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Objective: The current study examines longitudinal sleep patterns in relation to risky sexual behaviors in a racially/ethnically diverse sample of adolescents. ***Method:*** The sample comprises 1,850 youth (mean age at first wave = 16.21; 57% female). Sleep duration, sleep variability (difference between weekend and weekday sleep duration), and sleep quality were collected over four annual assessments from 2013 to 2017. Risky sexual behaviors (i.e., sex without condom use or sex after using drugs or alcohol) were examined at the fourth follow-up assessment when youth were 19 years old. Longitudinal latent class analysis characterized patterns of individual sleep dimensions over time, as well as the combination of sleep dimensions, and examined how emergent sleep classes associated with subsequent risky sexual behavior, after adjustment for sociodemographics and mental health. ***Results:*** After covariate adjustment, persistent "short" weekend sleepers were 2.2 times more likely to engage in risky sexual behaviors, compared to youth with sufficient weekend sleep duration. Contrary to expectations, adolescents with more consistent weekend/weekday sleep were 1.6–2 times more likely to engage in risky sexual behaviors, compared to those with greater variability; however, lack of variability may be an indicator of chronic insufficient sleep, both weekdays and weekends. There were no significant differences in risky sexual behavior according to classes of weekday sleep duration or quality. In the combined class model, those with persistently short and poor-quality sleep were at marginally greater risk for engaging in risky sexual behaviors. ***Conclusion:*** Insufficient sleep in adolescents may increase risk for sexual risk-taking and may set the stage for accelerated health risk trajectories into adulthood.

Keywords: sleep, adolescence, sexual activity, risky behavior, latent class analysis

Adolescence is characterized by dramatic changes in socioemotional, cognitive, physical, and neurobiological development. Biological changes in sleep timing (circadian phase delay), as well as the conflict between societal obligations (e.g., early school start times) and teen social pressures, put adolescents at high risk for sleep and circadian disruptions, including insufficient sleep duration, insomnia, and circadian misalignment (mismatch between sleep schedule and internal circadian timing; Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998; Dahl, 1996). An emerging body of cross-sectional and longitudinal research demonstrates that sleep problems increase risk for alcohol and other drug (AOD) use among adolescents (Wong, Brower, Fitzgerald, & Zucker, 2004; Wong, Robertson, & Dyson, 2015), although evidence for bidirectional associations also exists (Fakier & Wild, 2011; Giannotti, Cortesi, Sebastiani, & Ottaviano, 2002; Gromov & Gromov, 2009; Johnson & Breslau, 2001). Poor decision-making, as well as disruptions in impulse control, reward sensitivity, and emotional regulation, are purported mechanisms underlying a causal role of sleep disturbance in the development of risk-taking behaviors (Forbes & Dahl, 2005; Hasler & Clark, 2013), such as AOD use as well as other health risk behaviors, including risky driving, aggressive behaviors, and smoking (McKnight-Eily et al., 2011; O'Brien & Mindell, 2005). For example, sleep-deprived adolescents and adolescents who report high levels of daytime sleepiness show impairments in higher-level executive functioning, as well as reductions in emotion regulation, impulse control, and effortful control of attention (Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009; Beebe, DiFrancesco, Tlustos, McNally, & Holland, 2009). Furthermore, studies have shown that greater variability in weekday and weekend sleep durations (i.e., "weekend oversleep") is associated with changes in reward-related brain function among adolescents as well as increased risk for AOD use

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(Hasler, Bootzin, Cousins, Fridel, & Wenk, 2008; Hasler et al., 2012).

Sleep disturbances may also contribute to risky sexual behaviors in adolescents, such as sex without a condom or sex with multiple partners, perhaps through similar mechanisms. However, research to date has been mostly cross-sectional, and results have been equivocal. For instance, in a predominantly (78%) Caucasian sample of 388 high school students, O'Brien and Mindell (2005) found cross-sectional associations of self-reported sleep disturbances and greater delay in weekend bedtimes (relative to weekday bedtimes) with sexual risk-taking behaviors (e.g., having sex with multiple partners, sex without condom use). Other analyses from the Youth Risk Behavioral Surveillance System have shown that insufficient sleep duration (i.e., less than 8 hr) is associated with having had sex with one or more partners in the past 3 months (McKnight-Eily et al., 2011; Meldrum & Restivo, 2014). In contrast, in a rural sample of 322 teens from North Dakota, Reichenberger and colleagues (Reichenberger, Hilmert, Irish, Secor-Turner, & Randall, 2016) did not find significant cross-sectional associations of sleep duration with indicators of risky sex, such as having sex multiple partners, getting someone pregnant, not using condoms during sex, or using drugs while having sex. Although the authors did not report the racial/ethnic composition of the sample, according to Census data, the state of North Dakota is predominantly (88%) White/Caucasian (https://www.census.gov/quickfacts/ND).

Data in this area are further limited by the limited assessment of sleep, which has primarily focused on sleep duration. However, it is important to consider other types of sleep issues, including poor sleep quality and variability in sleep duration, in relation to risky sexual behavior, as these sleep issues are also highly prevalent in adolescents and are associated with health risk behaviors (Catrett & Gaultney, 2009; Shibley, Malcolm, & Veatch, 2008). Finally, most of the existing studies of sleep and risky sexual behavior have focused on univariate associations or have included a limited number of covariates, generally gender or age. Given that sleep and risky sexual behaviors are known to covary with other psychosocial characteristics, including mental health symptoms and sociodemographics, the question remains whether sleep issues uniquely contribute to adolescent sexual risk-taking, above and beyond these known risk factors (Shochat, Cohen-Zion, & Tzischinsky, 2014). In a notable exception, however, Wong and colleagues (Wong et al., 2015) found that short sleep duration and greater sleep difficulties predicted greater risk of "having regretted sex due to drinking" at a subsequent wave, even after controlling for alcohol-related problems and sociodemographic characteristics.

