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EMPIRICAL RESEARCH

Sleepless in Fairfax: The Difference One More Hour of Sleep Can Make for Teen Hopelessness, Suicidal Ideation, and Substance Use

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Abstract Insufficient sleep is a risk factor for depression, suicidality, and substance use, yet little is known about gender, ethnic, and community-level differences in sleep and its associated outcomes, especially during adolescence. Further, much of the prior work has compared groups of teens getting plenty as opposed to insufficient amounts of sleep rather than examine sleep hours continuously. The present study examined adolescent weekday self-reported sleep duration and its links with hopelessness, suicidality, and substance use in a suburban community with very early high school start times. We utilized a large ($N = 27{,}939$, 51.2 % female) and ethnically diverse sample of adolescents from the 2009 Fairfax County (Virginia) Youth Survey, an anonymous, self-report, population-level survey administered to all 8th, 10th and 12th grade students in public schools in the county. High-school students reported an average 6.5 h of sleep per school night, with 20 % obtaining ≤5 h, and only 3 % reporting the recommended 9 h/night. Females and minority youth obtained even less sleep on average, and the reduction in sleep in the transition from middle school to high school was more pronounced for females and for Asian students. Hierarchical, multivariate, logistic regression analyses, controlling for background variables, indicated that just 1 h less of weekday sleep was associated with significantly greater odds of feeling hopeless, seriously considering suicide, suicide attempts, and substance use. Relationships between sleep duration and suicidality were stronger for male teens, and sleep duration was more associated with hopelessness for white students compared to most ethnic minority groups. Implications for intervention at multiple levels are discussed.

Keywords Sleep · Adolescents · Depression · Suicide · Substance use

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Introduction

Adolescents in the USA are sleep deprived. Only about 20 % of American teens sleep the recommended amount of 9 h, 15 min a night (National Sleep Foundation [NSF] 2006). Other data show that, on weekday/school nights, only 7.6 % report reaching ≥9 h, with 69 % of high school students receiving insufficient amounts of sleep (≤7 h) (Eaton et al. 2010), and 44 % reporting serious difficulty staying awake in school (Calamaro et al. 2009). Adolescence is characterized by homeostatic and circadian changes in sleep (Colrain and Baker 2011), including the onset of a circadian phase delay, a biological tendency toward later bed and wake times (Crowley et al. 2007). Adolescents' sleep/wake schedules, particularly when high schools start early, are often at odds with changes in their circadian system (phase delays), resulting in circadian desynchrony and attendant chronic sleep deprivation. This combination of circadian desynchrony, inadequate sleep, and sleepiness places adolescents at increased risk for a

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variety of adverse health outcomes (Carskadon et al. 1998). The current study examined weekday reported sleep duration and its relationships to depression, suicidality, and substance use in a large and ethnically diverse sample of adolescents in a large, suburban Northern Virginia community with very early (7:20 a.m.) high school start times.

Sleep and Mental Health

Depression, suicide, and substance abuse are serious problems for teenagers. Suicide is the third leading cause of death among teens (Cash and Bridge 2009), and high rates of adolescent depression and substance use may contribute to the problem (Nrugham et al. 2008; Pena et al. 2012). Reduced sleep duration is associated with these important mental health concerns in adolescents, including depression (McKnight-Eily et al. 2011; Pasch et al. 2010), suicidality (Lee et al. 2012; Wong et al. 2011), and substance use (O'Brien and Mindell 2005). Decreased weekday sleep for adolescents is associated with increased depressive symptoms in numerous survey studies (Pasch et al. 2010). More specifically, insufficient sleep (defined as <8 h) is associated with significantly increased odds of feeing sad or hopeless and with suicidal ideation (McKnight-Eily et al. 2011), and very short sleep duration (≤ 4 h) is found to increase the odds of suicidal ideation and attempts (Fitzgerald et al. 2011). Although the typical focus has often been on reduced sleep, nonlinear relationships are often found, with additional sleep beyond recommended amounts (i.e., ≥ 10 h/night) also being associated with increased health problems, such as depression (Fitzgerald et al. 2011). Although there are bidirectional causal effects at play between sleep duration and adolescent mood disturbances (Gregory and Sadeh 2012), longitudinal studies and experimental studies in which sleep duration is modified show that lack of sleep leads to depression more than the converse (Dewald-Kaufmann et al. 2014; Gregory et al. 2009; Kelly and El-Sheikh 2014). Given the chronic and persistent nature of depression (Judd et al. 1997), better understanding its association with sleep can lead to more effective interventions targeting sleep and help prevent or mitigate depression, as is seen in adults (Manber et al. 2008).

Insufficient weekday sleep in youth is also linked to increased alcohol and substance use (McKnight-Eily et al. 2011). Sleep deprivation is known to impair prefrontal cortical functioning, a brain region critical for executive functioning and inhibitory control. Reduced prefrontal cortical functioning can increase risk taking and poor judgment (O'Brien and Mindell 2005). Loss of sleep and sleep problems are linked with earlier onset and increased use of alcohol, alcohol-related problems, and other unhealthy substances including tobacco, marijuana, and illicit/prescription drugs (Kenney et al. 2013; Wong et al. 2004).

Of note, most of the research cited above linking poor sleep with mental health problems among adolescents has treated sleep duration categorically, namely by categorizing youth into those receiving "sufficient" (typically defined as ≥ 7 or 8 h) vs. "insufficient" sleep (<7 or 6 h) and then comparing the two groups on outcomes. The current study makes an important contribution to the literature by examining sleep duration continuously, allowing estimates of the difference that one more hour (or 2 or 3 h more) of sleep can make in terms of adolescent health outcomes. Furthermore, prior adolescent sleep research has typically examined these health outcomes individually, when hopelessness, suicidal consideration, suicide attempts, and substance use are known to be highly comorbid (Nrugham et al. 2008; Pena et al. 2012). Thus, we also extend the literature by examining whether sleep hours are still related specifically to teen suicide attempts even after controlling for concurrent/prior hopelessness and suicidal ideation. If sleep duration is a direct risk factor for the behavior of teen suicide in addition to having an indirect effect on suicide by increasing the teen's risk for depression, there would be important implications for practice and intervention.

Gender and Ethnicity

Although main effects of sleep duration on adolescent depression, suicidality, and substance use have been documented as discussed above, it is also important to examine individual differences in sleep duration and potential moderators of the relationships between sleep and adolescent health outcomes. In particular, gender and ethnicity have not been sufficiently investigated. Regarding gender, several large-scales studies, including one nationally representative sample of youth from the US (Knutson and Lauderdale 2009; Maslowsky and Ozer 2014) and a large multi-country study in Europe (Sarchiapone et al. 2014) demonstrate that adolescent girls sleep less, on average, than boys. Although earlier pubertal onset for females (and, thus, earlier onset of circadian phase delay) is seen as a reason adolescent girls might get less sleep (Tonetti et al. 2008), the observation that, while weekday bedtimes are the same across genders, female youth report waking up earlier than males (Lee et al. 1999) is taken as evidence that perhaps increased personal preparation and/or household responsibilities in the morning before school also contribute to reduced sleep among female teens.

