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Adolescent Sleep and the Impact of Technology Use Before Sleep on Daytime Function

Ann E. E. Johansson, BSN, RN¹, Maria A. Petrisko, BSN, RN¹, and Eileen R. Chasens, PhD, RN¹

Ann E. E. Johansson: anj43@pitt.edu; Maria A. Petrisko: mpetrisko3@gmail.com; Eileen R. Chasens: chasense@pitt.edu

¹University of Pittsburgh School of Nursing, 415 Victoria Building, 3500 Victoria Street, Pittsburgh, PA 15261, United States

Abstract

Purpose—Technology has become pervasive in our culture, particularly among adolescents. The purpose of this study is to examine associations between use of technology before sleep and daytime function in adolescents.

Design and Methods—This study is a secondary analysis of respondents aged 13 to 21 years (N= 259) from the 2011 National Sleep Foundation’s Sleep in America Poll. The survey included questions on demographics, sleep habits, and use of technology in the hour before bedtime. Daytime sleepiness was assessed with the Epworth Sleepiness Scale (ESS). Student’s *t*-tests, Mann-Whitney U, and Fischer’s exact tests were performed to detect differences in demographics, sleep duration, and technology use in the total sample, and between respondents with “adequate” compared to “inadequate” sleep. Correlations were calculated between technology frequency and daytime function.

Results—Adolescents had mean sleep duration of 7.3±1.3 hours. Almost all respondents (97%) used some form of technology before sleep. Increased technology use and the frequency of being awoken in the night by a cell phone were significantly associated with waking too early, waking unrefreshed, and daytime sleepiness ($p<0.05$). Adolescents who reported “inadequate” sleep had shorter sleep duration, greater frequency of technology use before bedtime, feeling unrefreshed on waking, and greater daytime sleepiness than those reporting “adequate” sleep (all p -values <0.05).

Conclusion—Technology use before sleep by adolescents had negative consequences on nighttime sleep and on daytime function.

Practice Implications—Healthcare professionals who interact with adolescents should encourage technology to be curtailed before bedtime and for adolescents to value obtaining adequate sleep.

Corresponding Author: Ann E. E. Johansson, 415 Victoria Building, 3500 Victoria Street, Pittsburgh, PA 15261, Phone: 317-373-6202, anj43@pitt.edu.

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Keywords

adolescence; technology; daytime sleepiness

Introduction

Adolescents require approximately 8 to 10 hours of sleep per night, but many studies suggest that they obtain much less (Arora, Broglia, Thomas, & Taheri, 2014; Eaton et al., 2010; McKnight-Eily et al., 2011; Wolfson & Johnson, 2014). In the past two decades, the number of adolescents reporting more than 7 hours of sleep per night and the percentage reporting adequate sleep per night has steadily decreased (Iglowstein, Jenni, Molinari, & Largo, 2003; Keyes, Maslowsky, Hamilton, & Schulenberg, 2015). Studies comparing self-reported adolescent sleep duration with objectively measured sleep duration (i.e. actigraphy) suggest that self-reports frequently overestimate actual sleep duration. This suggests that sleep loss in adolescents may be even greater than many reports indicate (Fossum, Nordnes, Storemark, Bjorvatn, & Pallesen, 2014).

The decline in adolescent sleep quantity and quality is multifactorial, and is influenced by biological, environmental, societal, and behavioral factors (Bartel, Gradisar, & Williamson, 2015; Calamaro, Mason, & Ratcliffe, 2009; Pallesen et al., 2011). With the marked increase in technology during the 21st century, screen time has become an integral part of life for today's adolescent, who values the connectivity offered by technology and relies on digital interfaces to interact with the world. It is not surprising that technology devices such as computers, cell phones, video games, tablets, and e-readers are being used by adolescents prior to bedtime. In a study of adolescents recruited from a pediatric office (N=100, ages 12–18-years), the majority (66%) had a television in their bedroom, almost 30% had a computer, and 90% had a cell phone (Calamaro et al., 2009). In another, 76% of adolescents reported using a cell phone before sleep for playing games, surfing the internet, and texting (Fossum et al., 2014). Adolescents have been found to simultaneously engage with an average of four technology devices after 9:00 pm. This usage was positively correlated with severity of insomnia symptoms (Pilcher, Ginter, & Sadowsky, 1997). Engaging in a higher number of technologies, such as computer games and television, at bedtime has been associated with less nighttime sleep and more daytime sleepiness (Eggermont & Van Den Bulck, 2006).