In summary, despite compelling evidence that a variety of sleep problems, including, but not limited to, sleep duration, are associated with a range of health risk behaviors in adolescence, there has been little work addressing the association between sleep problems and risky sexual behavior. Furthermore, despite the dynamic nature of sleep and the fact that transient sleep problems are fairly normative in adolescents (Short, Gradisar, Gill, & Camfferman, 2013), the extant literature mostly captures sleep at a single snapshot in time and utilizes constrained measures of sleep. Finally, most of the literature has focused on predominantly Caucasian samples and has failed to statistically control for important confounders, including mental health symptoms. Importantly, sexual risk-taking in adolescence poses serious health risks that can have enduring effects on adolescents' health. For instance, sexually active adolescents have higher rates of sexually transmitted disease (STD) acquisition than any other age group (Weinstock, Berman, & Cates, 2004), and having an STD increases the susceptibility of contracting HIV (Newbern et al., 2013).

The present study addresses some of these limitations by examining the degree to which longitudinal trajectories of multiple types of common sleep disturbances in adolescents are associated with risky sexual behaviors, including sexual activity without a condom or sexual activity in combination with drugs or alcohol in a large, diverse sample of adolescents (ages 16–19). Recognizing the multidimensional nature of sleep and that acute or temporary sleep disruptions are fairly normative in adolescence (Short et al., 2013), the current study includes longitudinal assessments of key sleep domains that have been identified as particularly important for adolescent health and functioning (National Sleep Foundation, 2000)—sleep duration, variability in sleep duration (weekdays vs. weekends), and trouble sleeping—and examines sleep profiles over time, during adolescence and late adolescence. To assess longitudinal sleep patterns, we conducted a longitudinal latent class analysis (LLCA; latent class analysis applied to longitudinal data). LLCA is a type of mixture model that models patterns of states across time rather than scaled change (i.e., change across time is along a single continuous scale) as is common in growth mixture models. For instance, in a simple linear growth mixture model, one might have three classes (groups) of individuals where each class is characterized by a distinct intercept and slope (trajectory). However, in LLCA, intercepts and slopes are not estimated; instead, individuals are grouped into classes by similar patterns across time, which do not assume any particular growth function (e.g., linear). Therefore, in LLCA, assignment to classes is based on similarity of response patterns over time. These models are useful for determining longitudinal profiles of behaviors, such as sleep, particularly when it is not known a priori how the behavior is expected to change over a given developmental period. With regard to sleep during adolescence and late adolescence, whereas there is evidence that sleep problems, including higher rates of insufficient sleep duration, increase across the high school years (Eaton et al., 2010), there is also evidence that for those who transition to college, there may be improvements in sleep relative to high school (Doane, Gress-Smith, & Breitenstein, 2015), which may be due, at least in part, to the removal of a known exogenous contributor to insufficient sleep among high school teens: early school start times (Hale & Troxel, 2018; Owens, the Adolescent Sleep Working Group, & the Committee on Adolescence, 2014). Therefore, LLCA is a particularly useful approach as it can identify patterns of sleep across these developmental periods, and it does not assume a particular form of change over time (e.g., linear) but rather allows sleep patterns or profiles to emerge based on similarity of responses across respondents over time (Feldman, Masyn, & Conger, 2009). We hypothesized that adolescents who showed persistent (over time) sleep problems, including shorter sleep duration, greater variability between weekend and weekday sleep duration, and more trouble sleeping, would be more likely to report risky sexual behaviors at the follow-up assessment, as compared to those with transient sleep problems or "good sleepers." We further hypothesized that the combination of insufficient sleep duration (weekdays and weekends) combined with poor sleep quality would be associated with greater risk of sexual risk-taking.

Given that sleep disturbances are known to covary with a number of factors that are themselves risk factors for sexual risk-taking behavior, notably mental health symptoms (Gregory et al., 2005; Gromov & Gromov, 2009), the current analyses also examined the independent association between sleep trajectories and risky sexual behavior, after statistically controlling for these factors and sociodemographic characteristics.

Method

Participants

The current study utilized four waves of data from Wave 6 (2013) to Wave 9 (2017) from a large multiwave study of adolescents and young adults in Southern California. Participants were initially recruited in sixth and seventh grades (ages 11–13) for an AOD prevention program, CHOICE, and were representative of the 16 middle schools in Southern California from which they were recruited (D'Amico et al., 2012). The study has a Certificate of Confidentiality, and all procedures were approved by the RAND Human Subjects Protection Committee.

Adolescents completed Waves 1–5 in middle school; follow-up rates ranged from 74% to 90%, excluding new youth who could have come in at a subsequent wave. Adolescents transitioned from 16 middle schools to over 200 high schools and were recontacted and reconsented to complete annual web-based surveys. At Wave 6, 61% of teens participated in the follow-up survey. From Waves 6–7, 80% of the sample was retained, 91% of the sample from Wave 7 to Wave 8, and 89% of the sample from Wave 8 to Wave 9. If a participant did not complete a wave of data collection, he or she was still eligible to complete all subsequent waves. That is, we fielded the full sample at every wave so that all participants had an opportunity to participate in each survey. In this study, youth who did not complete at least one sex-related outcome measure at Wave 9 or who did not have sleep data for at least three timepoints were excluded ($N = 689$). The current analytic sample included 1,850 youth (mean age 16.23 at Wave 1 and 19.33 at Wave 4). Compared to excluded youth, the analytic sample had slightly more females (57% vs. 47%), more mothers with a college degree (52% vs. 46%), and fewer youth who reported mixed race/ethnicity (11% vs. 14%). No other significant differences on demographics were found.

