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Risk Behaviors and Negative Health Outcomes for Adolescents With Late Bedtimes

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Abstract

Late bedtimes in adolescence may be a serious risk factor for later poor health and functional outcomes. The current study sought to extend existing cross sectional data by examining whether late bedtimes in adolescence predicts poor outcomes in young adulthood. Data from wave 2 (1996) and wave 3 (2001-2002) of the nationally representative sample of US youth (National Longitudinal Study of Adolescent Health) was used to examine the longitudinal relationship between late bedtime, and several risk behaviors and negative health outcomes following 3,843 adolescents into young adulthood. At Wave 2 the mean age was 16 with 52.1% female. At wave 3 the mean age was 21.8. In cross sectional analyses, late bedtime was associated with 1.5 to over 3 times greater odds of involvement in risk behaviors and negative health outcomes, including emotional distress, suicidality, criminal and violent activity, and use of cigarettes, alcohol and illicit drugs. In longitudinal analyses, late bedtime assessed at wave 2 predicted a number of serious health outcomes at wave 3, with late bedtime in adolescence associated with around 1.5 greater odds of involvement in health jeopardizing behaviors such as criminal activity, alcohol abuse, cigarette use, illicit drug use and emotional distress in young adulthood. There was also a dose effect, such that the later the bedtime in adolescence, the greater the risk of involvement in risk behaviors in young adulthood. This research suggests that late bedtime in adolescence predicts multiple serious risk behaviors and health outcomes in young adulthood.

Keywords

late bedtime; eveningness; adolescent health; risk behaviors; health outcomes

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Authors' Contributions

EM conceived of the research question, performed the statistical analysis, interpretation of the data and drafted the manuscript. AH conceived of the research question, interpretation of the data and drafted the manuscript. Both authors read and approved the final manuscript.

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Introduction

Adolescence is a period of rapid and constant physical, cognitive, emotional and social development (Steinberg, 2010). Concurrently, the prevalence of various forms of psychopathology rise dramatically during adolescence (Costello, Mustillo, Erkanli, Keeler, & Angold, 2003; Wong, Brower, & Zucker, 2011), and often lead to chronic psychiatric problems in adulthood (Stringaris & Goodman, 2009). Increased alcohol and drug use are also common and predict risk for dependence when initiated during adolescence (Chen, Storr, & Anthony, 2009). Hence, an important public health priority is to identify the contributors to these adverse outcomes, a goal with profound implications for improving prevention and early treatment interventions.

Late bedtimes may be an important contributor to the escalating vulnerability for health related risk behaviors among youth. Late bedtimes are prevalent among adolescents with recent estimates indicating that more than 25% of teenagers go to sleep later than 12:00am during the school year (Asarnow, McGlinchey & Harvey, 2013). There are both biological and psychosocial factors that promote late bedtimes in adolescence. Biological influences include the onset of puberty triggering a change toward a distinct evening preference among approximately 40% of teens coinciding with a slower build-up of sleep pressure (Roenneberg et al., 2004; Tonetti, Fabbri, & Natale, 2008). This pubertal change peaks at 15 years old staying stable to 20 years old with a lasting influence throughout early adulthood (Randler, 2011). Teens who exhibit an evening circadian tendency follow a delayed sleep schedule, increasing activity later in the day and both going to sleep and getting up later, compared to their non-evening counterparts (Horne & Östberg, 1976; Adan et al., 2012). Throughout these important developmental years, the result is often sleep deprivation among teens who have to get up at a fixed time for school (Asarnow, McGlinchey, & Harvey, 2013; Hansen, Janssen, Schiff, Zee, & Dubocovich, 2005, Dahl & Lewin, 2002), a problem further compounded by psychosocial factors, including less parental control over bedtimes (Carskadon, 1990), increased access to stimulating social activities (e.g., interactions with peers, including instant messaging, text messaging, and cell phones) (Kauderer & Randler, 2012; Pea et al., 2012) and increased use of alcohol and other substances that contribute to sleep disruption (Wong, Brower, Fitzgerald, & Zucker, 2004). These biopsychosocial and behavioral forces converge to constrain time available for sleep, resulting in insufficient sleep defined as obtaining less than 8 hours of sleep at night (Asarnow et al., 2013; Roberts, Roberts, & Duong, 2009; Wolfson & Carskadon, 1998). Compounding this vicious cycle, most attempts to “catch-up” on sleep occur during weekends on a phase-delayed schedule. This is a critical problem because the circadian system adapts more easily to phase delays; endogenous rhythms are able to re-set quickly to later bed and wake times and have more difficulty accommodating phase advances (*earlier* sleep schedules). Thus, many youth are struggling with the burdens of late circadian timing, sleep deprivation *and* the consequences of repeated circadian shifts (Carskadon, 1990).