Adolescent sleep quantity is also greatly influenced by biological processes. The two-process model of sleep regulation describes sleep propensity (the likelihood of falling asleep) as the interaction between a homeostatic process (sleep need) and a circadian process (sleep-wake rhythm or “biological clock”). The homeostatic process increases sleep propensity while awake, and decreases it during sleep; while the circadian process is independent of sleep/wake state. The intersection between homeostatic and circadian processes determines wake-time (Borbély, Daan, Wirz-Justice, & Deboer, 2016). The rate at which homeostatic sleep propensity accumulates varies between prepubertal and postpubertal stages, and is correlated with secondary sex development (Carskadon et al., 1979). There is evidence to suggest that older adolescents accumulate sleep propensity more

slowly, resulting in a later bedtime and a later preferred wake-time (Jenni, Achermann, & Carskadon, 2005; Wolfson & Carskadon, 1998). This presents a challenge on weekdays, when early school times prevent adolescents from obtaining the sleep that they need. Other elements of the contemporary adolescent lifestyle, such as stress, anxiety, social pursuits, and caffeine use may interact with biological processes to further exacerbate sleep irregularities within this age group (Astill, Van der Heijden, Van Ijzendoorn, & Van Someren, 2012; Calamaro, Yang, Ratcliffe, & Chasens, 2012).

Insufficient sleep in adolescence has been linked to negative physiological consequences, including an increased risk of obesity and metabolic dysfunction; and psychological and behavioral consequences, such as an increased risk of anxiety, depression, mood disturbances, suicidal ideation, and drug and alcohol use (Chen, Beydoun, & Wang, 2008; Gupta, Mueller, Chan, & Meininger, 2002; Lowry et al., 2012). Adolescents with poor sleep quality and decreased sleep duration report a lower sense of well-being and a decreased quality of life (Pilcher et al., 1997). Chronic sleep loss in adolescents has also been linked to poor judgment, lack of motivation, and inattention (Gradisar, Terrill, Johnston, & Douglas, 2008; Owens, 2014; Wolfson & Carskadon, 1998), and consequently with an increase in risk-taking behaviors, such as drinking and driving, smoking, and delinquency (Catrett & Gaultney, 2009; O'Brien & Mindell, 2005). Driving while drowsy is a frequent complaint among older adolescents, and daytime sleepiness in this demographic has been associated with an increased rate of motor vehicle accidents (Martiniuk et al., 2013; Owens, 2014; Pizza et al., 2010).

It remains unclear if technology use before bed affects daytime function (wake-time, refreshment, and daytime sleepiness). Previous studies of adolescent sleep and technology use have used small sample sizes and narrow age ranges within adolescence. The purpose of this study is to describe sleep in adolescents, examine associations between use of technology in the hour before sleep and daytime function, and to compare technology use in adolescents who report adequate sleep with those who report inadequate sleep.

Methods

Parent Study and Sampling Methodology

The National Sleep Foundation's 2011 Sleep in America Poll (National Sleep Foundation, 2011) was a cross-sectional survey of a nationally-representative, random sample of 1,508 Americans aged 13–64 years. The survey, which was developed by a panel of sleep experts, examined the use of a range of technologies in the bedroom.

Data were collected using telephone (n=750) and internet (n=758) surveys. Telephone surveys were performed by random digit dialing (SDR Consulting Inc., Atlanta, USA) based on population sampling quotas by United States region. The telephone survey took approximately 18 minutes to complete. Internet surveys were distributed to members of an e-rewards panel. Maximum sampling error was ± 2.5 percentage points (95% CI) for the total sample. Incentives were not offered by the National Sleep Foundation (NSF) for completion of the survey.

De-identified data and details about study methodology were acquired from the NSF. The subsample studied was composed of 255 adolescents, aged 13–21 years from across the United States. Because one of the aims of this study is to describe sleep through adolescence, the subsample was divided into younger adolescents (13–17-years, $n=140$) and older adolescents (18–21-years, $n=118$). Maximum sampling error for the subsample was ± 7.5 percentage points (95% CI). The institutional review board at the University of Pittsburgh approved this secondary analysis of the NSF data.

