adds to the available literature by examining whether adolescents' time spent using technology, as compared to face-to-face interactions with friends and family, are associated with 3 objectively measured sleep behaviors. Uniquely, in addition to examining individual differences in adolescents' time use and sleep (ie, between-person associations), we examined whether day-to-day changes in technology use and

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face-to-face interactions were associated with corresponding day-to-day changes in sleep across 3 days (ie, within-person associations).

Adolescence is a sensitive age period for changes in sleep–wake patterns. Adolescents experience a biological shift in circadian timing, which leads to an increased eveningness preference.[9,10] Furthermore, psychosocial factors, such as early class start times, rigorous academic and extracurricular commitments, as well as increased opportunities to engage in late-night activities with friends, contribute to changes in adolescents' sleep behaviors.[11] Although the National Sleep Foundation recommends that 14- to 17-year olds get between 8 and 10 hours of sleep each night,[12] the reality is that many adolescents consistently get below the recommended amount of sleep and subsequently experience significant sleep debt.[5,13] For example, Winsler and colleagues[14] found that adolescents, on average, reported getting 1.5 hours less than the minimal recommended amount of sleep. Similarly, Polos and colleagues[5] found that over 70% of their sample of sixth to twelfth graders reported getting less than 8 hours of sleep on a typical school night. Importantly, adequate sleep plays a critical role across multiple domains of adolescent functioning.[15–19] Therefore, understanding the factors that predict adolescent sleep is an important undertaking.

One proposed contributing factor to the problem of adolescent sleep debt is technology use.[6,7] Among a US sample of adolescents, longer bedtime technology use was associated with shorter sleep duration during the week and poorer sleep quality.[1] Similar findings were reported with a Canadian sample of 10- to 11-year olds, such that the presence of multiple media devices (eg, TV, computer) in the bedroom, as well as the frequency of bedtime technology use, were associated with shorter sleep duration.[20] Notably, the link between technology use and poor sleep has been supported in diverse samples of adolescents from China,[21] Belgium,[22] and Japan.[23]

A few studies, however, have failed to find significant associations between technology use and poor sleep. For example, among a nationally representative sample of adolescents in China, neither the presence of a computer in the home nor the number of different online activities predicted sleep quality.[24] The authors did, however, find that adolescents' use of the internet for "fun" or "catharsis" was linked to poorer sleep, whereas the use of internet for scholastic purposes was linked to better sleep quality.[24] In another study of university students in Brazil, Mesquita and Reimão[25] reported that television viewing in the evening was not associated with perceived sleep quality but evening computer use was associated with an increased likelihood of reporting poor sleep quality. These findings highlight the need to assess multiple forms of technology use, particularly given the myriad of online activities currently available. Thus, in the present study, we specifically assessed a range of technology-based activities to determine the relative associations of various forms of technology use and sleep behaviors. Overall, although some exceptions exist, the evidence to date offers strong support for a link between technology use and poor sleep.[6] In fact, a recent review indicated that 90% of the 67 studies reviewed (published between 1999 and 2014) found evidence for a significant association between technology use and some index of poor sleep.[7]

The majority of past studies have assessed between-person associations, which allow us to determine how variability in technology use *between* individuals relates to average differences in sleep behaviors. An important gap in the literature, however, is determining how day-to-day changes in an individual's technology use are associated with that same individual's sleep from one night to the next (ie, *within-person* associations). Furthermore, in contrast to a between-person design, a within-person design makes it possible to draw inferences about reverse-causal associations due to the temporal precedence of daily technology-use behaviors (assessed during the day) in relation to subsequent sleep (assessed that night). In one recent study, Cespedes and colleagues[26] investigated within-person

associations between television use and sleep duration and found that more time spent watching television was associated with shorter sleep duration. Of note, the repeated assessments were based on annual parental reports of children's sleep and technology use (children were first assessed when they were 6 months up until 7 years old). Additionally, in a daily diary study of adults, using smartphones for work close to bedtime—more than was typical for that individual—was associated with less sleep that night, which, in turn, was associated with increased feelings of depletion the following morning.[27] Therefore, it remains unclear whether day-to-day variations in time spent engaged in various technology-based activities are associated with corresponding *day-to-day* changes in objective sleep outcomes among adolescents.

A second limitation of past research has been an overreliance on subjectively measured sleep behaviors. Furthermore, given the multi-dimensional nature of sleep, it is important to include assessments of multiple sleep behaviors.[28] The current study, therefore, employs objective assessments of 3 sleep behaviors: sleep latency, sleep hours, and sleep efficiency. A third limitation of past studies is the lack of assessment of time spent engaged in face-to-face interactions in addition to time spent engaged in technology-based activities. Given the link between technology-based and face-to-face interpersonal communication, as well as the significant amount of time adolescents spend engaged in face-to-face interactions,[29] it is worthwhile to determine the relative associations of both technology-based and face-to-face interactions in relation to adolescent sleep. Notably, past research has indicated that a critical function of technology-based activities, such as texting and instant messaging, is the maintenance of "offline" or in-person relationships with friends.[30] An important developmental task of adolescence is the establishment and maintenance of close social ties and the development of intimacy through friendships and romantic relationships.[31] Consequently, a major concern within developmental psychology has been the potential for increased time spent engaged with technology to interfere with time spent in face-to-face interactions with friends and thus detract from key developmental tasks of adolescence.[32] For these reasons, it is crucial to assess the relative contribution of adolescents' technology-based activities and face-to-face interactions.

Moreover, although past research has examined whether age moderates the association between technology use and sleep,[5] no studies to date have examined whether age moderates the link between face-to-face interactions and objectively measured sleep behaviors. This is an important question, given that adolescents increasingly spend more time with their peers as they age, as well as the fact that sleep behaviors undergo marked changes from childhood to adolescence.[10,33] The present study addresses this limitation by examining whether age moderates the association between time spent with both friends and family and 3 sleep behaviors.

The purpose of the present 3-day study was to examine both within- and between-person associations between adolescents' time use (technology-based activities and face-to-face interactions) and sleep behaviors. Specifically, we assessed time spent engaged in 8 different technology-based activities (eg, texting, working on the computer, video games, and social media), as well as time spent engaged in face-to-face interactions with friends and family. Additionally, we examined age as a potential moderator of the associations between time spent engaged in face-to-face interactions and sleep, given developmental changes in time spent with family and friends. Three actigraphy-based sleep behaviors were measured: sleep latency, sleep hours, and sleep efficiency. We employed hierarchical linear modeling (HLM) to examine: (1) *within-person associations* to determine whether day-to-day changes in technology-based and face-to-face time use were associated with corresponding day-to-day changes in 3 sleep behaviors; and (2)