The documented adverse consequences of delayed sleep among adolescents are wide ranging. An evening circadian tendency is associated with psychopathology, including more depression and anxiety symptoms (Chelminski, Ferraro, Petros, & Plaud, 1999; Gaspar-Barba et al., 2009; Gau et al., 2007; Kitamura et al., 2010), greater emotional instability

(Gau et al., 2007; Tankova, Adan, & Buela-Casal, 1994; Tonetti, Fabbri, & Natale, 2009), and suicidality (Gau et al., 2007). Associations have also been observed between late bedtime and aggressive and antisocial behavior, and rule-breaking (Goldstein, Hahn, Hasher, Wiprzycka, & Zelazo, 2007; Lange & Randler, 2011; Susman et al., 2007). Poor self-regulation (Negriff, Dorn, Pabst, & Susman, 2011) may partly explain the reports that adolescents with an evening circadian tendency are more likely to use alcohol and nicotine at higher amounts (Adan, 1994; Gau et al., 2007; Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002; Randler, 2008), particularly as adolescents progress through puberty (Pieters, Van Der Vorst, Burk, Wiers, & Engels, 2010). A greater tendency for impulsivity may partially explain some of these findings (Adan, Natale, Caci, & Prat, 2010). Despite occasional non-replications (Giampietro & Cavallera, 2007; Roberts & Kyllonen, 1999), the combined literature suggests a link between late bedtime and risk behaviors. However, most all the research in this area is cross-sectional and thus requires prospective studies as a logical next step. Hence, the current study sought to extend knowledge by examining whether a propensity toward going to bed late in adolescence predicts the risk behaviors and negative health outcomes that last into young adulthood.

Although there has been minimal research examining the longitudinal relationship between late bedtime in adolescence and later adverse consequences, there are several longitudinal studies examining the relationship between sleep duration and sleep quality in adolescence and later risk and problem behavior (Fredriksen et al., 2004; Gregory and O'Connor, 2002; Meijer et al., 2010; Paavonen et al., 2003; Roberts et al., 2008; Roberts et al., 2009). Fredriksen and colleagues (2004) report that, over time, less sleep was associated with heightened levels of depressive symptoms and decreased self-esteem among adolescents. Similarly, even sleep problems in children as young as 4 years old predicts later emotional and behavioral problems in mid-adolescence (Gregory & O'Connor, 2002). Meijer and colleagues (2010) report differences between adolescent males and females in the relationship between sleep and problem behavior over time. It appears that, for boys, shorter time in bed in interaction with lower sleep quality contribute to aggressive behavior as well as internalizing problem behavior, while, in girls, shorter time in bed was associated with a faster increase in anxious/depressed behavior. Similarly, Paavonen and colleagues (2003) report that persistent sleep problems from ages 8-12 years resulted in increased odds of having psychiatric problems at age 12. In a series of studies, Roberts and colleagues (2008, 2009) report that chronic sleep problems and short sleep duration defined as 6 hours or less in adolescence leads to increased risk of health problems, interpersonal problems, psychological problems, poor grades and drug use one year later. There are two recent studies that included both sleep duration and bedtime in adolescence as predictors of later adverse outcomes. Peach and Gaultney (2013) report that late bedtime directly predicts later involvement in delinquent behavior and Asarnow and colleagues (2013) report that late bedtime predicts poor school performance and internalizing symptoms. The longitudinal research in adolescence makes a clear link between poor and short sleep and later poor health outcomes and risky behaviors. However, there is a dearth of research on the impact of bedtime on later outcomes. Hence the current study sought to extend knowledge by examining the effect of sleeping at the recommended time as opposed to the recommended amount in adolescence.

A large sample of adolescents was used for these analyses to examine the impact of late bedtime. This is a sample of adolescents who report having a late bedtime, but do not necessarily have an “evening-type” chronotype. The use of the gold standard measures of circadian/sleep functioning were not used in this large survey study. Instead summer time bedtime was used. Summer time bedtime has been shown as a good proxy for other sleep and health related outcomes (Asarnow et al., 2013; Peach & Gaultney, 2013). Reported bedtime in an unrestricted schedule has been previously used as an index of chronotype (Roennberg, Wirz-Justice, & Merrow, 2003) and using a 1:00 a.m. bedtime as the cutoff in adolescents, as in the current analysis, is a conservative estimate for late bedtime in teens (Giannotti et al., 2002). Moreover, summer time bedtime was chosen rather than school year bedtime, given that school year bedtime is constrained by more outside environmental influences and may not as closely reflect the adolescent’s preference (Gradisar, Gardner, & Dohnt, 2011). The ADD Health Database includes many variables to measure negative health outcomes, however, given the current evidence from cross-sectional research and longitudinal research on the long term impact of short sleep duration, the current study focused on emotional distress, suicidality, criminal activity, violent activity, cigarette use, alcohol abuse, and illicit drug use. There is a dearth of longitudinal evidence and yet the existing data suggests these are important topics.