Survey instrument

The survey instrument was designed by content experts in sleep across the life-span. Questions fit into four categories: demographics, sleep habits, sleep quality, and technology use in the hour before bed and during the night. Demographic items included age, gender, race, ethnicity, and school and/or employment status. Sleep habits included bedtime, wake-time, sleep duration, and naps on week days and weekend days. Bedtimes were recoded as “early” (7:00–8:59pm), “standard” (9:00–10:59pm), “late” (11:00pm–1:59am), and “very late” (2:00–5:00am). Rise times were recoded as “early” (before 6:00am), “standard” (6:00–8:59am), “late” (9:00–11:59am), and “very late” (after 12:00pm). Subjective sleep quality and daytime function for a two-week period were assessed using a 4-item Likert-type scale —1 (never) to 4 (every night or almost every night)—reporting how often in the last two weeks the participant responded they “had difficulty falling asleep,” “woke during the night,” “woke too early,” and “woke unrefreshed.” Other variables included time needed to fall asleep, difficulty falling asleep, number and length of awakenings during the night, and if adolescents believe their weekday routine allows for “adequate” or “inadequate” sleep duration.

The survey included questions from the Epworth Sleepiness Scale (ESS), a validated 8-item self-report questionnaire about subjective sleep propensity in different situations (Johns, 1991). In initial studies, Johns (1992) found the ESS has strong test-retest reliability ($\rho=0.82$) and internal consistency ($\alpha=0.88$), and in factor analysis consists of only one factor. It has since been validated and used in a wide range of populations, and translated in several different languages. Items are scored from 0 (“no chance of dozing”) to 3 (“high chance of dozing”), and summed for a total score. Scores above 10 indicate excess daytime sleepiness. Finally, questions pertaining to technology use in the hour before going to bed or during the night focused on if and how frequently per week ten technologies were used. Follow-up questions included where and what type of TV shows were watched; the type and content of video games played (violence, crude humor, etc.), and what functions were used on the cell phone and computer (surf internet, watch videos, etc.).

Statistical Analysis

Analyses focused on weekday sleep habits. Descriptive statistical analyses were used to characterize respondents, weekday sleep habits, and frequency of technology use. Descriptive statistics were analyzed as means and standard deviations for continuous variables, and frequencies and percentages for categorical variables. The decision to use parametric versus non-parametric tests was based on level of measurement. Comparisons were made using independent Student’s *t* tests for continuous variables, Mann-Whitney U

for ordinal variables, and Fisher's exact test for categorical variables. Relationships between dependent and independent variables were investigated using Pearson's r for continuous variables, and Spearman's rho for ordinal variables. Frequencies coded using the 4-item Likert-type scale were collapsed to make a binary variable ("never/rarely," "a few nights a week/almost every night/every night"). Group comparisons were made between adolescents who reported that their weekday routine allows for "adequate" or "inadequate" sleep duration. Only significant correlations >0.15 are reported. The level of significance was set at $p<0.05$. Statistical analyses were performed on IBM SPSS Version 23.0.

Results

Sample

The characteristics of the full sample ($N=255$), and of the subsamples of respondents categorized by subjective report of "adequate" or "inadequate sleep," are shown in Table 1. The sample of adolescents was well-balanced by gender with the number of males and females almost equal (males: 52%). The majority of respondents were non-Hispanic Caucasian, with a smaller proportion of African-Americans (12%) and Hispanics (7%) than expected based on 2010 census data (United States Census Bureau, 2010). Most respondents completed the survey via the internet (70%). The majority of adolescents were full-time students (82%); more than 10% were both in school and working. There were no significant differences between those reporting "adequate" or "inadequate" sleep in terms of age or race. Respondents reporting "inadequate" sleep were significantly more likely to be female, both work and go to school, and complete the survey via the web.

