“SLEEP TIGHT, DON’T LET THE DYSFUNCTION BITE!” THE RELATIONSHIP BETWEEN SLEEP PROBLEMS AND BEHAVIORAL AND EMOTIONAL PROBLEMS IN ADOLESCENCE

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"SLEEP TIGHT, DON'T LET THE DYSFUNCTION BITE!"
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LIFESPAN DEVELOPMENTAL PSYCHOLOGY

ABSTRACT

The effects of sleep on behavioral and emotional functioning in a low income, urban sample of 84 African American adolescents was investigated over 3 years (mean ages: 13.36, 14.76, and 16.14 years) of parent and child interviews. Results suggest child-reported sleep duration decreased while all other sleep variables remained stable. Substance use increased over time. Physical aggression and conduct problems decreased; depression, emotional problems, and hyperactivity/inattention remained stable until late adolescence and then decreased. Lower duration of sleep and more sleep problems at age 13 predicted more conduct problems at age 15 which, in turn, predicted less sleep duration and more sleep problems at age 16. More weekend oversleep at age 13 predicted more depression at age 15 and more emotional problems at age 16. This implies that different aspects of sleep (e.g., duration vs. regularity) are associated with different types of psychosocial outcomes for adolescents. Developmental differences were investigated, but were found to be significant only in terms of sleep duration's relationship to conduct problems. Specifically, shorter sleep duration was significantly related to increased conduct problems during early adolescence but not later adolescence. This suggests interventions targeting sleep behavior might be particularly developmentally relevant for younger adolescents. The study was limited by a small

sample size and informant discrepancies but still provides valuable insight in a unique population.

Keywords: Sleep, adolescence, developmental psychopathology, behavioral problems, emotional problems

DEDICATION

This work is dedicated, with the deepest gratitude, to my entire family, whose members have ever been happy to lend an interested ear and a supportive word.

But, especially, in loving memory of my grandparents:

- Gleason Henry, who would have made sure to be front row, center, to watch me "graduate from law school or something"
- Dorothy Henry, who was always sure I'd be a doctor someday (even if her money was on pediatrician), and
- Reatha Spence, who first taught me to love solving problems with days together spent watching "The Wheel"

And with the sincerest love and appreciation for my brother, Matthew, who keeps my laughter well-practiced, and for my parents, Mark and Sylvia, who taught me to value both education and myself.

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CHAPTER ONE

INTRODUCTION

In 1896, Patrick and Gilbert conducted the first known study of the effect of sleep loss on human behavior. They observed three male subjects during a 90 hour enforced sleep fast, assessing their reaction times, discrimination times, memory, and sensitivity to pain, along with physical characteristics such as pulse, temperature, weight, and grip/pull strength. In general, their results suggest that prolonged periods of sleeplessness are detrimental to both cognitive and physical functioning (Gregory & O'Connor, 2002; Patrick & Gilbert, 1896). Since the nineteenth century, many researchers have expanded on Patrick and Gilbert's work. An ample body of literature now demonstrates the importance of sleep for general health, cognitive, and behavioral outcomes (Reynolds & O'Hara, 2013). In adults, insufficient sleep has been linked to lower self-control (Budnick & Barber, 2015), poorer working and short-term memory, lowered attention and increased risk of injuries (Lim & Dinges, 2010), and increased risk of substance abuse (Gregory, Rijsdijk, Lau, Dahl, & Eley, 2009). There is also growing evidence that adolescents may experience a developmental vulnerability for sleep problems and that sleep problems may contribute to behavioral and emotional problems in adolescence (Carskadon, 2011; Gregory & Sadeh, 2012). However, relatively little research has investigated these potential bi-directional relationships prospectively during adolescence and, to our knowledge, none has focused specifically on African American adolescents in an urban setting.