Hypotheses

The current study sought to replicate and extend the existing cross sectional data showing risk behaviors and negative health outcomes associated with late bedtime in adolescence. Data from the National Longitudinal Study of Adolescent Health (ADD Health) was used to examine two hypotheses. First, extending previous cross-sectional reports (Gau et al., 2007), we hypothesize that having a late bedtime will be associated with concurrent risk behaviors and negative health outcomes in adolescence and in young adulthood. This hypothesis is based on existing literature examining associations between late circadian timing and many health jeopardizing behaviors in adolescents (e.g., Gau et al., 2007, Lange & Randler, 2011). Second, we hypothesize that there is a temporal relationship between late bedtime in adolescence and risk behaviors and negative health outcomes in young adulthood such that late bedtimes will *predict* the occurrence of later risk behaviors and negative health outcomes. Furthermore, there will be a dose effect, such that the later the bedtime in adolescence, the greater the risk for engagement in health jeopardizing behaviors in young adulthood. This second set of hypotheses are based on longitudinal research indicating a link between poor sleep in adolescence and later adverse outcomes (e.g., Fredricksen et al., 2004; Roberts et al., 2008) and recent work indicating that later bedtime in adolescence is associated with poor outcomes in young adulthood (Peach & Gaultney, 2013; Asarnow et al., 2013).

Methods

Participants and Procedure

Data were analyzed from the public use version of waves 2 (1996) and 3 (2001–2002) of the National Longitudinal Study of Adolescent Health (ADD Health), a nationally representative sample of youth in grades 7 through 12 in the United States. During wave 1

(1995) of the study, a sample of 20,745 students from 134 US schools was initially interviewed in their homes. Wave 2 included 88.2% of all eligible wave 1 participants and 77.4% of all eligible wave 1 interviewees were again re-interviewed approximately 6 years later for wave 3. Wave 3 interviewees were between 18 to 26 years old. Wave 1 did not include different questions about sleep onset time for restricted schedules (e.g., school days) versus unrestricted schedules (e.g., weekends or summer). Therefore, wave 1 was not used in the current analysis. Survey procedures are described elsewhere (Resnick et al., 1997). At each wave, the in-home interviews included questions about sociodemographic characteristics, health-related behaviors and beliefs, and health status. For more sensitive parts of the interviews, participants were asked to listen to questions through earphones and respond directly on laptop computers, reducing the potential for interviewer or parent influences on the responses. In an effort to prohibit destructive disclosure of the participants' identities, and to maintain confidentiality, extensive precautions were taken (Udry, Li, & Hendrickson-Smith, 2003). In addition, data from the ADD Health study has been released in two sections; the restricted-use data set includes the whole sample and confidential information on participants, and the public-use data is half of the total sample of participants (Resnick et al., 1997; Udry et al., 2003). The public use version of the data includes 4,834 respondents at wave 2 and 4,882 at wave 3. Sampling weights were used in the current analysis so results remain generalizable to the US population. Only participants with data at waves 2 and 3 and the appropriate sampling weights were used in the current analyses. Adolescents and parents, or legal guardians, were asked to give written informed assent or consent for participant inclusion in the study. The institutional review board at the University of North Carolina approved all protocols instituted in this study.

Measures

Demographic variables—Demographic characteristics assessed at wave 2 included self-reported age, gender, race/ethnicity and welfare status. Age is a continuous variable; race/ethnicity is a categorical variable with white as the reference which is compared to African-American, Hispanic, Asian/Pacific Islander and Native American; and welfare status is a dummy coded variable defined by at least one parent receiving welfare versus neither parent receiving welfare (see Borowsky, Ireland, & Resnick, 2009).

Bedtime variables—Both waves 1 and 2 did not include questions on wake up time. Furthermore, wave 1 did not include different questions about sleep onset time for restricted schedules (e.g., school days) versus unrestricted schedules (e.g., weekends or summer). Therefore, wave 1 was not used in the current analysis.

Wave 2 bedtime variables: Adolescents with a late bedtime were defined as the top tertile of responses to the wave 2 question, "During the summer, what time do you usually go to bed on week nights?". Responses ranged from 6:00 p.m. to 5:30 a.m., with the top tertile cutoff as 1:00 a.m. or later. Bedtime at wave 2 was also coded to look at the dose effect of later bedtimes on a continuous scale and was rank ordered from 1 through 6 (i.e., 6 p.m.–7:59 p.m. = 1), such that higher scores indicated later bedtimes. Reported bedtimes falling outside the 6 p.m. to 6 a.m. window (4.5% of summer bedtimes) were coded as "other."