Sleep characteristics

Description of Sleep Patterns—Sleep characteristics are described in Table 2. Mean sleep duration for this sample was 7.3 ± 1.3 hours. The average sleep duration decreased steadily from 8.3 hours at age 13 to 6.7 hours at age 19, except for a spike at age 17 to 7.4 hours. After age 19, sleep duration began increasing again to 7.6 hours at age 21. No significant difference existed in sleep patterns between males and females, except that females were significantly more likely to report "woke unrefreshed" ($p<0.05$). There was no significant difference in sleep duration between students and participants who worked. During the week, one-half of respondents went to bed "late" (11:00pm and 2:00am), and 9% percent went to bed "very late" (after 2:00am). These bedtimes do not leave enough time for sleep when the majority (58%) of respondents woke before 7:00 am. Significantly more older adolescents went to bed after 11pm and woke after 9am than younger adolescents ($p<0.01$). Although about half of respondents were able to fall asleep in less than fifteen minutes, almost a third (30%) required more than half an hour. About 60% of adolescents report they rarely or never "woke during the night", and those who did reported an average of 28.2 ± 32.4 minutes awake. Only a quarter of respondents reported they frequently "woke too early." Approximately 67% of the sample responded that they "woke unrefreshed" a few days a week to every day. Approximately 20% of respondents had excess daytime sleepiness as indicated by an ESS score >10 (mean ESS score= 7.5 ± 4.2). A modest negative correlation ($r= -0.16$, $p<0.05$) exists between age and ESS score showing that as adolescents age, daytime sleepiness tends to decrease. As many as 40% of adolescents who drive admit to

driving while drowsy at least once in the past month, and 18% report driving while drowsy at least once per week. Age was significantly positively correlated with frequency of the response “woke too early” ($r=0.15$, $p<0.05$).

“Adequate” and “Inadequate” Sleep Duration—Significant differences exist between adolescents reporting “adequate” and “inadequate” sleep in weekday sleep duration, bedtime, daytime sleepiness, and frequency of reporting “woke unrefreshed.” Those reporting “inadequate” sleep had almost one hour less sleep than those reporting “adequate” sleep ($p<0.01$). The most common bedtime of respondents reporting “adequate” sleep was between 10:00 to 10:59pm, while the most common bedtime of respondents reporting “inadequate” sleep was between 11:00–11:59pm ($p<0.05$). Adolescents reporting “inadequate” sleep were significantly more likely to also report “woke unrefreshed” a few nights to every night per week ($p<0.01$), and significantly more likely to report daytime sleepiness. Almost twice as many reporting “inadequate” sleep had scores above the cutoff of ESS >10 (34% vs. 19%, $p<0.01$). Significantly more adolescents reporting “inadequate” sleep reported driving drowsy once or more per week than those reporting “adequate” sleep ($p<0.01$).

Technology Use at Bedtime

Use of technology at bedtime was virtually universal with 97% of respondents using some type of technology in the hour before sleep. The most commonly used devices were the cell phone (74%), computer (69%), music device (iPod, mp3 player) (61%), and television (55%). Almost half (47%) of adolescents used 3 or 4 technologies before bed; as many as 10% of the sample used six or more devices. Males were significantly more likely than females to play video/computer games, while females were significantly more likely than males to text, talk on the phone, use social media, receive or send personal email, and use a word processor (all $p<0.05$). The only difference in technology use between younger and older adolescents was greater use of music devices by younger adolescents ($p<0.05$). Individuals reporting “inadequate” sleep were significantly more likely than those reporting “adequate” sleep to text, use the internet and social media, and use a word processor before bed ($p<0.05$).

The number and type of devices used in the hour before sleep was associated with daytime function. The number of devices used, television, digital music players, and the phone were significantly associated with the response “woke too early” ($\rho=0.16$ to 0.23 , $p<0.05$). Use of the internet was significantly associated with frequency of the response, “woke feeling unrefreshed” ($\rho=0.16$, $p<0.05$). Use of the internet, social media, games with crude humor or violence, personal email, videos on mobile devices, instant messaging or Skype, and the phone were significantly associated with excess daytime sleepiness ($\rho=0.15$ to 0.31 , $p<0.05$). The frequency of being awoken by a cell phone was significantly associated with all three outcomes ($\rho=0.18$ to 0.23 , $p<0.05$).