The possibility that links between reduced sleep and adolescent mental health outcomes may differ for males versus females has, to our knowledge, not been explored systematically. In one study of 7th and 8th grade Dutch

students reporting 10 weeknight sleep hours (Meijer 2008), gender was found to be a moderator for relationships between sleep (quantity and quality) and school performance. The association between sleep and impaired academic functioning was stronger for the pre-adolescent girls than boys. Given that they also found that the girls had poorer quality sleep and a stronger circadian preference for later bed and wake times, the authors concluded that the earlier pubertal onset (and thus circadian phase delay) for females was responsible for sleep being particularly important for girls' school performance. The same research team (Meijer et al. 2010) subsequently examined internalizing (anxiety/depression) and externalizing (delinquent/aggressive) behavior problems longitudinally with an older Dutch sample of adolescents (who received over 8 h of sleep a night on average) and found that, while poor sleep quality and quantity were associated with behavior problems for both genders, the association for both internalizing and externalizing behavior problems was stronger for boys. These studies, however, were conducted in a different (Dutch) context, the teens were not sleep deprived, and they did not explicitly measure the outcomes examined in the present study, namely—hopelessness, suicidality, and substance use. The two studies found that examined gender as a moderator of links between sleep and substance use and/or depression had mixed results. Johnson and Breslau (2001) found that lack of sleep was more strongly associated with substance use for adolescent girls, whereas Pasch et al. (2010) found that specifically alcohol use was linked to sleep more strongly for boys, and there was no difference across gender in links between sleep and depression. The present study explored whether there are gender differences in sleep duration and whether sleep duration is differentially associated with mental health and substance use outcomes as a function of gender. We hypothesized that girls would report less sleep than boys, and that this differential would be more marked in high school than in middle school given the earlier onset of the circadian phase delay. Given very limited and mixed prior research concerning gender as a moderator of sleep effects on health outcomes, we do not offer an a priori hypothesis about whether adolescent males or females would be more affected by reduced sleep for the outcomes of depression, suicidality, and substance use.

Race/ethnicity and cultural context are also important factors to consider in adolescent sleep research although such variables have only recently begun to be explored. International studies show decreased sleep is associated with increased mood disturbances and suicidal ideation/attempts among Chinese (Liu 2004) and Korean adolescents (Lee et al. 2012). Korean adolescents manifest increased risk of both insufficient sleep and suicide compared to adolescents from other countries (Lee et al. 2012; Yang et al. 2005) perhaps due to increased academic pressure and extra-long school hours (Lee et al. 2009). Among minority groups within the US, numerous studies report that Black, Hispanic/Latino, and Asian adolescents obtain less sleep on average than White youth (Knutson and Lauderdale 2009; Nunes et al. 2008; Silva et al. 2011). Health disparities and socioeconomic (SES) stressors varying across ethnic groups are thought to be potential mechanisms. However, even when SES is controlled, Black children (at least children in elementary school) are still found to sleep less and be more at risk for cognitive/academic deficits as a result of sleep deprivation compared to White children (Buckhalt et al. 2007). To our knowledge, ethnicity has not been studied as a potential moderator of sleep quantity and mental health among adolescents. Thus, to advance the research literature, we explored potential ethnic differences in sleep duration and associated negative health outcomes in a culturally diverse community. We hypothesized, consistent with prior work cited above, that ethnic minorities would report sleeping less than White students, and that since poverty- and race-related stressors (i.e., racism, perceived discrimination) continue to operate and intensify in adolescence affecting multiple areas of health (Williams and Mohammed 2009), minority students would be at particular risk of poor mental health outcomes with reduced sleep. The same was hypothesized for Asian American students who, in addition to experiencing race-related stressors, also face intense pressure to succeed combined with increased stigma and reduced help seeking related to mental health issues (Lee et al. 2009).

High School Start Times

An important community factor that contributes to adolescent sleep deprivation is the time high schools start in the morning (Andrade et al. 1993; Kirby et al. 2011). The shift that takes place with the circadian rhythms of adolescents makes it difficult for adolescents to fall asleep early at night and more critical for them to be asleep in the early hours of the morning (Crowley et al. 2007). For around 40 % of teens, this natural tendency toward an eveningness chronotype is so severe that it is practically impossible for them to fall asleep much before midnight even under the most supportive of parental/familial conditions and bedtime routines (Giannotti et al. 2002), and such children appear to be at particular risk of mental health problems (Wolfson and Carskadon 1998). High school start time is a stronger predictor of adolescent sleep quantity, than bedtimes, bedtime routines, and time spent doing homework (Knutson and Lauderdale 2009). In communities where high schools start much earlier than middle schools, teens have a hard time making the

adjustment in their sleep schedule, and the resultant loss of sleep places high school teens at increased risk for adverse health outcomes (Wolfson and Carskadon 1998). It is therefore critical for adolescent sleep research to be conducted in the context of such communities. Thus, the current article adds much needed data on adolescent sleep duration and its associated health outcomes in a community with very early high school start times (7:20 a.m.). According to data on all US high schools from the National Center for Education Statistics (NCES n.d.), the average high school start time in the US is 8:00 a.m., with only 9 % of high schools nationwide starting before 7:30 a.m.

The Present Study

We investigated self-reported weekday sleep duration and its association with feelings of hopelessness, suicidality, and substance use in a large and diverse population-based sample ($N = 27{,}939$) of middle-school students (8th grade) and high-school students (10th and 12th grade) in Fairfax County, VA. To provide context, Fairfax County, VA, near Washington, DC, is home to over 1 million residents and according to 2010 census figures, is ranked second nationally in terms of highest median household income, with 62.5 % of the population being White/Caucasian and the next largest group being those of Asian descent (17.5 %, with Koreans being the second largest Asian subgroup behind Indians) (Fairfax County, Virginia n.d.). The Fairfax County Public School (FCPS) system is the 13th largest school system in the US, with the largest fleet of school buses in the nation (Fairfax County Public Schools n.d.), with 25 regular high/secondary schools and 26 middle schools (FCPS 2014).

Our aims extend the current literature in several ways. First, as described above, we provide new, population-level data on adolescent sleep duration in an important and novel community context, one with early high school start times, to compliment what is known from both smaller convenience samples and national datasets. We hypothesized that the high school students in this community would report significantly less sleep than middle school students, and significantly less sleep compared to national averages and medical recommendations. Representing another novel contribution to the literature, we also examined gender and ethnic differences in sleep duration in both middle school and high school. We expected females and ethnic minority students would report less sleep than male and White adolescents, with these gaps widening in high school compared to middle school.

Second, we tested hypotheses that self-reported weeknight sleep deprivation among adolescents would be associated with increased (a) feelings of hopelessness, (b) suicidal ideation, (c) attempted suicide, and (d) substance use, controlling for relevant demographic variables. Importantly, however, our analyses improve upon previous work in several ways. First, our hierarchical, multivariate, logistic regression analyses and continuous measure of sleep duration allow us to examine the difference that 1 h (or more) makes in the odds of the adolescent experiencing each mental health outcome. By contrast, most previous work has categorized youth into groups receiving "adequate" and "inadequate" amounts of sleep. Second, our hierarchical models, including numerous demographic variables (i.e., gender, ethnicity, high vs. middle school) at the first step and sleep hours in the second step, allow us to test for a variety of interesting process/mechanism/mediation questions. For example, if a significant school-level effect (showing that high school students are more hopeless/depressed than middle school students) dissipates when we add sleep hours to the model, it suggests that it is the sleep differential between high school and middle school, in particular, that is important for teen hopelessness, not student age or type of school. Similarly, if a significant ethnicity effect (showing that Blacks and Asians are more likely than Whites to have seriously considered suicide) disappears when we add sleep at Step 2, it suggests that it is the sleep difference between the ethnic groups rather than ethnicity itself that explains the increased suicidality. Finally, as hopelessness, suicidal consideration, suicide attempts, and substance use are clearly interrelated, we also examine, for example, whether sleep remains related to suicide attempts after controlling for teen hopelessness and prior suicidal ideation. Prior research has typically examined each outcome individually.