Measures

Sleep measures. Self-reported sleep items were added to the ongoing survey in 2013 (Wave 6) and continued through 2017 (Wave 9). The primary sleep measures for the current study were calculated sleep duration for weekdays and weekends separately (derived from reported bedtimes and waketimes), sleep variability (calculated as the difference between weekend and weekday sleep duration), and trouble sleeping (as an indicator of sleep quality). Similar measures have been used in several prior studies with adolescents (Larson, Laska, Story, & Neumark-Sztainer, 2015; Pasch, Laska, Lytle, & Moe, 2010) and have been shown to significantly correlate with diary and actigraphy assessments of sleep (Wolfson et al., 2003). Specifically, for weekday or weekend sleep duration, respectively, youth were asked, "What time do you usually go to bed on school days (or weekend days)?" and "What time do you usually wake up on school days (or weekends)?" The difference between bedtime and waketime was computed and used in analyses for weekday or weekend sleep duration. Notably, because this calculated measure does not account for wakefulness during the sleep period, it is actually a measure of "time in bed." However, to be consistent with the literature, which has used similar methods and used the term "sleep duration," we refer to this variable as "sleep duration" (Kurina et al., 2013; Miller et al., 2015). Weekday and weekday sleep durations were calculated separately given substantial prior research showing considerable variability between weekday and weekend sleep durations for adolescents, largely due to the constraints of early school start times during the week (Owens, the Adolescent Sleep Working Group, & the Committee on Adolescence, 2014). Sleep variability was calculated as the difference between weekday and weekend sleep duration (23). Trouble sleeping was assessed using an item taken from the 15-item Patient Health Questionnaire Somatic Symptom Severity Scale measure (Kroenke, Spitzer, & Williams, 2002). Youth were asked, "During the past 4 weeks, how much have you been bothered by trouble sleeping?" Responses included 1 = not bothered, 2 = bothered a little, and 3 = bothered a lot. These procedures were applied at each assessment in Waves 6–9.

Risky sexual behavior. Risky sexual behavior (Centers for Disease Control and Prevention, 2014) was assessed by combining information obtained from youth who reported on whether they used alcohol/marijuana/other drugs right before (within an hour or so) or during sex (0 = no, 1 = yes) and whether they used a condom during sex (0 = no, 1 = yes; Centers for Disease Control and Prevention, 2014). Responses were then combined such that if youth reported either substance use before/during sex or not using a condom, they were scored as engaging in risky sexual behavior (1 = yes) whereas not using substances before/during sex and using a condom would be scored as not engaging in risky sexual behavior (0 = no).

Covariates. We adjusted for covariates[1] (assessed at Wave 6) known to be associated with sleep and/or risky sexual behavior, such as age, race/ethnicity, gender, maternal education (as a proxy for socioeconomic status), and mental health. Participants were classified into one of five racial/ethnic groups: non-Hispanic White, non-Hispanic Black, Hispanic, Asian, and any other ethnicities. Mental health was assessed using the Mental Health Inventory–5 (MHI-5; Berwick et al., 1991), which comprises five items focused on past-month anxiety and depression symptoms (e.g., felt downhearted and blue, been a very nervous person). Scores on the MHI-5 were scaled such that they ranged from 0 to 100, with higher scores indicating better mental health ($\alpha = .77$). Finally, we included an indicator for whether the student had attended one of the original intervention schools in 2008.

Analytic Methods

To estimate LLCA models, we used the manual three-step approach (Nylund-Gibson, Grimm, Quirk, & Furlong, 2014) using Mplus Version 8.0 (Muthén & Muthén, 2012–2018) to extract classes. First, models were developed separately for each individ-

[1] We ran sensitivity models, additionally controlling for past-month AOD use; however, analyses were virtually the same. Given the overlap with the outcome, models are presented without AOD use as a covariate.

ual sleep measure, resulting in four final best class solutions. These class solutions are based on individual sleep dimensions and characterize distinct developmental patterns associated with each sleep characteristic across the data collection waves, which span adolescence through late adolescence. To determine the best-fitting solution for each individual sleep measure across time, we estimated separate models that fit one to five latent class solutions. Second, we used LLCA to model the developmental patterns of several sleep measures simultaneously, consisting of three of four of the individual sleep dimensions: both weekday and weekend sleep duration, as well as sleep quality. In the multidimensional sleep model, we did not include sleep variability, as it is a variable constructed from weekday and weekend sleep duration and therefore conflated with those variables. Consistent with prior literature using LLCA (Laska, Pasch, Lust, Story, & Ehlinger, 2009), we determined the best final class structure for the individual sleep dimensions and the multidimensional sleep measure by evaluating the combination of several fit indices, including −2 log-likelihood (−2LL), Akaike information criterion (AIC), Bayesian information criterion (BIC), the sample size–adjusted Bayesian information criterion (aBIC), the Vuong-Lo-Mendell-Rubin adjusted likelihood ratio test (VLMRT), and the bootstrapped likelihood ratio test (BLRT). The −2LL, AIC, BIC, and aBIC are all log-likelihood measures for which lower values indicate better fit (Nylund, Asparouhov, & Muthén, 2007). Likelihood ratio testing was determined by the VMLRT and BLRT tests, which compare the improvement between sequential class models (i.e., compare two-class vs. three-class models) and provides a significance test to evaluate the improvement in model fit by including an additional class (Nylund et al., 2007). In addition, theoretical consideration was given to the meaning of the emergent classes as well as the final resulting sample sizes of each class. Thus, decisions on final best-fitting solutions were based on both statistical and theoretical rationale (Lanza, Patrick, & Maggs, 2010).