Discussion

Adequate sleep is vital for optimal physical and mental health, growth, learning, memory, and peak academic performance in children and adolescents. However, data from the NSF’s

2011 Sleep in America Poll revealed that adolescents aged 13–21-years are reporting average sleep duration an hour or more below that recommended by the American Academy of Pediatrics (American Academy of Pediatrics, 2014) and the NSF (Hirshkowitz et al., 2015). This is exacerbated by many participants' late bedtime, and having to wake early for work or school. Consequently, almost half report not getting "adequate" sleep. Although there was no significant difference in sleep duration between younger and older age groups, older adolescents tended to go to bed later and wake up later, consistent with changes in sleep patterns as adolescents age (Wolfson & Carskadon, 1998). As expected, the group reporting "inadequate" sleep reported significantly later bedtime, shorter mean sleep duration, and a greater frequency of the response "woke unrefreshed" than those reporting "adequate" sleep. Although the mean ESS score for both groups was below the cutoff for problematic excess daytime sleepiness (ESS>10), almost twice as many of those reporting "inadequate" sleep had scores above the cutoff. In addition, it is concerning that significantly more adolescents reporting "inadequate" sleep also reported driving drowsy once or more per week.

Data from the poll also show that, for almost all adolescents, some form of technology was present and used in the bedroom in the hour before sleep. In more than half the sample, participants used three or more forms of technology within the hour before bed, which is noteworthy as the number of devices used was significantly associated with the response, "woke too early." Consistent with other reports (Hysing et al., 2015; Van den Bulck, 2007), phones were the most frequently used technology before bed, especially among females and those reporting "inadequate" sleep; and use before bed was correlated with the response "woke too early" and excess daytime sleepiness. In the present study, about a third of adolescents reported their cell phone waking them a few times per week to every night. This was similar to a report of 23% of high school students being woken at least once a week by their phones (Van Den Bulck, 2003). Being awoken by a phone results in shorter total sleep duration, and lighter sleep as the body is continually aroused (Munezawa et al., 2011; Van Den Bulck, 2003; Van den Bulck, 2007). Also consistent with findings from the present study are those showing that males are more likely to play video games before bed (Hysing et al., 2015), and that prolonged play of video games is associated with shorter and less efficient sleep (King et al., 2013). Surprisingly, the strength of association between video games and next-day function was stronger for games with crude humor than those with violence and blood.

Several mechanisms have been proposed to explain how technology use affects sleep. One mechanism is that light, especially short wave-length light, emitted from screens may alter circadian processes such as melatonin release (Cajochen et al., 2011; Chellappa et al., 2011; van der Lely et al., 2015). The findings of the present study may lend support to this theory, as all the technology devices found to affect daytime function, except for traditional phones, have light-emitting screens. A second mechanism proposed is that cognitive and physiologic arousal from stimulating technologies such as video games, computers, or cell phones may make it difficult for the body to "wind-down". Several studies found that TV, video games, cell phones, music, computers, and social media were significantly related to difficulty falling asleep because of stimulation (Arora et al., 2014; Weaver, Gradisar, Dohnt, Lovato, &

Douglas, 2010), and the present study found associations between these devices and excess daytime sleepiness, and the responses “woke too early” and “woke unrefreshed.”

The present study explored the survey question inquiring if participants’ daytime routine allowed for “adequate” or “inadequate” sleep. “Inadequate” sleep may truly be because of daytime routine, because of demographic characteristics, or it may be because of sleep habits and/or technology use. Because the parent study did not ask for details about participants’ daily routine, it is difficult to comment on how those reporting “adequate” and “inadequate” sleep differed in their daytime duties. Although those reporting “inadequate” sleep blame it on their daily routine, this group may be underestimating the influence of technology use on sleep habits and daytime function. For instance, individuals reporting “inadequate” sleep were significantly more likely to also report frequent use of cognitively stimulating technologies—the internet, social media, and texting, in the hour before sleep. “Inadequate” sleep appears to be a problem across adolescence, as there was no significant difference in the number reporting “inadequate” sleep between younger and older adolescents.

Implications for nursing

The United States Office of Disease Prevention and Health Promotion in their Healthy People 2020 initiative has set as a goal sufficient sleep duration in high-school aged adolescents (Office of Disease Prevention and Health Promotion, 2015). Nurses are in the ideal position to address this goal by educating adolescents, their families, and the broader community about good sleep hygiene. Nurses in primary care or outpatient clinics should inquire about an adolescent’s sleep habits, sleep quality, and technology use before bed. In addition, nurses should take the opportunity to counsel families in healthy sleep habits. School nurses are well-placed to instruct adolescents in proper sleep hygiene. Previous studies found that elementary-school aged and younger children are also using technology before bed. Therefore, school nurses should begin sleep hygiene education as early as possible. Wing et al. (2015) have shown that an in-school sleep education program is feasible, and has a positive effect in reducing two consequences of insufficient sleep, hyperactivity and conduct problems.