Third, we advance the field by exploring whether relationships between sleep and adolescent hopelessness, suicidality, and substance use are the same for males and females and for different ethnic groups. As described above, given the exploratory nature of the question with regard to gender, we did not test an a priori hypothesis. However, in the case of ethnicity as a moderator of sleep effects, we expected links between sleep and the outcomes to be stronger for ethnic minority youth.

Method

Participants

Data for this study came from the 2009 Fairfax County Youth Survey, a county-wide, comprehensive, voluntary, and anonymous survey designed to assess the health, wellbeing, and behavioral risk factors of the county's adolescents. The survey is an ongoing collaborative effort between the County of Fairfax Government Office and Fairfax County Public Schools (http://www.fairfaxcounty.gov/demogrph/youthpdf.htm) and is given to all (99 %) consenting 8th, 10th and 12th-grade students in the

county's public schools (less than 1 % of families opted their child out for survey participation). Originally, a total of 29,223 "valid" responses were obtained and distributed in the public use data set, however, additional careful data cleaning and cross-validation analyses revealed numerous student responses that were impossible or frivolous that were deleted. For example, students who selected all eight types of listed parents (i.e., biological and adoptive fathers and mothers and both grandparents, and a legal guardian) as all currently living in the home, and students with impossible ages listed for their grade (i.e., a 6-year-old 12th grader) were deleted. Also, students younger than 12 were excluded as were students who indicated that they were "not honest at all" or "honest only once in awhile" (a "4" or "5" on a 5-point scale) on an item indicating how honestly they completed the questionnaire. Finally, the analysis sample was limited to those who completed the survey item on sleep, yielding a final analysis sample of 27,939 students.

Table 1 shows basic demographic details of the sample. About a third of the sample was in 8th grade (middle school), 10th grade (high school), and 12th grade (high school). The sample was evenly distributed in terms of gender, and diverse in terms of ethnicity. White students made up 46 % of the sample, with Asians, Latinos, Black, and "Mixed" being the next largest groups. The increased minority representation in our sample (46 % White) compared to the county in general (62.5 % White) is due to the age of the students involved (younger population demographics are more ethnically diverse), and because the county-wide figure is based on adult census data. About 14 % of students were from single-parent homes.

Procedures

Using a census approach, the 2009 Fairfax County Youth Survey was administered (paper and pencil) to all 8th, 10th, and 12th grade public school students in the county who were present in their "home" classroom periods at school on the day of administration in the Fall of 2009 (Fairfax County 2009). Parents/guardians received a letter describing the survey and allowing them access to view all the items. Parents/guardians could "opt out" of having their child complete the survey and <1 % elected to do so. Parents and students were assured that student survey responses were completely confidential and anonymous. No student numbers or names appeared anywhere on the surveys. Students were instructed that participation was voluntary and that they could choose not to answer any particular set of, or all, questions. This research involving existing, publicly available, archival data with anonymous and unidentifiable records was approved/exempted from the institutional review boards of each of the participating institutions.

Variables

Items for the survey were pulled largely from well-known and validated surveys, including the Substance Abuse and Mental Health Services Administration Communities That Care Survey (SAMHSA 2004), and the Centers for Disease Control and Prevention Youth Risk Surveillance System (CDC n.d.). Gender was coded as female = 1 (male = 0).

Sleep Duration

The primary predictor for this study was self-reported, school-night, sleep duration. Similar to prior research (Fitzgerald et al. 2011), one item on the survey asked, "On an average school night, how many hours of sleep do you get?" The response categories were *4 or less hours, 5 h, 6 h, 7 h, 8 h, 9 h,* and *10 or more hours*. For ease of interpretation in the logistic regression analyses, this was recoded such that bigger numbers represented a *decrease* in hours slept—i.e., "a decrease of 1 h a night of slept was associated with an increased odds of X."

Hopelessness/Suicidality

Mental health outcome variables (depression/hopelessness, suicidal ideation, and attempted suicide) each came from single items on the survey, each with yes or no response options—(a) "During the past 12 months, did you ever feel so sad or hopeless almost every day for 2 weeks or more in a row that you stopped doing some usual activities?" (b) "During the past 12 months, did you ever seriously consider attempting suicide? (c) "During the past 12 months, did you ever actually attempt suicide?"

Substance Use

Two substance use composite variables were created from a variety of substance use items. The primary item stem was "During the past 30 days, on how many occasions (if any) have you used: (cigarettes; beer, wine, hard liquor; marijuana; LSD or other hallucinogens (acid, angel dust, special k, shrooms); cocaine or crack; sniffed glue, breathed (huffed) the contents of an aerosol spray can, or inhaled other gases or sprays in order to get high; methamphetamine (speed, crystal, crank, or ice); ecstasy; steroids without doctor's order; heroin; painkillers (such as Oxycontin, Vicodin, Percocet, Codeine, and opium) without a doctor's order; prescription drug other than painkillers without a doctor's order (such as Ritalin, Adderal, or Xanax)." The original response categories for each of these items were 0 occasions, 1–2 occasions, 3–5 occasions, 6–9 occasions, 10–19 occasions, 20–39 occasions, 40 or more occasions. Because these variables were highly skewed (most students never did these substances or did so rarely), and in order to be consistent with the

Table 1 Sample description and descriptive statistics (overall sample N = 27,937)

	Overall *N* (%)		
School type/ grade			
Middle school			
8th grade	10,055 (36 %)		
High school			
10th grade	9,307 (33.3)		
12th grade	8,577 (30.7 %)		
Gender			
Female	14,216 (51.2 %)		
Male	13,574 (48.8 %)		
Ethnicity			
White	12,834 (46.2 %)		
Asian	5,124 (18.4 %)		
Hispanic/Latino	4,578 (16.5 %)		
Black	2,660 (9.6 %)		
Mixed	2,248 (8.1 %)		
Pacific Island	226 (0.8 %)		
Native American	138 (0.5 %)		
Single-parent home	3,842 (13.8)		
	Overall	Middle school	High school
Weekday sleep duration			
4 h or less	1,621 (5.8 %)	293 (2.9 %)	1,328 (7.4 %)
5 h	2,798 (10 %)	411 (4.1 %)	2,387 (13.3 %)
6 h	5,786 (20.7 %)	1,128 (11.2 %)	4,658 (26 %)
7 h	8,083 (28.9 %)	2,618 (26 %)	5,465 (30.6 %)
8 h	6,999 (25.1 %)	3,782 (37.6 %)	3,217 (18 %)
9 h	2,023 (7.2 %)	1,411 (14 %)	612 (3.4 %)
10 h or more	629 (2.3 %)	412 (4.1 %)	217 (1.2 %)
M (*SD*)	6.88 (1.36)	7.50 (1.26)	6.53 (1.29)
Hopelessness	7,809 (28.3 %)	2,685 (25.9 %)	5,450 (29.8 %)
Considered suicide	3,903 (14.2 %)	1,373 (13.3 %)	2,684 (14.7 %)
Attempted suicide	974 (3.5 %)	346 (3.3 %)	700 (3.8 %)
Use alcohol, tobacco, marijuana	7,164 (26.7 %)	1,324 (13.1 %)	6,151 (34.8 %)
Use illicit substances	2,762 (10.3 %)	975 (9.9 %)	1,925 (10.9 %)

other (dichotomous) outcome variables examined, each substance item was dichotomized (yes = 1 or more occasions, 0 = none). We then aggregated the relevant dichotomous items to yield two composite recent use items—*tobacco, alcohol, marijuana* (more frequent/available, relatively less illegal substances), and more *illicit/prescription* substances (all the other substances without a prescription).[1]