Next, we sought to understand the association between the emergent classes of longitudinal sleep patterns for each of the sleep dimensions individually (i.e., weekday sleep duration, weekend sleep duration, sleep variability, and trouble sleeping) as well as the multidimensional sleep measure (i.e., consisting of sleep duration and quality) and the outcome: risky sexual behavior assessed at Wave 9. We assessed differences in risky sexual behavior by implementing the manual three-step auxiliary Bolck-Croon-Hagenaars (BCH) approach, which tests for mean differences in the outcome between classes using a Wald chi-square test (Asparouhov & Muthen, 2014). This method fixes the parameters of latent classes to ensure that the measurement of latent classes is not influenced by the inclusion of covariates.

Missing data were handled by Mplus such that it adjusts for missing data using a maximum likelihood estimator under the assumption that data are missing at random and uses all data that are available for each participant.

Results

Sample Description

On average, participants were 16.21 (SD = 0.72) years old at Wave 6 (see Table 1). The sample was 57% female and 44% Hispanic. About 28% of participants had mothers with a high school education or less. Average amount of self-reported sleep across waves ranged from 7.40 to 7.78 hr for weekdays and 8.73 to 9.28 hr for weekends, with sleep quality rated between 1.57 and 1.61 (with 1 = not bothered at all and 2 = bothered a little). At Wave 9, 37% of youth reported engaging in risky sexual behavior.

Table 1
Sample Descriptive Statistics

Variable	Value (N = 1,850)
Demographics	
Age, M (SD)	16.21 (.72)
Female, % (n)	57 (1,054)
White, % (n)	21.6 (399)
Hispanic, % (n)	44.0 (814)
Asian, % (n)	21.1 (390)
Black, % (n)	2.5 (46)
Other race, % (n)	10.9 (201)
Mother's education, % (n)	
Did not finish high school	12.7 (235)
High school	15.4 (284)
Some college	12.7 (234)
College	52.4 (970)
Don't know	6.9 (127)
Mental health (MHI-5), M (SD)	66.28 (19.55)
Weekday sleep duration (hours), M (SD)	
Wave 6	7.62 (1.08)
Wave 7	7.40 (1.19)
Wave 8	7.71 (1.39)
Wave 9	7.78 (1.43)
Weekend sleep duration (hours), M (SD)	
Wave 6	9.28 (1.45)
Wave 7	9.12 (1.43)
Wave 8	8.89 (1.40)
Wave 9	8.73 (1.42)
Sleep variability (hours), M (SD)	
Wave 6	1.65 (1.60)
Wave 7	1.70 (1.62)
Wave 8	1.16 (1.60)
Wave 9	.94 (1.72)
Trouble sleeping, M (SD)	
Wave 6	1.61 (.74)
Wave 7	1.60 (.73)
Wave 8	1.58 (.71)
Wave 9	1.57 (.70)
Any risky sexual behavior, % (n)	36.5 (638)

Note. Demographics, mental health, and sleep measures are taken from Wave 6 in 2013. Risky sexual behavior is measured at Wave 9 in 2017. MHI-5 = Mental Health Inventory–5.

Based on results from the likelihood ratio test (e.g., VLMRT) from the LLCAs, in combination with theoretical consideration, a three-class solution best represented longitudinal patterns of sleep for weekday sleep duration, sleep variability, and sleep quality. Model fit indices and likelihood ratio tests are presented in Table 2. For weekend sleep duration, a four-class structure was also significantly identified; however, it was likely to be a smaller subset of another class already identified and as such resulted in a very small proportion of individuals (< 5%); thus, we kept our three-class solution across all individual sleep measures. For the multidimensional sleep models, a four-class solution best fit the data. Figure 1 shows the pattern of latent classes for each individual sleep dimension.

Weekday sleep duration. Patterns of weekday sleep duration over 4 years revealed three clear latent classes. Group 1, called

Table 2
Model Fit Statistics and Entropy for Longitudinal Latent Class Analyses

Model	(−2LL)	Free parameters	AIC	BIC	aBIC	VLMRT	BSLRT	Entropy
Weekday sleep duration								
One class	23,693.24	8	23,709.24	23,753.43				
Two classes	22,850.48	13	22,876.48	22,948.28	22,906.98	842.76[a]	842.76[a]	.64
Three classes	22,658.89	18	22,694.89	22,794.30	22,737.12	191.59[a]	191.59[a]	.62
Four classes	22,594.36	23	22,640.36	22,767.39	22,694.32	64.53	64.53	.66
Five classes	22,509.03	28	22,565.03	22,719.67	22,630.71	85.33	85.33	.67
Weekend sleep duration								
One class	25,349.35	8	25,365.35	25,409.53	25,384.11			
Two classes	24,505.78	13	24,531.78	24,603.58	24,562.28	843.57[a]	843.57[a]	.59
Three classes	24,276.23	18	24,312.23	24,411.64	24,354.46	229.55[a]	229.55[a]	.68
Four classes	24,196.88	23	24,242.87	24,369.91	24,296.84	79.35[a]	79.35[a]	.66
Five classes	24,151.02	28	24,207.02	24,361.66	24,272.70	45.86	45.86	.71
Sleep variability								
One class	27,037.12	8	27,053.12	27,097.30	27,071.89			
Two classes	26,437.34	13	26,463.34	26,535.14	26,493.84	599.78[a]	599.78[a]	.59
Three classes	26,326.78	18	26,362.78	26,462.20	26,405.01	110.56[a]	110.56[a]	.61
Four classes	26,236.31	23	26,282.31	26,409.34	26,336.27	90.47	90.47	.66
Five classes	26,181.62	28	26,237.62	26,392.26	26,303.31	54.69	54.69	.66
Trouble sleeping								
One class	15,771.35	8	15,787.35	15,831.53	15,806.11			
Two classes	14,261.81	13	14,287.81	14,359.61	14,318.30	1,509.54[a]	1,509.54[a]	.82
Three classes	14,027.91	18	14,063.91	14,163.32	14,106.14	233.90[a]	233.90[a]	.79
Four classes[b]	14,027.91	23	14,073.91	14,200.94	14,127.87	—	—	.83
Five classes[b]	14,027.80	28	14,083.91	14,238.55	14,149.60	—	—	.85
Multidimensional sleep measure								
One class	64,813.93	24	64,861.94	64,994.49	64,918.24			
Two classes	63,035.63	37	63,109.63	63,313.98	63,196.43	1,778.30[a]	1,778.30[a]	.731
Three classes	62,081.46	50	62,181.46	62,457.61	62,2298.76	954.17[a]	954.17[a]	.755
Four classes	61,662.56	63	61,788.56	62,136.51	61,936.36	418.89[a]	418.89[a]	.754
Five classes	61,449.62	76	61,601.62	62,021.37	61,779.92	212.94	212.94	.760