Limitations—This study had several factors that may limit generalizing the results. First, data was drawn from a larger cross-sectional study of sleep and technology use which limited analyses to the questions asked by the original researchers. The sample of adolescents 13–21-years-old was fairly small, and correlations between technology and daytime function were modest. No objective evaluation of sleep or technology use was obtained. Thus, data may have been subject to recall bias, or under- or over-estimation of sleep or technology use. In addition, it is possible that adolescents with difficulty sleeping may use more technology while they are awake. This may inflate significant correlations between technology use and daytime function. Because of the broad age range of the parent study, the ESS originally developed for adults was used for all participants. Some items, (ex. “...in a car, while stopped for a few minutes in the traffic”) may not have applied to all adolescents.

Conclusion—Inadequate sleep is widespread among adolescents, and technology has been implicated as a potential factor in adolescent sleep deprivation. The use of technology, and the number of devices used in the hour before sleep were significantly associated with problems in daytime function, increased frequency of waking too early, waking unrefreshed, and daytime sleepiness. This study suggests that adolescents need to be helped in developing good sleep habits, and that one way to improve sleep in this age group is to encourage disengagement from electronic devices during the hour before bed.

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Highlights

- Adolescents get less sleep than recommended by medical experts.
- Technology use before sleep is associated with daytime consequences.
- Nurses need to provide education and community advocacy regarding adolescent sleep.

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Table 1

Comparison of Sample Characteristics in Adolescents reporting Adequate and Inadequate Sleep

	Total sample ^a	Adequate sleep ^b	Inadequate sleep ^c	<i>p</i>
Mean age in years (SD)	17.1 (<0.01)	17.1 (2.6)	17.1 (2.5)	ns
13–17 yrs	136 (53.3)	76 (51.0)	60 (56.7)	ns
18–21 yrs	119 (46.3)	73 (49.9)	46 (43.4)	
Gender ^d				
Male	133 (52.2)	93 (62.4)	40 (37.7)	<0.01
Female	122 (47.8)	56 (37.6)	66 (62.3)	
Race ^d				
Caucasian	171 (68.1)	103 (70.5)	68 (64.2)	ns
African American	21 (8.6)	15 (10.3)	6 (5.7)	
Asian	33 (12.8)	13 (8.9)	20 (18.9)	
Other	9 (3.5)	17 (16.0)	25 (23.6)	
Hispanic ^d	30 (11.8)	18 (12.2)	12 (11.3)	ns
Occupation ^d				
Student	210 (82.4)	124 (83.2)	86 (81.1)	<0.01
Employed	14 (5.4)	13 (8.7)	1 (0.9)	
Both	28 (10.8)	11 (7.4)	17 (16.0)	
Neither	3 (1.2)	1 (0.7)	2 (1.9)	
Survey method ^d				
Phone	77 (30.2)	58 (38.9)	19 (17.9)	<0.01
Web	178 (69.8)	91 (61.1)	87 (82.1)	

^aN=255;^bn=149;^cn=106^dData are n (%) unless otherwise indicated

Table 2

Comparison of Daytime Function between Adolescents reporting Adequate and Inadequate Sleep

	Total Sample ^a	Adequate Sleep ^b	Inadequate Sleep ^c	<i>p</i>
Mean sleep duration: (SD)	7.3 (1.3)	7.7 (1.4)	6.8 (1.4)	<0.01
Excess daytime sleepiness ^{d, f}	64 (25.1)	28 (18.8)	36 (34.0)	<0.01
Woke too early ^{e, f}	64 (25.5)	34 (23.0)	30 (29.1)	ns
Woke unrefreshed ^{e, f}	171 (67.1)	85 (57.0)	86 (81.1)	<0.01

^aN=255;

^bn=149;

^cn=106;

^dESS >10;

^e“A few nights per week/every or almost every night;”

^fData are n (%) unless otherwise indicated

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