Results

The results follow the order of our three original aims. To address our first aim, namely understanding how much sleep children obtain in this community and how that varies by school type (high school vs. middle school), gender, and

[1] We also ran regression models with the substance use composites treated continuously and found the same pattern of results as reported here, with no particular type of substance showing a noticeably different pattern.

ethnicity, we first report simple univariate descriptive statistics on sleep duration, and then bivariate analyses (Chi square, *t* tests, and ANOVAs) demonstrating how sleep varies as a function of background variables. Two types of analyses are then conducted to get at our second aim, namely, relationships between sleep duration and the health outcomes. First, we report the results of unadjusted bivariate (Chi square) analyses linking sleep with each outcome. Second, we report the main analyses consisting of a series of hierarchical, multivariate, logistic regression analyses examining links between sleep and the adolescent health outcomes controlling for relevant background variables, and, in some cases, controlling for hopelessness. Finally, to examine our last aim concerning gender and ethnicity as potential moderators of links between sleep and health outcomes, we discuss the results obtained when we added interaction terms in the logistic regression analyses.

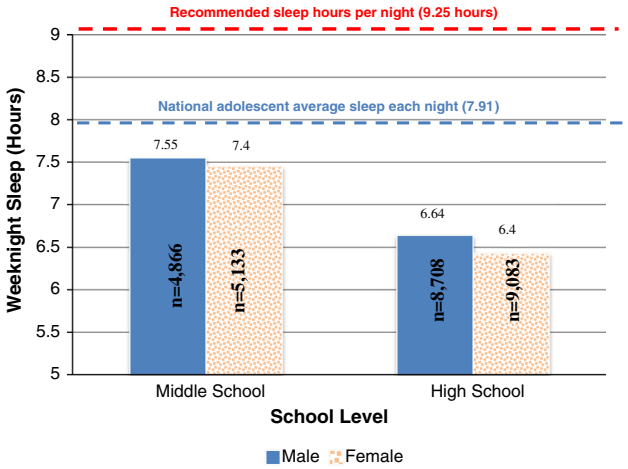

Fig. 1 Reported week night sleep hours by gender and school level. *Note*: Statistically significant gender effect, significant school level effect, and significant gender by school-level interaction, all *p*'s < .001

Aim 1: Sleep Duration

Table 1 lists the number (and %) of individuals who reported various hours of average weekday sleep along with the mean number of hours of sleep, both overall for the entire sample and by school type (middle vs. high school). Overall, teens reported, on average, < 7 h of sleep, which is considerably lower than the 9.25 h recommended by the National Sleep Foundation (NSF 2006). High school students reported fewer hours of sleep (about 6.5 h) compared to middle-school students (about 7.5), t (21,243.13) = 60.69, $p < .001$, effect size $d = .76$. Only 18.1 % of middle-school students slept the recommended 9 or more hours, and only 4.6 % of high school students attained 9 or more hours of sleep on weeknights. A full 20 % of high school students reported only 5 h of sleep or less on weeknights. We tested whether the observed sleep duration for high school students in the current community (6 h 32 min) was significantly less than that observed in Maslowsky and Ozer's (2014) national sample of high school students by calculating a weighted average of the number of sleep hours in that study who were presumably in high school (those who were ages 14, 15, 16 and 17) which came to 7 h 49 min. This value was entered as the population test value in a one-sample T test selecting just high school students in the present sample. This was statistically significant, t (17,981) = 132.23, $p < .001$) which allows us to conclude that students in Fairfax County, VA indeed receive significantly less sleep than do high school students nationally.[2]

[2] It is worth noting, however, that whereas we used hours of sleep reported, Maslowsky and Ozer (2014) calculated youth sleep hours on the basis of reported bedtime and waketime. It is not known whether this methodological difference also contributes to the difference observed.

Average sleep duration varied somewhat by child gender, as indicated by a significant main effect for gender, $F(1, 27{,}786) = 88.32$, $p < .001$, in a 2 (gender) × 2 (school type) ANOVA with sleep hours as the dependent variable. Figure 1 displays average sleep duration by gender and school type. Female teens obtained slightly less sleep on average ($M = 6.8$, $SD = 1.35$) than males ($M = 6.97$, $SD = 1.34$, effect size $d = .13$), and this gender difference was twice as strong (albeit still small) in high school ($d = .16$), compared to middle school ($d = .08$), according to a significant gender by school type interaction, $F(1, 27{,}786) = 12.96$, $p < .001$.

Sleep duration also varied by ethnicity as indicated by a significant ethnicity main effect, $F(6, 27{,}794) = 51.91$, $p < .001$, in a similar 7 (ethnicity) by 2 (school type) ANOVA. Post-hoc least significant difference (LSD) contrasts revealed that White students reported more sleep than all other ethnic groups and this was consistent across both middle school and high school. Black students slept more than Asian and Pacific Islanders. Hispanic students reported more sleep than Black, Asian, Pacific Islander, and Mixed-race students. Asian students slept less than all groups except for Native Americans and Pacific Islanders. These ethnic differences, however, are qualified somewhat by a significant ethnicity by school type interaction, $F(6, 27{,}794) = 9.75$, $p < .001$, indicating that the decrement in hours of sleep received between middle and high school students differed by ethnic group. Figure 2 displays mean hours of sleep by ethnic group and by school type. As seen in the Figure, the loss of sleep moving from middle school to high school was most prominent for Asian students (from 7.39 to 6.19 h), and is somewhat less dramatic for Native American and Pacific Islander students. It is worth noting

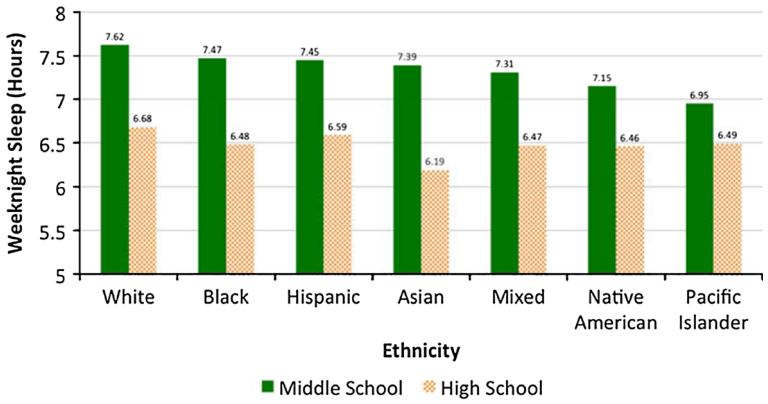

Fig. 2 Reported week night sleep hours by ethnicity and school level. *Note*: Statistically significant school level effect, significant ethnicity effect, and significant ethnicity by school-level interaction, all p's $< .001$

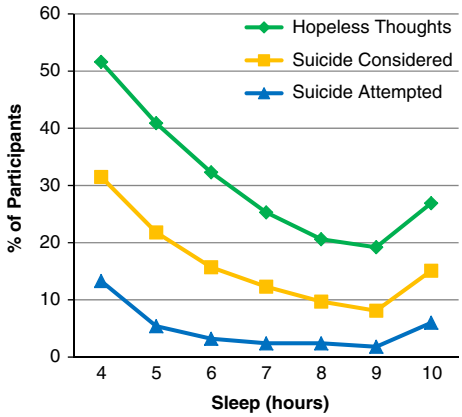

Fig. 3 Hopelessness and suicide by reported number of hours of sleep. *Note*: Each hour less of sleep is associated with a significant increase in odds of the outcome, p's $< .001$