Note. −2LL = −2 log-likelihood; AIC = Akaike information criterion; BIC = Bayesian information criterion; aBIC = sample size–adjusted Bayesian information criterion; BLRT = parametric bootstrapped likelihood ratio test; VLMRT = Vuong-Lo-Mendell-Rubin likelihood ratio test.
[a] Denotes the current class structure (*k* classes) was a significant improvement over the previous class structure (*k* – 1 classes). [b] Denotes models with nonconvergence perturbations.

short weekday sleepers (n = 250, 14%), includes adolescents who slept an average of 6.35 hr per weekday with a range between 5.8 and 6.8 hr across waves. This is the smallest group and includes adolescents who had the poorest (i.e., shortest) weekday sleep duration pattern over assessment waves. Group 2, called *intermediate weekday sleepers* (n = 1,095, 60%), includes adolescents who slept an average of 7.53 hr per weekday with a range of 7.3 to 7.7 hr across waves. This is the most common cluster; however, this cluster notably still falls short of the 8–10 hr of sleep recommended for this age group. Group 3, called *sufficient weekday sleepers* (n = 484, 26%), includes adolescents who consistently slept an average of 8.55 hr per weekday with a range of 8.5 to 8.6 across waves. After accounting for covariates, there were no significant differences between the three weekday sleep duration classes on risky sexual behavior (see Table 3).

Weekend sleep duration. Three distinct classes were identified for weekend sleep duration over the four assessment waves. Group 1, called *short weekend sleepers* (n = 436, 24%), includes adolescents who consistently slept, on average, 7.8 hr on weekend nights with a range of 7.6 to 8.0 hr across waves. Group 2, called *intermediate weekend sleepers* (n = 1,213, 67%), includes adolescents who slept on average approximately 9.2 hr per night on the weekend with a range of 8.9 to 9.5 hr across waves. Group 3, called *long weekend sleepers* (n = 169, 10%), includes adolescents who reported the greatest amount of weekend sleep across the assessments with an average sleep time of 10.64 hr on the weekend with a range of 9.9 to 11.1 hr across waves. As shown in Table 3, after controlling for covariates, significant differences were found such that *short weekend sleepers* were 2.24 times more likely to engage in risky sexual behavior than *long weekend sleepers* (χ^2 = 10.756, p = .001). Similarly, *intermediate weekend sleepers* were 2.28 times more likely to engage in risky sexual behavior than *long weekend sleepers* (χ^2 = 11.995, p = .001).

Sleep variability. Group classification for sleep variability (i.e., differences in weekday/weekend sleep duration) revealed three distinct classes. Group 1, called *low-variability sleepers* (n = 784, 43%), includes adolescents with a relatively small difference in weekday/weekend sleep duration with an average difference of approximately 30 min. Group 2, called *moderate-variability sleepers* (n = 937, 52%), includes adolescents with weekday/weekend sleep duration differences of 1.83 hr (~1 hr and 50 min). Group 3, called *high-variability sleepers* (n = 82, 5%), includes adolescents with relatively large differences between weekday/weekend sleep duration with an average difference of 3.59 hr (~3 hr and 36 min). On average, sleep durations across the week for Classes 1, 2, and 3 are 8.2 hr, 8.39 hr, and 8.59 hr, respectively, indicating that the low-variability class had consistently shorter sleep than the other classes, $F(2, 1{,}847) = 18.741$, $p < .001$. As shown in Table 3,