Wave 3 bedtime variables: At wave 3, young adults were questioned about both bedtime and waketime. Therefore, both late bedtime and late midsleep were approximated in the wave 3 sample. Midsleep has been used extensively in previous research as a proxy for chronotype (e.g., Roenneberg, Wirz-Justice, & Merrow, 2003) and is reported as the best phase anchor point for melatonin onset (Terman, Terman, Lo, & Cooper, 2001). The wave 3 questions were, “On days you don’t have to get up at a certain time, what time do you usually get up?” and “On those days, what time do you usually go to sleep the night or day before?” Wave 3 midsleep time was highly correlated with bed time (r = .94) and the top tertile of bed time was defined as 2:00 a.m. or later. Midsleep was defined by calculating the midpoint between bedtime and wake time. Given the strong correlation between bed time and midsleep in wave 3, the wave 2 question from an unrestricted schedule (summertime) may be considered a good proxy for defining chronotype in wave 2 adolescents. Moreover, there is reason to believe that bed time in an unrestricted schedule is a good proxy for chronotype among adolescents (Giannotti et al., 2002). However, we remain conservative in our interpretation of chronotype and recognize that this is a sample of adolescents who report having a late bedtime, but do not necessarily have an “evening-type” chronotype.

Risk behaviors and negative health outcome variables—The wave 2 and 3 risk behaviors and negative health outcomes, derived in previous factor analysis research (Borowsky et al., 2009; Resnick et al., 1997; Sieving et al., 2001) were emotional distress, suicidality, criminal activity, violent activity, cigarette use, alcohol abuse, and illicit drug use. These specific health outcomes were chosen given cross-sectional evidence indicating the relationship between these factors and late bedtime. Furthermore, validity of these items in the ADD Health database have been established previously (Borowsky et al., 2009) and the questions used to determine these outcomes were identically worded at both wave 2 and wave 3, providing further stability.

Emotional distress: Emotional distress was defined by reporting feeling sad, feeling depressed, feeling bothered by things that do not normally bother you and not being able to shake the blues for a lot of the time over the past week and crying more than once a week over the past year. All items were rated on a likert scale from 0-3, where a rating of 2 or more on any item indicated moderate levels of distress. Participants who endorsed moderate levels of distress on 2 or more of the emotional distress variables were categorized as distressed (*0 = not distressed, 1 = distressed*).

Suicidality: Suicidality was defined as indicating any suicidal thoughts or attempts in the past year (*0 = no suicidal thoughts, 1 = suicidal thoughts*).

Criminal activity: Criminal activity was defined as indicating a positive response to having ever stole something, damaged property, sold drugs or broke into someone’s property in the past year (*0 = no criminal activity, 1 = criminal activity*).

Violent activity: Violent activity was defined as indicating a positive response to having ever taken part in a physical fight that required you or someone else to need treatment by a doctor or nurse, ever threatening to or pulling a knife or gun on someone or shot or stabbed someone in the past year (*0 = no violent behavior, 1 = violent behavior*).

Cigarette use: Cigarette use was defined as indicating ever smoking cigarettes regularly – that is, at least one cigarette every day for 30 days (*0 = non-smoker, 1 = smoker).*

Alcohol abuse: Alcohol abuse was defined as indicating being very drunk more than once a week in the past year (*0 = no alcohol abuse, 1 = alcohol abuse).*

Illicit drug use: Illicit drug use was defined as indicating a positive response to ever having used marijuana, cocaine, inhalants, heroine, or other illegal drugs (*0 = no drug use, 1 = drug use)*.

Controls—Delinquency and many of the other negative health outcomes included in the current analyses have been found to be associated with a number of variables that necessitate their inclusion as control variables into any analysis of risk behavior and, in this case, variables are included as controls that relate to both sleep and risk behaviors (e.g., Lemola, Schwarz, & Siffert, A., 2012). Although not the focal point of the study, previous research suggests an effect of parental attachment and delinquent peers on the outcomes of interest. For this study, age, gender, race, receipt of public assistance, parental attachment, and delinquent peers are included as controls (Gault-Sherman, 2012). All control variables were measured using the data from wave 2.

Parental attachment: Adolescents were asked how close they feel to their mom (1 = not at all to 5 = very much) and how much they think she cares about them (1 = not at all to 5 = very much). Adolescents were then asked to what extent they agreed or disagreed with the following: most of the time, your mom is warm and loving toward you (1 = strongly agree to 5 = strongly disagree); you are satisfied with the way you and your mom communicate with each other (1 = strongly agree to 5 = strongly disagree). The same questions were asked about the father. The scores were recoded so that a high score indicated higher parental attachment. If the adolescent did not have a father present, the section answering the questions for the father was skipped and then the parental attachment measured the mean of reported attachment to the mother only.