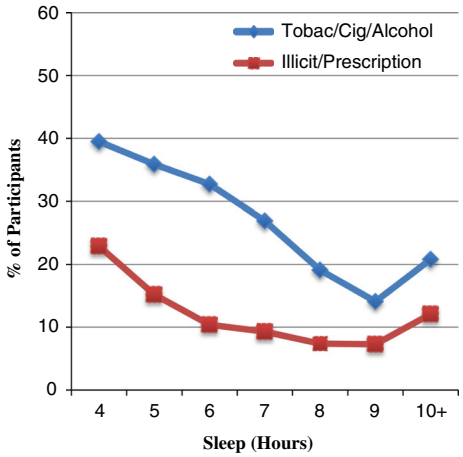

Fig. 4 Substance use by hours of sleep. *Note*: Each hour less of sleep is associated with a significant increase in odds of the outcome, p's $< .001$

that the sample sizes are smallest for these latter two groups suggesting that findings involving Native Americans and Pacific Islanders need to be interpreted with more caution.

Aim 2: Association Between Sleep and Health Outcomes

Figure 3 shows the percentage of students who reported feeling sad and hopeless, who have seriously considered suicide, and who have actually attempted suicide at least once as a function of the numbers of weekday hours slept. As is clearly seen in the Figure, for each hour less of sleep received, student hopelessness, χ^2 (6) = 1,011.12, $p < .001$), suicidal ideation, χ^2 (6) = 736.06, $p < .001$), and attempted suicide, χ^2 (6) = 564.90, $p < .001$), increased significantly. For students obtaining the recommended 9 h of sleep a night, only 19.2 % felt hopeless, 8.1 % considered suicide, and 1.8 % attempted to kill themselves, but these figures rose fairly linearly to 51.6 % being hopeless, 31.5 % having considered suicide, and 13.3 % having already attempted suicide for those attaining only 4 h of sleep a night. The relatively small group of students who reported sleeping 10 or more hours of sleep a night on the weekdays noted an increased risk for all three of these negative outcomes compared to those who receive the recommended 9 h of sleep.

Figure 4 similarly shows the prevalence of substance use as a function of number of hours of sleep received. Similar to the depression and suicide findings reported above, substance use, both for tobacco, alcohol, and marijuana, χ^2 (6) = 714.37, $p < .001$), and for illicit/prescription substances (χ^2 (6) = 423.81, $p < .001$) increased steadily as students obtained less sleep. Percentages of tobacco/alcohol/and marijuana use in the last 30 days were 14.1 %, and 7.3 % for illicit/prescription drug use for those reporting 9 h of sleep per night on average, but these increased linearly to as high as 39.5 % and 22.9 % respectively for those obtaining only 4 h of sleep. Those reporting 10 or more hours of sleep were also at increased

risk of substance use compared to those obtaining 8 or 9 h of sleep.

We conducted a series of hierarchical, multivariate, logistic regression analyses predicting the occurrence (Yes/No) of each of the five health outcomes as a function of sleep duration and background variables. We first entered background/control variables in block one—gender (female), two parent household, ethnicity (dummy coded with White as reference group), and school level (High School), and then entered sleep hours in block two. Given the nonlinear shape of increased risk for students reporting 10 or more hours of sleep, and the desire to model the best parameter estimates for risk of the outcomes for linear decreases in amount of sleep (i.e., "for each hour less of sleep received, how much do the odds of experiencing the outcome increase?"), we only included students who reported 9 or less hours of sleep per night in the regression models reported below.[3] Table 2 provides the results of these analyses in the form of odds ratios for each of the outcomes. An odds ratio greater than 1 indicates increased odds of the outcome compared to the reference group and an odds ratio less than 1 indicates decreased odds of experiencing the outcome.

Hopelessness

As seen in the first column of Table 2 which provides the results for the background variables, girls had 61 % greater odds of feeling sad and hopeless compared to boys, and students with two parents at home were significantly less likely to feel sad and hopeless than those with a single parent. In terms of ethnicity, each minority group was significantly more likely than Whites to report hopelessness. Teens were more likely to report hopelessness if they were in high school rather than middle school, but this age/grade effect disappeared and even reversed once the significant effect of sleep hours was considered in Step 2, suggesting that it is the sleep hours experienced in high school rather than child age/grade itself that is associated with increased depression/hopelessness. The significant odds ratio of 1.38 for sleep in Step 2 indicated that for each hour less sleep youth obtain, the odds of them feeling sad and hopeless increased by 38 %, controlling for other background variables. So a difference of 3 h of sleep a night was associated with more than 2.5 the odds of experiencing this negative mental health outcome (exponentiated [b multiplied by 3] = 2.64). Also notable was that the increased risk of feeling sad and hopeless among Asians dissipated after adding sleep hours to the model in Step 2, indicating that it is specifically the reduced sleep associated with being Asian that is likely mediating the increased risk of hopelessness for this group.

Considering Suicide

Results for considering suicide were very similar to those seen for hopelessness and with similar effect sizes. Females, those with single parents, those in high school, and all minority ethnic groups were more likely to consider suicide compared to males, those with two parents, those in middle school, and Whites. Controlling for other variables, each hour less of sleep was associated with a 42 % increase in the odds of seriously considering suicide. Adding sleep hours in Step 2 removed the effects of being in high school, being Black, and being Asian, suggesting that it is specifically the number of hours slept that is associated with suicidal ideation and not ethnic status and type of school attended.

Because suicidal ideation is typically correlated with hopelessness ($r = .43$ in this sample), we investigated if sleep duration predicted youth suicidal ideation even after controlling for hopelessness. Thus, we ran the same model as above but entered youth hopelessness as well in Step 1. Sleep duration entered at Step 2 was *still* significantly associated with suicidal ideation ($b = .191$, $OR = 1.21$, $p < .001$) even controlling for student hopelessness. For each hour less sleep, the odds of seriously considering suicide still increased by 21 %.

Attempted Suicide

We found similar patterns when predicting actual suicidal attempts among adolescents. The same background variables were associated with an increased risk of attempting suicide. However, Blacks and Asians were no more likely to try to kill themselves than were Whites. Each hour less of sleep reported per night was associated with 58 % greater odds of attempted suicide. As with the above mental health outcomes, the high school effect disappeared after entering sleep hours into the model. The increased risk of suicidal attempts seen among Native Americans and Pacific Islanders failed to reach significance after including sleep hours, again indicating that sleep hours are more important than ethnic background in

[3] Supplemental and parallel logistic regression analyses to those reported here were also done to see if the difference in receiving 9 vs. 10+ hours of sleep mattered for the outcomes. In all cases, the demographic predictors behaved the same as what is reported below. Moving from 9 to 10+ hours of sleep night was not significantly associated with increased hopelessness, but was significantly associated with increased odds of the other four negative health outcomes.

