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Editorial

An introduction to the special issue on sleep

David Bowie, Ozzy Osbourne and Tupac sang about them: *Changes*. Change is an apt descriptor of adolescence. With the onset of puberty, adolescents rapidly journey through physical changes in height and shape, and through neurological developments that herald cognitive, emotional, and social transitions, developing from the parented children in the back seats of cars to the soon-to-be-adults behind the literal and metaphorical steering wheels. And at the end of the day, they lay themselves down to sleep. This brings us to the focus of this special issue in the *Journal of Adolescence*. Aside from the rapid changes that occur during infancy, adolescence is the second-most dynamic period of development for sleep. Changes in circadian rhythms and sleep homeostatic pressure lie behind the changes seen in the timing of sleep, leading to sleep duration deficits for most adolescents. These deficits have important implications for adolescents' functioning, as documented in this issue and other research.

Although the scientific and popular press have paid more attention to adolescents' sleep in the past decade or so, we locate the emergence of this topic nearly 40 years ago, in the work of a vibrant researcher who had just finished her Ph.D. thesis entitled, "*Determinants of daytime sleepiness: Adolescent development, extended and restricted nocturnal sleep*" (1979). We are very fortunate to begin our special issue with a review by this researcher, Professor Mary Carskadon, who has teamed up with her second generation of pathfinders (Crowley, Wolfson, Tarokh, & Carskadon, 2018). Their review provides an update on Carskadon's "Perfect Storm" model of adolescent sleep, written several years ago (2011). The model centers on maturing bioregulatory processes converging with psychosocial factors to affect sleep. In her original model, Carskadon described developmental changes in sleep/wake homeostatic regulation that coincide with changes in circadian rhythms, favoring greater alertness in the evening, later sleep onset, and resulting in poorly timed and lower duration of sleep. Carskadon's (2011) model also suggested that screen time and social networking, as well as other social pressures, contribute to a late sleep onset. Early school start times meant adolescents' sleep was chronically restricted. The review in our issue updates the "Perfect Storm" model, showing support for an interaction between bioregulatory and psychosocial pressures, and provides contemporary evidence of biological, technological, and societal constraints on adolescents' sleep. This review provides a backdrop for other papers in this issue, which focus on both the timing and duration of adolescents' sleep. From this review and other literature, there is no doubt that many adolescents suffer from deficits in the amount of sleep they get. Moreover, sleep deficits continue during the transition to adulthood (Perlus, O'Brien, Haynie, & Simons-Morton, 2018). In line with Carskadon's ideas, several papers in this issue add to her model by expanding on the precursors and correlates of change in sleep patterns. Some reports focus on the biological underpinnings of changes in sleep, while others focus on behaviors that they theorize coincide with the biological change to create or contribute to the "Perfect Storm".

Where biological processes are concerned, researchers have often referred to sleep changes occurring "at the onset" or "during" puberty. Using longitudinal data, Foley, Ram, Susman, and Weinraub (2018) provide more specific information about the links between pubertal processes and changes in sleep patterns. They showed that the timing and tempo of puberty, measured in terms of the emergence of secondary sex characteristics (e.g., pubic hair), are related to sleep timing, particularly for girls. Their findings not only suggest a link between pubertal changes and reductions in sleep homeostatic pressure, but direct attention to the possibility that adrenarche, the preceding hormonal event occurring around age 6–8 years, plays a causal role in sleep changes during adolescence.

Carskadon's model also featured the effects of screen time on young people's sleep. Two of our studies provide additional insight into this issue. Scott and Woods (2018) show that late-night media use is related to later bedtimes. Interestingly, Mazzer, Bauducco, Linton, and Boersma (2018) concur that time spent using technology is associated with sleep difficulties and provide longitudinal evidence that the associations are bidirectional. Specifically, not only was earlier media use related to increases in sleep problems, but prior sleep difficulties were associated with increased technology use (for girls only). These studies provide support for the psychosocial pressure delaying sleep onset in the Carskadon et al. model, but also suggest the link between bioregulatory pressures and sleep may be bidirectional, at least for girls. Although their data cannot address which comes first, it is possible that when bioregulatory pressure delays sleep, adolescents turn to their technological devices. If so, the very tool some girls turn to cope with their late sleep onset may harbor one of sleep's rivals.