Delinquent peers: The measure of peer delinquency used in this study is a count of the number of delinquent peers based on three questions. Youth were asked how many of their three best friends smoke at least one cigarette a day, drink alcohol at least once per month, and/or use marijuana at least once per month. The scale ranges from zero (none of three best friends are delinquent) to three (all three best friends are delinquent).

Statistical Analysis Plan

As mentioned previously, sample weights were used in all analyses; therefore, results are considered generalizable to the US population. Procedures for developing sample weights are described elsewhere (Tourangeau & Shin, 1999). All analyses compared adolescents with a late bedtime (defined above) to the remainder of the sample. Cross-sectional bivariate associations of adolescents with a late bedtime and demographic characteristics were examined at wave 2 using χ^2 tests. Cross-sectional bivariate associations were used to assess the impact of late bedtime on concurrent risk behaviors and negative health outcomes in

adolescents and young adults at waves 2 and 3. Multivariate analyses using the longitudinal data assessed the impact of reported late bedtime at wave 2 on health risk behaviors at wave 3. The same analyses were used to examine the dose effect of later bedtime. A final analysis entered the parental attachment and delinquent peers variables into the models. For all longitudinal analyses, we only analyzed respondents with data from both waves 2 and 3, leaving a final sample of N=3,843 for the longitudinal analyses. Participants who were not included in the analyses because of missing data, did not differ from the rest of the sample on any of the outcome variables of interest. We used STATA 12, Survey tabulate for bivariate analyses and Survey logistic regression for multivariate analyses, because both can control for the cluster sampling design of the ADD Health data (Harris, Gordon-Larsen, Chantala, & Udry, 2006; STATA Statistical Software, Version 12).

Results

Participants

At Wave 2 the mean age of all participants was 16, 52.1% female and race breakdown was 58.9% white, 24.1% African American, 7.8% Hispanic/Latino, 4.7% Asian, 3.6% Native American. At wave 3 the mean age was 21.8. At wave 2, 35.1% (n = 1699 of 4834) of the adolescent respondents reported going to bed at 1:00 a.m. or later in the summer. Participants with a late bedtime differed from the participants with an earlier bedtime on age, gender and ethnic breakdown, with participants with a late bedtime being slightly older, a greater percentage of earlier bedtime participants being female, and a greater percentage of African American participants with late bedtime. There were no other racial/ethnic differences in bedtime. Bedtime did not vary by receipt of public assistance. Participants with a late bedtime had lower parental attachment scores and a higher count of delinquent peers (Table 1).

Cross-sectional Analyses

Late bedtime was associated with involvement in risk behaviors and negative health outcomes at waves 2 and 3 (Table 2). At both of these time points, late bedtime was cross-sectionally associated with all of the outcomes of interest including emotional distress, suicidality, criminal activity, violent activity, cigarette use, alcohol abuse and illicit drug use relative to the respondents who reported an earlier bedtime. At wave 3, the same pattern of results remained significant for all outcome variables when late mid-sleep was entered as the independent variable. Engagement in problem behavior based on percentages revealed that for all participants, emotional distress, suicidality, criminal activity and violent activity decreased from wave 2 to wave 3, but cigarette use, alcohol abuse and illicit drug use increased from wave 2 to 3 (Table 2).

Effect of control variables—There was a significant effect of gender such that females experienced increased odds of wave 2 suicidality and wave 2 and wave 3 emotional distress, decreased odds of wave 2 and 3 criminal activity, violent activity, alcohol abuse, and decreased odds of wave 3 illicit drug use. There was a significant effect of older age on odds of wave 2 cigarette use, wave 2 and wave 3 emotional distress and criminal activity, and wave 3 suicidality and violent activity. There was a significant effect of ethnicity/race on

odds of wave 2 criminal activity, wave 2 and wave 3 cigarette use, emotional distress, criminal activity, and violent activity, and wave 3 alcohol abuse and illicit drug use. There was a significant effect of receipt of public assistance on odds of wave 2 and wave 3 suicidality, emotional distress, and violent activity, and wave 3 cigarette use.

Longitudinal Analyses

Effect of late bedtime—To assess the relationship between late bedtime at wave 2 and involvement in risk behaviors and negative health outcomes at wave 3, multivariate analyses were conducted on waves 2 and 3 longitudinal data. Controlling for demographic factors and the matching risk behavior/health outcome at wave 2 as covariates in the model, late bedtime at wave 2 predicted emotional distress, criminal activity, alcohol abuse, cigarette use and illicit drug use, at wave 3. There was a trend for significance for violent activity and no effect on suicidality (Table 3).