Table 2 Logistic regression results predicting health outcomes from sleep duration

	Hopelessness		Suicide considered		Suicide attempted		Alcohol, marijuana, cigarettes used		Illicit/prescription substances used	
	Step 1 *OR*	Step 2/3 *OR*	Step 1 *OR*	Step 2/3 *OR*	Step 1 *OR*	Step 2/3 *OR*	Step 1 *OR*	Step 2/3 *OR*	Step 1 *OR*	Step 2/3 *OR*
Step 1										
Female	1.61***	1.56***	1.62***	1.56***	1.50***	1.43***	0.84***	0.81***	0.81***	0.77**
Two-parents	0.69***	0.71***	0.67***	0.68***	0.63***	0.66***	0.70***	0.71***	0.71***	0.73***
High school	1.24***	0.93*	1.13**	0.26*	1.17*	0.79**	3.74***	3.17***	1.11*	0.85***
Black	1.24***	1.16**	1.16*	1.07	1.22	1.08	0.75***	0.71***	1.03	0.96
Native American	2.48***	2.23***	2.12**	1.84**	2.49*	1.97	1.30	1.20	3.19***	2.82***
Pacific Islander	1.93***	1.73***	2.02***	1.79**	2.12*	1.75	1.06	0.99	2.09***	1.86**
Hispanic	1.89***	1.83***	1.49***	1.41***	2.01***	1.85***	1.20***	1.17***	1.43***	1.36***
Asian	1.18***	1.02	1.14**	0.98	0.99	0.80*	0.41***	0.37***	0.66***	0.57***
Mixed	1.46***	1.35***	1.77***	1.63***	1.96***	1.71***	0.99	0.94	1.27**	1.16*
Step 2—sleep hour lost		1.38***		1.42***		1.58***		1.23***		1.37***
Step 3										
Female × sleep		1.01		0.94*		0.85**		0.98		0.98
Ethnic × sleep		Wald χ^2		Wald χ^2		Wald χ^2		Wald χ^2		Wald χ^2
		19.85**		8.43		5.85		0.48		13.56*
Black		0.90**		0.93		0.96		0.98		0.90
Native American		0.91		1.14		1.15		1.01		0.01
Pacific Islander		0.79*		1.01		0.84		1.02		0.79
Hispanic		0.93*		0.92*		0.90		0.99		0.95
Asian		0.92**		0.94		1.07		0.99		0.86**
Mixed		0.92*		0.98		0.95		0.99		0.99

OR odds ratio. ORs for sleep and background variables in the Step 2/3 columns are from Step 2, for the interaction terms, they are from the Step 3

* $p < .05$; ** $p < .01$; *** $p < .001$

predicting attempted suicide for those groups. Interestingly, students of Asian descent were slightly less likely to try to kill themselves (odds ratio = 0.80) than Whites after factoring in sleep hours. Only Hispanics and those of mixed ethnic backgrounds were at greater risk of suicide compared to Whites after sleep was entered into the model at Step 2.

As before, given that youth suicidal attempts are also correlated with hopelessness ($r = .23$ in this sample) and suicidal ideation ($r = .41$ in this sample), we investigated if sleep duration predicted youth suicide attempts even after controlling for hopelessness (and then for suicidal ideation in addition to hopelessness). We ran the same models as described above but entered youth hopelessness as well in Step 1 (and then again entering both hopelessness and ideation in Step 1). Sleep duration entered at Step 2 was *still* significantly associated with suicide attempts ($b = .23$, $OR = 1.26$, $p < .001$) after controlling for student hopelessness (for each hour less of sleep, the odds of attempting suicide still increased by 26 %) and after controlling for both hopelessness and suicidal ideation ($b = .13$, $OR = 1.14$, $p < .001$) (for each hour less of sleep, the odds of attempting suicide still increased by 14 %).

Substance Use

Predictors of substance use were somewhat different than for the mental health variables reported above. For *tobacco, alcohol, and marijuana* use in the last 30 days, females were less likely to be users, as were those with two parents present in the home. Those in high school were more likely than those in middle school to have recently used the substances. Black and Asian students were less likely than Whites to report using these substances lately, and Hispanics were more likely to report use compared to Whites, and these odds ratios did not change notably after entering sleep into the model. For each hour of sleep lost, the odds of using tobacco, alcohol, or marijuana increased by 23 %. It is notable that for this type of substance use, unlike all other outcomes examined in this study, sleep hours did not eliminate the

increased risk associated with attending high school. For use of *illicit/prescription drugs*, females, those with two parents at home, and those in middle school were again less likely to experience these risky behaviors. Blacks and Whites were equally likely to use these substances. Asians were less likely to have used them compared to Whites. Other ethnic minority groups manifested greater odds of using compared to Whites. Each hour less of sleep obtained was associated with a 37 % increase in the odds of using illicit/prescription substances.

Aim 3: Gender and Ethnic Group Moderation of the Association between Sleep and Health Outcomes

To examine moderation by gender and ethnicity, we simply added the relevant interaction terms (gender by sleep hours, ethnicity by sleep hours) in Step 3 of the logistic regression analyses reported above and these are found at the bottom of Table 2.

Hopelessness

The association between sleep and hopelessness was similar for boys and girls as indicated by a non significant interaction term. However, ethnicity did interact significantly with sleep duration as indicated by the significant Wald χ^2 value provided in Table 2. The association between sleep and sadness/hopelessness was present for all students but was stronger for White students than for each ethnic group, except for Native Americans who were not statistically different from Whites in the strength of the sleep-hopelessness association.

Considering Suicide

Sleep duration interacted with gender in predicting suicidal ideation, indicating that the link between sleep loss and suicidal ideation was slightly stronger for males than for females (although present for both groups). The association between sleep and suicidal ideation did not vary across ethnic groups.

Attempted Suicide

The interaction term of sleep by gender behaved the same for attempted suicide as it did for suicidal ideation, indicating that the association between sleep duration and attempted suicide was even stronger for male youth.

Substance Use

For tobacco/marijuana/alcohol, neither gender nor ethnicity moderated relationships between sleep duration and this type of substance use. For illicit/prescription drug use, links between sleep and recent use of these drugs were the same across both genders, but differed somewhat by ethnicity. The link between sleep and illicit/prescription drug use was stronger for White students compared to Asian students.

Discussion

Insufficient sleep in adolescence is associated with serious mental health risks including depression, substance use, and suicide (McKnight-Eily et al. 2011; Lee et al. 2012; O'Brien and Mindell 2005). Communities vary in their high school start times, a contextual factor known to be linked with both adolescent sleep and mental health (Carskadon et al. 1998), yet little is known about adolescent sleep and health in communities with early high school start times. Further, little attention has been given to potential ethnic and gender differences in adolescent sleep, and prior studies have tended to categorize students into extreme sleep groups rather than examine the difference that an hour or two more of sleep can make for adolescent functioning. The current study examined self-reported weekday sleep among a large, community-based sample of 8th, 10th, and 12th grade students in Fairfax County, Virginia, a community with very early high school start times. We examined links between a continuous measure of sleep duration and adolescent hopelessness, suicidality, and substance use. Furthermore, we explored potential ethnic and gender differences in both sleep duration and increased odds for these negative health outcomes.

By any standard, youth in this community are sleep deprived. High school students in Fairfax County, Virginia report sleeping an average of 6 h 30 min on weekday nights, considerably less sleep than the sleep obtained by middle school students in the same community (7 h 30 min). This is also statistically significantly less sleep than that reported by high school students in large-scale national samples (Maslowsky and Ozer 2014), and far less than the 9 h of sleep per night recommended for adolescents (NSF 2006). Only 3.4 % of high school students in Fairfax County obtain the recommended 9 hours of sleep, and, more importantly, over 20 % report attaining only 4–5 h of sleep a night. Nationally, the percentage of teens who obtain this critical threshold of <6 h of sleep per night is only 3–6 % depending on age (Maslowsky and Ozer 2014). These alarmingly low sleep duration figures for

teens suggest a serious public health concern in this community. Links have been found recently between insufficient/reduced sleep in adolescents and negative outcomes, including depression (McKnight-Eily et al. 2011; Pasch et al. 2010), suicide (Fitzgerald et al. 2011), substance abuse and alcohol (McKnight-Eily et al. 2011; O'Brien and Mindell 2005), poor academic performance (Ming et al. 2011), and risky behavior (O'Brien and Mindell 2005). Our findings are consistent with and extend this work.