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Other studies in our issue suggest additional precursors and mechanisms affecting sleep. Several of these involve social contexts and related emotions, cognitions, and behaviors. Scott and Woods (2018) focused on a relatively new emotional-cognitive construct—fear of missing out. Their results support the idea that what might be anxiety-provoking cognitions are related to later bedtimes in two possible ways: through adolescents turning to social media to alleviate their fears and through increasing cognitive arousal. This paper adds a motivational aspect to Carskadon's model, proposing a theoretical explanation for why adolescents turn to their phones, pads, and computers late at night. In another study, Jose and Vierling (2018) provide temporal evidence that adolescents who report being cyber-victimized tend to ruminate and, in turn, experience inadequate sleep. Like Carskadon's media use, stressful events and poor coping strategies may be pressures that contribute to poor sleep. However, victimization and rumination may be more ideopathic than the trends described by Carskadon. Nonetheless, this study also suggests ways in which technology and social media could affect sleep. These studies also point to the importance of examining cognitive and emotional responses to social events that may compound developmental shifts in sleep cycles. In another paper examining theoretical precursors, Perlus et al. (2018) found that poor sleep hygiene in high school predicted poor sleep one year after high school. This continuity suggests that adolescence is an important period for prevention-intervention efforts aimed at minimizing the harms of sleeplessness as individuals enter their third decade of life.

Another set of papers in this issue address the consequences of the sleep problems during adolescence. Several strengthen the evidence that biological processes affected by sleep are related to poor cognitive and academic performance. Among these, Reynolds, Short, and Gradisar's meta-analysis (2018) showing that sleep spindles are linked to cognitive performance. These brain waves may be one of the mechanisms through which sleep deficits could detract from cognitive and academic performance. In addition, their study provides evidence for the hypothesis that sleep affects cognition through consolidation mechanisms. Other authors (Lau, McAteer, Leung, Tucker, & Li, 2018 discussed below) provided similar evidence.

Other papers focused on emotional, physical, and psychological outcomes. Norrell-Clarke and Hagquist (2018) provide historical documentation that sleep duration is linked to psychological and somatic complaints (e.g., body aches, sadness, and irritability). Although their data were from several cohorts, their study suggests that results found elsewhere (e.g., Roberts, Roberts, & Duong, 2009) are not a new phenomenon. If anything, these results suggest that secular declines in sleep among adolescents are worrisome.

Using two weeks of intensive repeated measures data, Chue, Gunthert, Kim, Alfano, and Ruggiero (2018) showed that the relations between stressful events and affect was moderated by sleep quantity, but not quality. The greater the sleep deficit, the more adolescents reported negative affect spilling over to the following morning. By comparison, when adolescents had more sleep, their positive morning affect reverted to pre-stress levels. This study had several interesting features, including the use of technology (wireless activity trackers) and short-term intervals of data collection, as well as focusing on sleep as a moderating, rather than a causal variable.

Our issue also includes papers suggesting remedies, including daytime naps (Lau et al., 2018) and later school start times (Chan, Poon, Leung, Lau, & Lau, 2018). These papers showed that meaningful increases (30–45 minutes) in sleep duration improve adolescents' cognitive functioning and academic performance. Where clinical levels of sleep problems are concerned, Richardson et al. (2018) indicated that light therapy and morning activity can reverse some of the effects suggested by the Carskadon et al. review (i.e., earlier sleep onset, greater sleep duration). As a result, short-term memory performance improved as did the speed of information processing. Combined, these quasi-experimental and longitudinal studies provide evidence-based solutions for prevention-intervention for sleep-deprived adolescents. As the later school start time and naps were trialed in residential schools, we caution that implementing these strategies elsewhere requires careful consideration of the accommodations others (e.g., parents, teachers and their families) would need to make.

1. Future directions

The papers in this issue ranged in design and analytical methods, from quasi-experimental to correlational designs, using cross-sectional, longitudinal, and cohort data, featuring very simple to complex analytical models, including meta-analysis. Each study adds to the greater picture of adolescent sleep issues, filling in missing pieces and providing inspiration for future research. Although there are many avenues researchers could take, we focus on five issues here: (1) considering other dimensions of sleep, (2) clarifying patterns of change, (3) tackling bidirectionality, (4) broadening the scope of sleep change correlates, and (5) looking for sex and gender differences.

First, we note that the papers in this issue focus almost exclusively on the timing and duration of sleep (Chue et al. being the notable exception), with some additional focus on pre-sleep conditions and difficulty falling asleep. With evidence of secular trends pointing to decreasing sleep quality during adolescence (Kronholm et al., 2015), we believe it is important to consider how this quality is related to the constructs examined in the papers of this issue. Undoubtedly, night-time awakenings and other symptoms of insomnia detract from the amount of sleep adolescents obtain. Such indicators of poor sleep quality are not necessarily captured by estimating sleep duration from adolescents' self-reports of the times they go to sleep and wake up, nor from objective measures of sleep (e.g., actigraphy). It would be interesting to see comparisons of sleep quality and quantity as outcomes and predictors of other constructs. Like many other aspects of functioning, it could be that these two dimensions of sleep interact to affect individual functioning more negatively than either does alone.

Second, with strong evidence of age-related changes in sleep patterns, combined with individual differences in sleep changes related to pubertal maturation, it is time to differentiate ontological development of sleep issues from ideopathic problems. Many of the studies in this issue and in the broader literature neglect maturational differences in sleep patterns. Either analyses are collapsed across adolescents of different ages or limited to single cohorts. While collapsing may be necessary when sample sizes are limited, the