Dose effect of late bedtime—The impact of late bedtime on later risk behaviors and negative health outcomes was also assessed through the use of the wave 2 rank ordered bedtime variable in order to look at possible dose effects of a later and later bedtime. Controlling for demographic factors and the matching risk behavior/health outcome at wave 2 as covariates in the model, a later bedtime at wave 2 predicted increased odds of engaging in criminal activity, alcohol abuse, cigarette use and illicit drug use and having emotional distress at wave 3. There was a trend for significance for suicidalilty ($p = 0.06$). There was no dose effect of later bedtime at wave 2 for engagement in violent activity at wave 3.

Effect of control variables—There was a significant effect of gender such that females experienced increased odds of wave 3 emotional distress, and decreased odds of wave 3 criminal activity, violent activity, alcohol abuse, cigarette use and illicit drug use. There was a significant effect of older age on odds of wave 3 violent activity, emotional distress, suicidality, illicit drug use, and criminal activity. There was a significant effect of ethnicity/race on odds of wave 3 illicit drug use, alcohol abuse, and cigarette use. There was a significant effect of receipt of public assistance on odds of wave 3 emotional distress.

All patterns of late bedtime at wave 2 predicting later involvement in risky behaviors/negative outcomes at wave 3 remained significant when the measure of parental attachment and peer delinquency were entered into the longitudinal models with the exception of alcohol abuse moving to a trend for significance ($p = 0.09$). Wave 2 lower parental attachment was a significant predictor of wave 3 illicit drug use, suicidality, and emotional distress. Having more wave 2 delinquent peers was a significant predictor of wave 3 criminal activity, violent activity, alcohol abuse, cigarette use, and illicit drug use.

Discussion

In this national sample of US adolescents, 1 in 3 report going to bed later than 1:00 a.m. during the summer. For adolescents with late bedtime, there was also increased odds of being involved in a range of concerning behaviors including criminal and violent activity, cigarette, alcohol and drug use, and emotional distress with suicidal thinking. These concurrent associations are consistent with previous cross-sectional research (Gau et al.,

2007). Perhaps most importantly, our longitudinal analyses indicated that late bedtime in adolescence predicts many of the same risk behaviors and negative health outcomes in young adulthood, including young adult criminal activity, cigarette, alcohol and drug use, and emotional distress. Furthermore, the current analyses demonstrated that, the later the bedtime in adolescence, the greater the risk of adverse behavioral outcomes in young adulthood. This is one of the first studies to demonstrate a temporal link between late bedtime in adolescence and adverse outcomes in young adulthood. It is consistent with recent reports that late bedtime is a risk factor for later poor outcomes (Peach & Gaultney, 2013; Asarnow et al., 2013). This study highlights the importance of considering the timing of sleep when discussing adolescent risk factors for later adverse emotional and behavioral outcomes.

The first hypothesis tested was that having a late bedtime would be associated with concurrent risk behaviors and negative health outcomes in adolescence and in young adulthood. This hypothesis was fully supported, extending previous cross-sectional research (Gau et al., 2007; Goldstein et al., 2007; Lange & Randler, 2011). We found that late bedtime was a predictor of emotional distress, suicidality, criminal activity, violent activity, cigarette use, alcohol abuse and illicit drug use. Given the range of alarming outcomes, it appears that late bedtime is a risk factor that is involved in both internalizing- and externalizing-type behaviors. It may be that late bedtime exacerbates the vulnerabilities that children already have toward psychological impairment (Tankova et al., 1994). It is important to consider the possible external factors that may be playing a role in the link between late bedtime and involvement in health jeopardizing behaviors. For example, it may be that adolescents in wave 2 with earlier bedtimes also work during summer or are more healthy, both being factors that may play a protective role against delinquent behavior or emotional distress. The same might apply to young adults at wave 3. These will be important factors to consider in future research on the impact of late bedtime on concurrent risk behaviors. However, given the current results and previous cross-sectional research, late bedtime may be an important target in intervention and prevention efforts for all adolescents, given its association with a range of negative outcomes.

The second hypothesis posited that there would be a temporal relationship between late bedtime in adolescence and risk behaviors and negative health outcomes in young adulthood such that, late bedtimes will *predict* the occurrence of later risk behaviors and negative health outcomes. Furthermore, it was hypothesized there would be a dose effect, such that, the later the bedtime in adolescence, the greater the risk for engagement in health jeopardizing behaviors in young adulthood. In support of this hypothesis, late bedtime in adolescence predicted emotional distress, criminal activity, and use of substances including cigarettes, alcohol and drugs in young adulthood even after controlling for the presence of these behaviors concurrently in adolescence. Moreover, the dose effect of later bedtime in adolescence led to greater odds of engaging in criminal activity, alcohol abuse, cigarette use and illicit drug use and having emotional distress as a young adult. Together these findings highlight that late bedtime is an important contributor to vicious cycles of escalating vulnerability and increased risk among youth (Carskadon, 1990; Carskadon, Acebo, & Jenni, 2004). There are several possible explanations for the observed relationship to be