An estimated 50 to 70 million adults in the United States suffer from some sort of sleep problem, with the resulting costs rising into the billions (Harding & Feldman, 2008). In addition, national surveys over recent years have indicated that insufficient sleep and sleep problems are increasing for both children and adults (National Sleep Foundation, 2014). As a result, sleep problems are viewed as a growing health concern worldwide. The Centers for Disease Control (CDC) has even established National Sleep Week in an effort to promote awareness of the potential dangers of sleep problems and to disseminate education on good sleep hygiene (Centers for Disease Control, 2011). Sleep problems may take the form of specific sleep disorders, such as insomnia, night terrors, sleep apnea, and restless leg syndrome (American Psychiatric Association, 2013a, 2013b). However, because of the low prevalence rates of many of the sleep disorders described in the DSM 5 (American Psychiatric Association, 2013a), most of the research on sleep problems has focused more broadly on insufficient sleep. In general, insufficient sleep refers to any situation in which an individual receives less sleep than is needed for optimal rest and rejuvenation, typically 7-8 hours for adults (Owens et al., 2014). National estimates indicate that 30-40% of adults average less than seven hours of sleep each night (Centers for Disease Control, 2011). Among children and youth, approximately 56% of 15-17 year olds, 29% of 12-14 year olds, and 8% of 6-11 year olds sleep for seven or fewer hours each night (National Sleep Foundation, 2014).

Insufficient sleep has been linked to negative outcomes for both adults (Budnick & Barber, 2015) and adolescents (N. B. Bryant & Gómez, 2015; Owens et al., 2014). Insufficient sleep is a particular concern for adolescents, because the prevalence of insufficient sleep increases with age (National Sleep Foundation, 2014). Sleep problems

are common to adolescents worldwide (Carskadon, Acebo, & Jenni, 2004; Gradisar, Gardner, & Dohnt, 2011). Depending on the study, 11-47% of adolescents report trouble getting to and/or staying asleep (Liu & Zhou, 2002; Russo, Bruni, Lucidi, Ferri, & Violani, 2007), while 20-25% report excessive daytime sleepiness (Pieters et al., 2015). Comparatively, the current generation is more sleep deprived worldwide than previous generations (Matricciani, Olds, & Petkov, 2012), likely due to a combination of environmental, psychological, and physiological factors (Gregory & Sadeh, 2015).

Developmental Changes to the Sleep-Wake Cycle in Adolescence

Recent research suggests that increases in levels of insufficient sleep during adolescence are at least partly attributable to three key changes in sleep patterns which occur as part of the developmental shift from childhood to adolescence (Pieters et al., 2015). First, *delayed phase preference* refers to adolescents preferring to go to sleep and wake up later than children (Adair & Bauchner, 1993; Pieters et al., 2015), with studies from multiple countries (e.g., Canada, Poland, Australia, Finland, Belgium, and Brazil) documenting later bedtimes worldwide as adolescence progresses (Adair & Bauchner, 1993). Second, earlier school start times typically occurring for older students (Gregory & Sadeh, 2012) result in accumulation of *sleep debt* (N. B. Bryant & Gómez, 2015). Finally, adolescents show more extreme *differences in the timing and duration* of their sleep during the week versus over the weekend than younger children (Adair & Bauchner, 1993).

A key factor underlying delayed phase preference in adolescence is physical maturation (Carskadon, Vieira, & Acebo, 1993), which affects two biological processes

driving sleep (Adair & Bauchner, 1993). First, the *homeostatic sleep drive* builds the longer one is awake, exerting sleep pressure and helping one to fall asleep. More mature adolescents accumulate sleep drive more slowly during the day than less mature adolescents, and thus have a harder time falling asleep and stay awake later as a result (Adair & Bauchner, 1993). The second process involves the *circadian system* which regulates one's internal biological clock. Adolescents produce melatonin later in the day than younger children or adults, which contributes to the experience of a longer internal day and a preference for a later bedtime (Adair & Bauchner, 1993). Pubertal development is the key underlying factor of these changes, as it is more strongly related to a preference for later bedtimes than age, especially in females (Carskadon et al., 1993).