The present study found that sleep was not distributed evenly across gender and ethnic groups. Females obtained less sleep on average than males, and this gender gap increased in size with the developmental transition from middle school to high school. White students attained more sleep than minority groups, with Asian students being most at risk for limited sleep, followed by Black and Hispanic youth. Such ethnic disparities in sleep increased in high school compared to middle school. Similar gender and ethnic differences have been found in the limited literature in this area (Maslowsky and Ozer 2014), but documenting as we do here that such gender and ethnic disparities in sleep duration appear to be exacerbated for youth in high school compared to middle school within the same community with early high school start times is an important contribution to the literature. Our finding that Asian high school youth in this community are particularly at risk for reduced sleep is consistent with other research identifying increased stress, health, and wellbeing concerns among Asian American youth (Lee et al. 2009). These findings suggest that additional intervention efforts could perhaps be targeted to this at-risk population. It is notable that the White-Asian sleep gap observed for youth in our study was larger than that seen in another study (Maslowsky and Ozer 2014) though our methods did differ.

Supporting our hypotheses, we found that reduced sleep was strongly associated with each of the adverse health outcomes we examined among Fairfax County youth. Controlling for background variables, the odds of a student feeling sad and hopeless increased by 38 %; of reporting serious suicidal ideation, by 42 %, and of having already attempted suicide increased by a striking 58 % *for each hour less of sleep* a student obtained. These odds accumulate multiplicatively with each hour of sleep lost such that for a student receiving three less hours of sleep (e.g., 5 h/night - compared to a student receiving 8 h) the beta coefficient would be multiplied by 3, yielding odds ratios of 2.64, 2.85, and 3.92 respectively, making such a youth more than 2.5 to almost 4 times more likely to be depressed and/or suicidal. We obtained similar findings with regard to youth substance use. Controlling for background variables, the odds of a student recently using tobacco, alcohol, and/or marijuana increased by 23 %, and the odds of using illicit/prescription drugs increased by 37 %. These findings are consistent with other studies that find increased risk of mood disturbances, depression, and suicidality (Fitzgerald et al. 2011; Gangwisch et al. 2010), and increased risk taking and substance use (Johnson and Breslau 2001; Mednick et al. 2010) among youth who are sleep deprived.

Importantly, our study shows the difference a *mere hour of sleep* can make in terms of increasing the odds of adverse outcomes in adolescents. Many of the prior studies categorize students into either a reduced sleep group (defined variously as <6 or 7 or 8 h/night) or a normal sleep group, showing that those who obtained considerably less sleep are more likely to have negative outcomes than those who garner sufficient sleep (McKnight-Eily et al. 2011; Mednick et al. 2010). Our findings suggest, however, that even within what are often considered normal sleep ranges of 7 versus 8 h, just 1 h less of adolescent sleep is associated with statistically and practically significant increases in the probability of experiencing multiple adverse health outcomes. The difference between 6 versus 7 h of sleep is similarly striking. Experimental studies have also revealed important health and performance benefits in youth who obtain only 45–60 min more of sleep (Dexter et al. 2003; Owens et al. 2010).

Another goal of the present study, and a novel contribution to the literature, was to examine whether associations between sleep and adverse health outcomes were similar for male and female teens and for those from different ethnic backgrounds. Links between sleep and both hopelessness and substance use in the current study were found to be the same for males and females. We, thus, did not replicate either of the two prior studies in this area. Pasch et al. (2010) found links between sleep and alcohol use to be present only for boys, while Johnson and Breslau (2001) demonstrated that sleep was more strongly associated with substance use for adolescent girls. Links between sleep and suicidal ideation and attempted suicide, however, were found to be stronger for male compared to female youth. Perhaps the increased risk taking (Byrnes et al. 1999) and poor inhibitory control (Else-Quest et al. 2006) seen among males makes them at particular risk for suicidal acts when they are low on sleep. While the effect size of this gender moderation was only modest (especially for suicidal ideation), this finding still suggests that practitioners working with sleep-deprived adolescents might be especially concerned about suicidal behavior among males, especially if they have access to lethal means for suicide.

In terms of ethnicity, risks associated with sleep deprivation were similar across groups for suicidality and for the use of tobacco, alcohol, and marijuana. However, links between sleep and feelings of hopelessness were stronger for White youth compared to minority youth, and the link between sleep and illicit/prescription drug use was stronger for White compared to Asian students. Minority youth were

more likely to feel hopeless in general but it would appear that the source of their sense of hopelessness is something other than lack of sleep, perhaps race-related stressors, whereas among White students, sleep plays a larger role in feelings of hopelessness. Similarly, abuse of prescription or illicit drugs was much less common among Asian students compared to White students. However, when it was present, it did not appear to be as linked with sleep duration as it was for White youth. Given that we found several instances of risks associated with sleep duration to be different across gender and ethnic lines, future research should continue to explore gender and ethnicity as potential moderators of sleep effects on adolescent health.

The multivariate, hierarchical regression analyses we conducted allowed an examination of the extent to which increased odds of negative health outcomes due to demographic factors such as gender, ethnicity, age/school type (high vs. middle school) could be explained by sleep duration. This was the case for depression and suicidality. Youth were more likely to report hopelessness and suicidal ideation if they were in high school rather than middle school; Asians and Blacks were more likely to report these symptoms of depression than other groups; and Native Americans and Pacific Islanders were more likely to have attempted suicide. However, all of these school type and ethnicity effects disappeared once the significant effect of sleep duration was added in Step 2, indicating that it was specifically sleep hours that predicted these negative outcomes, not the age/grade level or ethnicity of the student. Interestingly, students of Asian descent were actually significantly *less* likely to have tried to kill themselves compared to Whites after sleep hours were factored into the regression equation. This suggests that Asian students in this community obtain less sleep and sleep duration plays a greater role in the suicidality for this group than for White teens. Parents, teachers, and interventionists should assess sleep levels for all teenagers and be particularly careful to assess the sleep duration of teenagers of Asian descent.

Another advantage of our multivariate regression analyses was that we could examine not only each outcome individually but also whether sleep still predicted suicidality even after controlling for teen hopelessness/depression. Reduced sleep was still associated with increased risk for suicidal consideration and suicidal attempts even after teen hopelessness/sadness was included in the model. Furthermore, sleep loss continued to sizably predict recent suicide attempts even after both suicidal ideation and hopelessness were included. This suggests that sleep has both direct and indirect (through depression) associations with teen suicide. Such findings are consistent with longitudinal findings (Wong and Brower 2012) on the indirect and direct associations between sleep and suicidal attempts. Nevertheless, one study found a non-significant link between sleep and suicide attempts after controlling for depression and suicidal ideation (Nrugham et al. 2008).