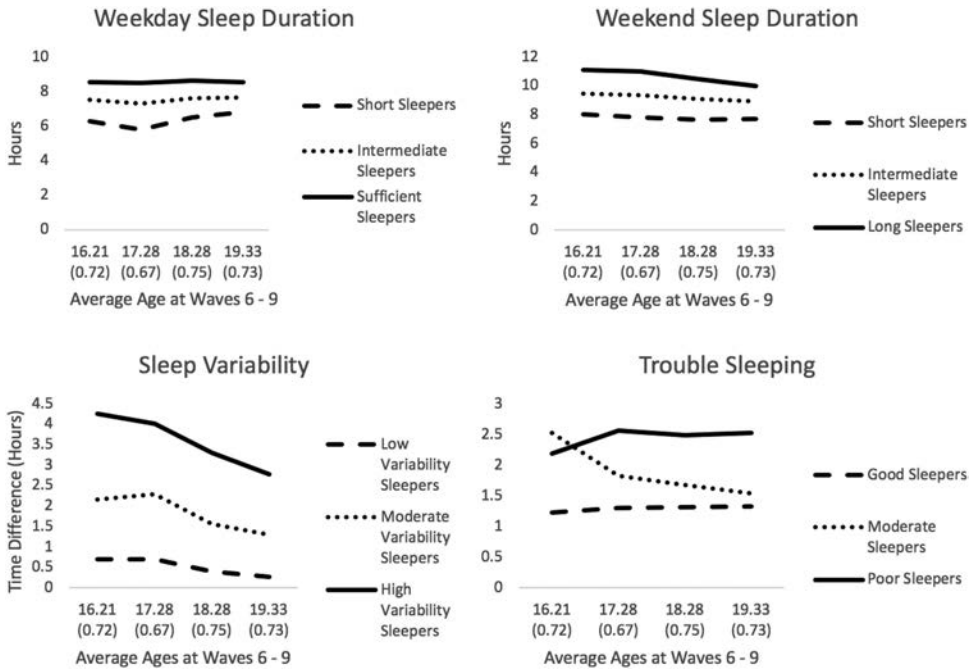

Figure 1. Longitudinal latent classes for individual sleep dimensions.

after controlling for covariates, significant differences were noted such that *low-variability sleepers* were 1.6 times more likely to engage in risky sexual behavior than *moderate-variability sleepers* ($\chi^2 = 8.526$, $p = .004$) and 1.96 times more likely than *high-variability sleepers* ($\chi^2 = 5.244$, $p = .022$).

Trouble sleeping. Three distinct classes of sleep quality (i.e., trouble sleeping) were identified over the four assessment waves. Group 1, called *good sleepers* ($n = 1{,}250$, 68%), includes adolescents who reported on average "little to no" ($M = 1.3$) trouble sleeping across the assessments. Group 2, called *moderate sleepers* ($n = 297$, 16%), includes adolescents who on average reported "little" ($M = 1.9$) trouble sleeping across the assessments. Group 3, called *poor sleepers* ($n = 299$, 16%), includes adolescents who on average reported "little to a lot" ($M = 2.4$) of trouble sleeping across assessments. Table 3 shows that after controlling for covariates, there were no significant differences between the three sleep quality classes on risky sexual behavior.

Multidimensional sleep patterns. Four distinct longitudinal classes emerged for the multidimensional sleep pattern (see Figure 2). Class 1, called "sufficient, poor sleepers" ($n = 260$, 14%), includes adolescents who slept between 7.6 and 8.18 hr across waves ($M = 7.95$ hr) on weekdays and 9.5 hr, on average, on weekends and who reported "little to a lot" ($M = 2.2$) trouble sleeping. In contrast, Class 2 is called "short, poor sleepers" ($n = 216$, 12%), who were characterized by relatively short longitudinal patterns of both weekday and weekend sleep durations (Ms = 6.7 and 8.2 hr, respectively) but similar levels of trouble sleeping ($M = 2.4$). Classes 3 and 4 were differentiated from Classes 1 and 2 by an overall lack of trouble sleeping, despite differing patterns of sleep duration. Specifically, Class 3, called "short, good quality sleepers" ($n = 539$, 29%), was characterized by relatively short weekday ($M = 7.1$ hr) and weekend sleep duration ($M = 8.2$ hr) and minimal trouble sleeping ($M = 1.4$). Class 4, called "sufficient, good sleepers" ($n = 833$, 45%), includes adolescents who slept, on average, 8.1 hr during weekdays and 9.6 hr, on average, on weekends, and who reported minimal trouble sleeping ($M = 1.3$). As shown in Table 3, after controlling for covariates, statistical comparisons for class differences in risky sexual behavior revealed that Class 3 was marginally ($p = .08$) more likely to engage in risky sexual behavior than Class 1 ("sufficient, poor sleepers") and Class 4 ("sufficient, good sleepers"). Given that Classes 2 and 3 both represented "short sleepers" and Classes 1 and 4 "sufficient sleepers," we conducted exploratory analyses of the differences between the two groups of classes. Results indicated that "short sleepers" were 1.25 times more likely to engage in risky sexual behavior than "sufficient sleepers" ($\chi^2 = 5.12$, $p = .024$).

Discussion

The current study is only the second to examine longitudinal patterns of specific adolescent sleep issues as well as a multidimensional sleep measure, consisting of duration and quality, in relation to risky sexual behavior in a racially/ethnically diverse sample of adolescents. Class analyses revealed three distinct longitudinal patterns for each of the individual sleep measures and four distinct patterns for the multidimensional sleep measure. Consistent with prior reports suggesting that insufficient sleep is highly prevalent among adolescents (Matthews, Hall, & Dahl, 2014; Owens, the Adolescent Sleep Working Group, & the Committee on Adolescence, 2014), even the "intermediate" weekday sleep duration group did not meet current recommendations for optimal sleep duration for adolescents. Importantly, the terminol-