considered. First, a recent report by Meldrum and colleagues (2013) found a strong relationship between concurrent sleep deprivation and delinquency, which was further mediated by low self-control. Moreover, later bedtimes have also been associated with sensation-seeking and poor impulse control, thereby leading to more delinquent behavior in both adolescents and adults (Peach & Gaultney, 2013). It may be that, over time, later bedtimes and thus poor sleep lead to a steady decrease in self-control while also increasing the need for novel sensation-seeking. Second, in animal models, a desynchronized circadian rhythm contributes to the onset of multiple behavioral abnormalities and mood regulation difficulties that can be partially explained by molecular imaging of disturbed brain activity (for review, see McClung, 2013). Related to this evidence, insufficient sleep contributes to emotion dysregulation in humans (Cartwright, Luten, Young, Mercer, & Bears, 1998; Perlis & Nielsen, 1993), involving the loss of top-down regulatory control usually exerted by the medial-prefrontal cortex (mPFC) on the amygdala (Yoo, Gujar, Hu, Jolesz, & Walker, 2007). This is likely to have particularly profound effects on adolescents given the active changes in structure and function occurring in the brain throughout adolescence (Giedd, 2004; Giedd et al., 1999). Importantly, the brain regions undergoing the greatest changes in adolescence are the same prefrontal and inter-related limbic regions that display the greatest sensitivity to insufficient sleep (Drummond et al., 2000; Killgore, 2010; Yoo et al., 2007). Hence, the asynchronous brain development, the resulting dysregulation of emotion and cognitive dysfunction, exacerbated by repeated circadian shifts and sleep deprivation, seem likely to be important contributors to the rise in morbidity among adolescents with late bedtimes. The current results suggest that late bedtime should be monitored and modified during these important developmental years.

The current results are concerning given how prevalent late bedtime appears to be. However, it is important to note that most adolescents are quite resilient and are not adversely affected by late bedtime on the outcomes measured in this study. There are also adolescents with early bedtimes who show problem behavior, although to a lesser degree. The current analyses examined other factors, including the effects of gender, age, race/ethnicity, welfare status, parental attachment and peer delinquency as they are already known to be associated with problem behaviors (Gault-Sherman, 2012). Late bedtime continued to be a predictor of later adverse outcomes even when these other factors were included as predictors. However, we cannot exclude the possibility that there may be several variables that are important to consider in future analyses that may affect the results, either as risk factors or protective factors.

We note that the results of the present analysis should be interpreted within the confines of several limitations. First, the ADD Health questions used to determine a proxy for an evening circadian tendency were phrased in a vague manner as they were not designed for this purpose and this is not the typical way to measure circadian chronotype. However, they serve as worthy proxies because reported bedtime and midpoint of sleep in an unrestricted schedule has been previously used as an index of chronotype (Roennberg, Wirz-Justice, & Merrow, 2003) and using a 1:00 a.m. bedtime as the cutoff in adolescents is a conservative estimate for late bedtime in teens (Giannotti et al., 2002). Moreover, even if the current findings are not a result of circadian chronotype and are rather a function of a reported bedtime, then the public health implications remain significant, especially given that one

third of the adolescents in this nationally representative sample reported going to bed later than 1:00 a.m. Second, all of the data are based on self-report. However, evidence suggests that adolescents are largely accurate and reliable using self-report measures (Winters, Stinchfield, Henly, & Schwartz, 1990). Third, as is the case with nationally representative databases, each of the outcomes examined are rough proxies for the constructs of interest (i.e., all are dichotomous presence/absence variables). For example, “emotional distress” is a rough proxy for depression and does not fully capture the nuance of anxious and/or depressive symptomatology or associated impairment. Similar issues are present with the other outcomes included in the current analysis. Fourth, some of the variables of interest were assessed by one item (e.g., alcohol use, cigarette use) thus creating greater risk of measurement error and restricting the range of outcome scores. Future replication of this work in other samples and in experimental work will help to understand the full effects of late bedtime on later problem behaviors. Finally, this was a cohort analysis and therefore risk for later outcomes was not analyzed purely as a function of age or stage of development. Future studies should follow individuals over each year in adolescence to model the risks associated with late bedtime as a function of age.