Strengths and Limitations

The current study had a number of important strengths that add to prior research on adolescent sleep and mental health. First, we employed a large and ethnically diverse, population-level, community sample of youth in both middle schools and high schools and used a fully anonymous survey with a very high response rate. Second, our examination of one community with early high school start times adds information about contextual variation to what has been learned from national samples. Third, by examining hours of sleep rather than categorizing youth in groups of those receiving adequate or inadequate sleep, we were able to estimate the increased odds for mental health outcomes related to obtaining just one hour more of sleep. Fourth, our use of multivariate, hierarchical logistic regression analyses allowed us to control for relevant demographic factors and examine sleep hours as a potential explanatory variable of other effects (e.g., high school or ethnicity effects on the outcomes going away after sleep hours are added to the model). Finally, we add to the limited literature by examining gender and ethnicity as moderators of links between sleep duration and adolescent health outcomes, a particularly neglected area of research, to date.

However, there are also numerous limitations of the study that must be considered. First, we did not use objective measures of sleep such as polysomnography or actigraphy. With such a large population, these techniques would not be feasible. Instead, we utilized adolescent self report of weekday sleep duration with one item from a survey. The use of self report is quite common in large-scale sleep research (Fredriksen et al. 2004), even one-item measures like the one we examined (Fitzgerald et al. 2011). Although youth self-reports of sleep hours have been shown to be accurate and reliable (Tremaine et al. 2010; Winters et al. 1990), the use of additional, more nuanced survey measures of adolescent sleep (sleep quality, weekend-weekday sleep differentials, bedtimes and wake times, circadian chronotype, etc.) would be preferable moving forward. Such measures of sleep quality and quantity are also associated with adolescent health outcomes (Carskadon and Acebo 2002; Lee et al. 2012). Indeed, Short et al. (2013) show that circadian chronotype (individual differences in "morningness" vs. "eveningness") is a more important predictor of adolescent outcomes than sleep duration. Thus, future research would do well to include a measure of youth circadian chronotype.

Other study limitations include that we did not have information about youth prescription use of either sleep aids or antidepressants, which can alter sleep and/or the

mood-related outcomes. However, as we were examining depressive symptomatology, not diagnoses of clinical depression, absence of such information is less likely to impact our key hypotheses. It is also worth noting that although typical of survey sleep research (Fitzgerald et al. 2011), the response options for our sleep item were 1-h increments when perhaps a more precise estimate could have been obtained if smaller units of time were available. Also, our outcome variables were all self-reported. However, this could also be viewed as a strength as well since some outcomes (i.e., suicide attempts) may not be medically attended nor documented and so self-reported measures can provide key information not obtainable in other ways (Liu 2004).

A final limitation of this study is its cross-sectional design. Although we were able to show differences in sleep quantity in middle school versus high school students and how reduced sleep duration is associated with a myriad of negative outcomes, we could not assess causality or direction of effect. Mental health disturbances and substance use can also precede reductions in sleep quantity. Longitudinal research that follows children as they make the transition from middle school to high school, especially in communities with early high school start times would be particularly welcome. Such longitudinal work would also help to clarify the direction of effect between sleep and mental/behavioral health concerns. Last, it is important to note that the survey employed was conducted by Fairfax County in 2009, which preceded ubiquitous use of smart phones by teenagers. Access to the internet, social media, and texts 24/7 via smart cellphones has recently been shown to contribute to adolescent sleep deprivation (Chahal et al. 2013). Thus, sleep quantity may have even worsened since these data were collected.

Implications

Reducing the incidence and prevalence of mood disorders and substance abuse is of particular import in the adolescent population. Given the persistent and chronic nature of depression (Judd et al. 1997), the present findings have significant public health implications. We found sleep duration to be strongly associated with these adverse mood and substance use outcomes. Insufficient sleep is known to be causally linked to mood disturbances, cognitive difficulties, risk taking, and other adverse health outcomes from other experimental research (Dahl and Lewin 2002). We identified certain groups in this study that interventionists should perhaps monitor more closely with respect to sleep and suicide: (a) female teens, who sleep less in general and are already at increased risk for depression, (b) Asian teens, who are the most sleep deprived and for whom amount of sleep appears particularly important in predicting suicidality, and (c) males with reduced sleep who appear to be most susceptible to actual suicidal attempts. The current study also suggests that sleep continues to be important for predicting teen suicidality independent of its role in teen depression, suggesting that adults need to continue to monitor and facilitate teen sleep even after knowledge that their adolescent is depressed.

Adolescents nationwide do not get enough sleep (NSF 2006), but the problem appears to be considerably worse in Fairfax County, Virginia. This county may have a number of unique features, but one potentially relevant feature is that it has an early high school start times of 7:20 a.m. With these data, one cannot conclude that high school start times directly contribute to the reduced sleep duration and related negative health outcomes observed. This remains a relevant consideration worthy of future study. Regardless, however, the level of teen sleep restriction observed in this community is of concern and worthy of intervention. At the individual and family level, behavioral family and school-based interventions focusing on monitoring, regulating, and enforcing bedtimes, rules and limitations for bedtime routines and pre-sleep activities (screen time, lights etc.…) have been shown to be helpful, not only for increasing sleep, but also elevating mood (Dewald-Kaufmann et al. 2014; Gangwisch et al. 2010; Moseley and Gradisar 2009), at least for adolescents with a morning chronotype. But these interventions are unlikely to be effective for the large percentage of teens whose biological clock makes it virtually impossible to fall asleep before midnight even under the best of circumstances and pre-sleep routines (Giannotti et al. 2002), suggesting that perhaps community-wide policy change in the form of delaying the start time for high school may be needed to make a dent in this serious public health concern. Early high school start times are known to contribute to adolescent sleep restriction (Knutson and Lauderdale 2009; Perkinson-Gloor et al. 2013). Experimental and quasi-experimental studies find that changing school start times does result in youth getting more sleep, with multiple positive mental health and cognitive benefits such as higher quality sleep and less daytime sleepiness (Dexter et al. 2003; Vedaa et al. 2012), improvements in attention, impulsivity, and math (Lufi et al. 2011), and more satisfaction with sleep, less depressed mood, more motivation, better attendance, and fewer visits to the nurse's office (Owens et al. 2010).

Conclusion

Adolescents, as a group, are not getting enough sleep and a burgeoning literature associates this with serious health problems, including depression, substance use, and suicide (Dewald-Kaufmann et al. 2014). Reduced sleep may be more

marked in communities, such as the one investigated here, with early high school start times (Carskadon et al. 1998). Sleep duration for female and minority youth appears to decline even more during the transition from middle school to high school. The present study found that the odds of teen hopelessness, suicidal ideation and suicide attempts, and substance use are sizeably reduced with one more hour of weeknight sleep. Thus, it appears that one does not have to make a huge leap from obtaining, say, 6 h to getting nine hours of sleep as a teen in order to see the positive health benefits of increased sleep. Attention to, and intervention for, reduced adolescent sleep is critically needed at multiple levels (individual, family, school, and community) in order to optimize the mental health and wellbeing of adolescents.

Author contributions A.W. conceived of the study, coordinated the project, conducted the final data analyses, reviewed the literature, and drafted most of the manuscript and revisions. R.V. contributed to the conceptualization of the project and writing of the manuscript. P.P. helped conceive of the study and acquire the data, gathered collaborators, and provided input on the writing. A.D. conducted most of the original data analyses, prepared earlier conference presentation versions of the work, and provided input on the writing. M.S.C. contributed to the conceptualization of the project and interpretation of results, reviewed the literature, wrote the first partial draft of the manuscript, and contributed substantially to the writing of subsequent drafts. M.S.C. and R.V. provided critical revisions of the manuscript for important intellectual content. All authors read and approved the final manuscript.

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