Table 3
Risky Sexual Behavior Estimates and Standard Errors by Sleep Measure

Variable	Risky sexual behavior				
	Estimate	*SE*	χ^2	*p*	*OR* [CI]
Weekday sleep duration					
Short sleepers	.33	.04			
Intermediate sleepers	.38	.02			
Sufficient sleepers	.35	.03			
Short vs. intermediate			.92	.337	.94 [.68, 1.29]
Short vs. sufficient			.10	.757	1.14 [.91, 1.42]
Intermediate vs. sufficient			.57	.451	.82 [.62, 1.10]
Weekend sleep duration					
Short sleepers	.38	.03			
Intermediate sleepers	.38	.02			
Long sleepers	.21	.04			
Short vs. intermediate			.02	.901	1.02 [.82, 1.28]
Short vs. long[a]			10.76	.001	2.24 [1.48, 3.39]
Intermediate vs. long[a]			11.99	.001	2.28 [1.55, 3.36]
Sleep variability					
Low variability	.43	.02			
Moderate variability	.32	.02			
High variability	.27	.06			
Low vs. moderate[a]			8.53	.004	1.61 [1.32, 1.96]
Low vs. high[a]			5.24	.022	1.97 [1.19, 3.26]
Moderate vs. high			.34	.560	1.22 [.74, 2.03]
Trouble sleeping					
Good sleepers	.36	.02			
Moderate sleepers	.39	.04			
Poor sleepers	.37	.03			
Good vs. moderate			.61	.435	.86 [.66, 1.12]
Good vs. poor			.19	.667	.93 [.72, 1.21]
Poor vs. moderate			.11	.740	.92 [.66, 1.28]
Multidimensional sleep measure					
Sufficient, poor sleepers (1)	.33	.04			
Short, poor sleepers (2)	.40	.04			
Short, good sleepers (3)	.40	.03			
Sufficient, good sleepers (4)	.34	.02			
1 vs. 2			1.70	.192	.72 [.49, 1.04]
1 vs. 3			2.97	.085	.71 [.52, .97]
1 vs. 4			.14	.713	.93 [.69, 1.25]
2 vs. 3			.00	.970	.99 [.72, 1.37]
2 vs. 4			1.85	.174	1.29 [.96, 1.77]
3 vs. 4			3.03	.082	1.31 [1.05, 1.64]

Note. [a]Covariates in the models included age, race/ethnicity, gender, maternal education (as a proxy for socioeconomic status), mental health, and an indicator for whether the participant was in one of the original intervention schools.

ogy for naming the different classes is somewhat arbitrary and intended primarily to be descriptive in nature.

We hypothesized that greater weekend/weekday sleep differences would be associated with increased risk of engaging in risky sexual behaviors, based on prior cross-sectional work indicating that the tendency for "weekend oversleep" among adolescents may be a marker of circadian misalignment (Owens, the Adolescent Sleep Working Group, & the Committee on Adolescence, 2014). Contrary to our hypothesis, we found that smaller weekday/weekend differences (i.e., lesser variability) in sleep duration were associated with greater likelihood of engaging in risky sexual behavior. This may be due to the low-variability group having a shorter sleep duration across the week than the groups with greater variability.

We also found that the persistently short weekend sleep duration group was more likely to engage in risky sexual behavior. This suggests that adolescents who fail to "catch up" on sleep on the weekends may be chronically sleep deprived and therefore may be at risk for engaging in risky health behaviors. This interpretation is plausible given that two out of three classes of weekday sleep duration fell below recommended guidelines for sufficient adolescent sleep, and only 27% of youth were in the persistently sufficient sleep class (i.e., 8.5 hr). Moreover, our multidimensional sleep models lend further support to this interpretation, as two classes emerged from these models that could be characterized by short weekend and short weekday sleep, with or without trouble sleeping; these "short weekend and weekday sleepers" were disproportionately likely to be characterized as "low-variability" sleepers (50%), as compared to the two other classes with relatively sufficient sleep, at least on the weekends (39% characterized as low-variability sleepers). Furthermore, the pattern of results suggested that those with short weekend and weekday sleep duration (Class 3) were at marginally greater risk for risky sexual

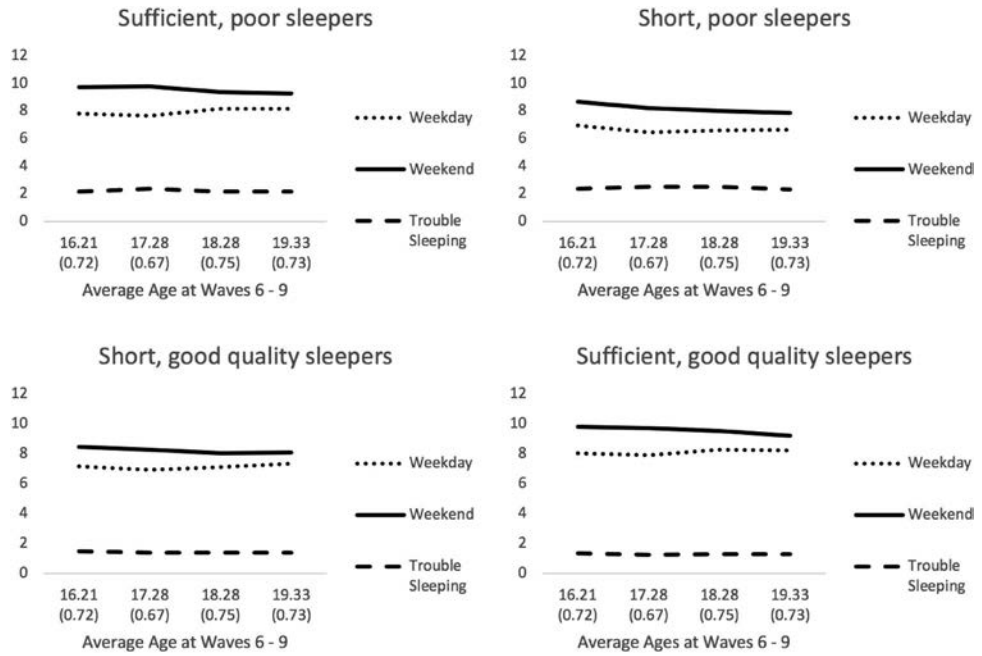

Figure 2. Multidimensional sleep classes.

behavior, as compared to the sufficient sleep classes. Therefore, there may be competing pathways through which chronic insufficient sleep versus weekend "catch-up" sleep are associated with increased risk for poor health behaviors among adolescents.