Conclusion

This study examined the long term behavioral and health consequences of late bedtime in a nationally representative sample of US adolescents. In addition, the data supports the hypothesis that there is a temporal relationship, with late bedtime predicting serious risk behaviors and negative health outcomes among US youth. Taken together, the results emphasize that late bedtime is an important contributor to vicious cycles of escalating vulnerability and increased risk among youth. Given the significant relationship between adolescent late bedtime and serious risk behaviors and health outcomes, those who work with teenagers, including primary care physicians, teachers, coaches, and social service providers, must undertake the task of monitoring and intervening with this common behavior in order to reduce adolescent morbidity and mortality. While the basic biological shift toward an evening circadian preference during puberty is likely to be difficult to modify, the psychosocial and behavioral contributors *can* be modified. For example, at the level of public health, more and more middle and high schools are adopting later school start times, given the known advantages when school start is moved from 8:00am to 8:30am (Owens, Belon & Moss, 2010). Moreover, modifying some of the individual psychosocial and behavioral contributors such as late night screen time will eliminate key factors that exacerbate the biological shift. Therefore, future research should develop interventions aimed at promoting healthy biological rhythms and sleep in adolescents so that health outcomes might improve.

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Table 1

Demographic and Selected Characteristics at Wave 2 (1996)

	Late Bedtime (*n* = 1699)	Earlier Bedtime (*n* = 3135)	Statistical difference values
Mean age in years (SD)	16.4 (1.5)	15.8 (1.6)	$t = 11.17$, $p < .001$
Gender			$\chi^2(1) = 5.35$, $p = .021$
Male	852 (50.1)	1463 (46.7)	
Female	847 (49.9)	1672 (53.3)	
Race/Ethnicity (%)			$\chi^2(4) = 35.31$, $p < .001$
White	723 (42.6)	1575 (50.2)	
African American (%)	370 (21.8)	510 (16.3)	$p < .001$
Hispanic	110 (6.5)	203 (6.5)	$p = .502$
Asian/Pacific Islander	49 (2.9)	126 (4.0)	$p = .412$
Native American	64 (3.8)	110 (3.5)	$p = .414$
Parent receives public assistance (%)			$\chi^2(1) = 2.63$, $p = .105$
Yes	167 (9.8)	268 (8.5)	
No	1401 (82.5)	2661 (84.9)	
Parental attachment score (SD)	4.2 (0.6)	4.3 (0.6)	$t = 8.23$, $p < .001$
Peer delinquency count (SD)	1.8 (1.1)	1.2 (1.2)	$t = 16.24$, $p < .001$

Table 2

Cross-sectional ORs of Risky Behaviors and Outcomes Among Adolescents at Wave 2 and Young Adults at Wave 3 With Late Bedtimes Compared to Those With Earlier Bedtimes – Bivariate Analyses

	Wave 2 (1996)			Wave 3 (2001)		
	Late Bedtime (N = 1699), *n* (%)	**Earlier Bedtime (N = 3135), *n* (%)**	**OR(95% CI)**	**Late Bedtime (N = 1900), *n* (%)**	**Earlier Bedtime (N = 2982), *n* (%)**	**OR(95% CI)**
Emotional Distress	549 (32.3)	696 (22.2)	1.76 (1.47 – 2.10)*	466 (24.5)	610 (20.5)	1.33 (1.11 – 1.60)†
Suicidality	233 (13.8)	290 (9.3)	1.63 (1.50 – 2.05)*	173 (9.1)	130 (4.4)	1.48 (1.15 - 1.92)†
Criminal Activity	593 (35.2)	718 (23.0)	1.89 (1.59 – 2.25)*	509 (26.8)	386 (12.9)	1.94 (1.61 – 2.35)*
Violent Activity	340 (20.1)	341 (10.9)	1.96 (1.57 – 2.44)*	271 (14.3)	242 (8.1)	1.43 (1.11 – 1.83)†
Cigarette Use	560 (33.0)	425 (13.6)	3.04 (2.51 – 3.68)*	870 (45.8)	1078 (36.2)	1.63 (1.39 – 1.90)*
Alcohol Abuse	197 (11.6)	121 (3.9)	3.13 (2.28 – 4.28)*	318 (16.7)	153 (5.1)	3.24 (2.44 – 4.31)*
Illicit Drug Use	688 (40.8)	577 (18.5)	2.71 (2.27 – 3.22)*	1105 (58.2)	1141 (38.3)	2.14 (1.83 – 2.50)*

† $p < .01$.

* $p < .001$.

Table 3

Late Bedtime at Wave 2 (1996) as a Predictor of Risk Behaviors and Negative Health Outcomes at Wave 3 (2002) – Multivariate Analyses

Late Bedtime *predicts* negative outcomes (N = 3843)		
	OR(95% CI)	***p***
Emotional Distress	1.23 (1.02 – 1.49)	.033
Suicidality	1.24 (0.95 – 1.62)	.107
Criminal Activity	1.33 (1.09 – 1.63)	.005
Violent Activity	1.25 (0.97 – 1.62)	.087
Cigarette Use	1.21 (1.01 – 1.46)	.041
Alcohol Abuse	1.31 (1.01 – 1.68)	.038
Illicit Drug Use	1.61 (1.36 – 1.91)	<.001