In contrast to prior research showing that self-reported sleep difficulties are associated with "having regretted sex due to drinking" (Wong et al., 2015), we did not find significant associations between the "trouble sleeping" classes or the multidimensional class that included short weekend and weekday sleep duration and trouble sleeping (Class 2) and the sexual risk behaviors examined in this study. The reasons for this discrepancy are unclear, but they are likely due to differences across studies in the measurement of self-reported sleep quality, differences in the type of sexual risk behavior examined (e.g., regretting sex vs. reporting sex without a condom), or other factors. Given limited work in this area, it is important for future studies to better understand the conditions under which insomnia-related symptoms may impact sexual risk behavior.

Based on the emergent classes from these longitudinal data in adolescence, lack of variability is likely an indicator of the risk associated with chronic sleep insufficiency, rather than a marker of the relative stability or instability of sleep–wake patterns. Indeed, from an intervention perspective, this poses a significant challenge, as the standard sleep hygiene recommendation is to maintain consistent bedtimes and wake-up times throughout the week. However, for the majority of U.S. adolescents, whose weekday sleep opportunity is constrained due to early school start times, maintaining consistency in sleep–wake schedules throughout the week may be not only unrealistic but also unhealthy—if it perpetuates a pattern of chronic sleep insufficiency. On the other hand, excessive weekend "oversleep" can exacerbate teens' biologically driven phase delay, making it even harder to fall asleep at a reasonable hour during the school week. Therefore, finding a "middle ground" that allows for some weekend catch-up sleep, while maintaining some level of consistency in sleep–wake patterns, may be warranted, although more research is needed to determine the most beneficial (and attainable) balance for teenagers (Crowley & Carskadon, 2010).

Importantly, all analyses statistically adjusted for factors known to be associated with both sleep problems and risky sexual behavior, including baseline mental health symptoms. Therefore, findings suggest that persistent sleep problems may uniquely contribute to adolescent risky sexual behavior. Consequently, improving adolescent sleep health may be an important target of prevention and intervention. Alternatively, it may be that weekend insufficient sleep is a marker, rather than a predictor, of risky sexual behaviors, as perhaps adolescents who are staying out later on the weekends, presumably without parental supervision, are more likely to engage in a variety of risky behaviors, including sexual risk-taking. Other unmeasured factors may also play a role, such as greater time spent with peers, greater susceptibility to peer influences and peer pressure, and less parental involvement.

Nevertheless, there are several plausible pathways through which sleep disturbances, including insufficient sleep or poor sleep quality, could influence sexual behavior outcomes among adolescents. Consistent with the literature on sleep disturbances and other risk-taking behaviors, including AOD use, sleep loss and problems may increase the likelihood for risky sexual behaviors via changes in reward-related neural circuitry and by influencing impulsivity and decision-making processes (Hasler & Clark, 2013). For instance, in a study that utilized a task that simulated real-life decision-making, under sleep-deprived conditions, participants made dramatically riskier decisions as compared to their own performance under rested conditions (Killgore, Balkin, & Wesensten, 2006). Thus, sleep loss or problems in adolescents may increase risk for sexual risk-taking, by compromising decision-making and by altering

reward-related brain function. In addition, sleep problems may also be implicated in adolescent sexual risk-taking by influencing affective and behavioral regulation (Dahl & Lewin, 2002). Although we statistically adjusted for mental health symptoms, it is possible that other unmeasured mental health symptoms or problems with emotion or behavior regulation may underlie some of the associations between sleep problems and risky sexual behaviors.

Our findings add to the small literature on longitudinal sleep patterns and health risk behaviors among adolescents by examining trajectories of sleep patterns in association with sexual risk-taking. Strengths of the study include the large, racially ethnically diverse sample of youth; the longitudinal assessment of sleep; the inclusion of multiple domains of sleep relevant to adolescent health behaviors; and inclusion of key covariates known to be related to sleep and/or risky sexual behaviors.

It is also important to note study limitations. First, findings cannot establish causality or temporality between sleep problems and sexual behaviors, as items used to assess risky sexual behavior were examined only at Wave 9. In addition, due to concerns about insufficient power and parameter and standard error bias, biological sex was treated as a covariate rather than as a multigroup indicator (Nylund et al., 2007). However, it will be important for future studies to assess larger samples and consider whether differential associations between sleep classes and sexual behaviors emerge. An additional limitation is the use of self-reported measures of sexual behavior and sleep patterns, which may have introduced bias or common method variance. Moreover, self-reported sleep duration was calculated from self-reported bedtimes and wake-up times, which may overestimate actual sleep time, given it does not account for sleep latency or middle-of-the-night awakenings. However, similar methods are used in other epidemiologic sleep studies (Hasler et al., 2004; Miller et al., 2015) and have shown modest correlations with actigraphy-assessed sleep time spent asleep (Cespedes et al., 2016). As mentioned, a strength of our study is the broader assessment of longitudinal sleep patterns using assessments that have been validated in prior work with adolescents (Wolfson et al., 2003), particularly given that prior work primarily has been on sleep duration only. However, research that includes objective measures of sleep patterns via wrist actigraphy or polysomnography would reduce recall or other biases inherent to self-report and provide a more comprehensive assessment of sleep patterns and variability. Furthermore, our measure of trouble sleeping was based on a single-item measure, rather than a validated measure of sleep quality, such as such as the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), which may have limited its utility in predicting risky sexual behaviors.

In summary, current findings add to the growing literature suggesting a potential role of sleep disturbances in contributing to adolescent risk-taking behaviors, including, in this case, sexual risk-taking. The epidemic nature of insufficient sleep among adolescents has been well documented. Findings further demonstrate the persistence of insufficient sleep across the adolescent years. Multipronged strategies that consider both individual/family-level interventions, including increased parental monitoring/rule-setting around bedtimes and use of technology, as well as policy-levers, such as delaying school start times, are needed to reduce the epidemic of teen sleep problems and mitigate the impact of sleep problems on risk-taking behaviors, including sexual risk-taking.

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