However, environmental factors also contribute to developmental changes in adolescent sleep (Adair & Bauchner, 1993), including increased homework demands (Manber et al., 1995), increased time commitments to work or extracurricular activities and decreased parental supervision of bedtimes (Carskadon, 1990), and use of electronic devices (Adair & Bauchner, 1993; Cain & Gradisar, 2010; Van den Bulck, 2004). Such factors make later bed times more likely as adolescence progresses. These delayed bed times, coupled with continued early school start times, make insufficient sleep more likely for adolescents.

Sleep Problems in Relation to Behavioral and Emotional Functioning

In addition to developmental changes in sleep patterns, adolescence is also a period characterized by developmental changes in biology, cognition, and social relationships which put adolescents at increased risk for behavioral and emotional

problems. Compared to other age groups, adolescents are more likely to engage in risk taking (e.g., risky sexual behavior, risky driving, etc.) and to experience lower self-regulation, increased aggression and delinquency, and greater prevalence of psychological disorders (e.g., anxiety, depression, and substance use; Steinberg, 2014). Importantly, both behavioral and emotional functioning has been linked with sleep problems (Pieters et al., 2015). Since maladaptive behaviors and emotions in adolescence contribute to lifelong trajectories of psychopathology (Newman, Harrison, Dashiff, & Davies, 2008) and influence health and success later in life (Steinberg, 2014), it is important to consider the role of related factors, such as sleep, in the development of these problems. Below, we summarize existing literature on the links between sleep and specific types of behavioral and emotional problems.

Aggression

Both quantity (sleeping more or less than others) and quality (e.g., feeling tired) of sleep have been associated with higher rates of aggression in adolescence across normative, clinical, and criminal populations of youth (Coulombe, Reid, Boyle, & Racine, 2011; Dahl & Harvey, 2007; Ireland & Culpin, 2006). Possible mechanisms explaining the effects of sleep on aggression include increased irritability and impulsivity, which have been linked to sleep problems (Dahl & Harvey, 2007) and contribute to more aggressive responses (Steinberg, 2014). Interestingly, one study with adults failed to find an effect of induced sleep deprivation on most measures of impulsivity, although sleep-deprived males made more risk-taking decisions on the Balloon Analogue Risk Task (BART; Acheson, Richards, & Wit, 2007). By contrast,

sleep deprived women made *fewer* risk-taking decisions on this task. It is possible that sleep problems are related to impulsivity in adolescents but not adults, and possible gender differences in this relationship may need to be further explored.

Some have proposed that sleep problems may be more strongly related to aggression in youth already at high risk for aggression. For instance, lower duration and quality of sleep were associated with higher self-reported aggression in juvenile offenders (Ireland & Culpin, 2006). In this study, lower duration and quality of sleep were most strongly related to hostility, a cognitive component of aggression assessing rumination and enduring resentment after acute anger has passed (Buss & Perry, 1992). Insufficient sleep also predicted later self-reported aggressive behavior in adolescents who completed outpatient substance abuse treatment (Haynes et al., 2006). However, neither study compared the adolescents to a community sample, so it is unknown how these relationships between sleep and aggression compare to normative youth populations.

In summary, multiple studies have linked sleep problems with aggression across various adolescent populations. Although a few of these studies used a prospective design to predict changes in aggression from previous sleep problems, most studies were cross-sectional and thus could not determine the direction of the relationships between sleep and aggression. While most studies conceptualized sleep problems as a predictor of aggression, it is also possible that the emotional arousal or cognitive rumination associated with aggression contributes to poorer sleep.

Substance Use

In one national study, adolescents who experienced sleep problems were more than twice as likely to have used inhalants, marijuana, cigarettes, or alcohol during the past year compared to youth without sleep problems (Johnson, Breslau, Roehrs, & Roth, 1999). Adolescents who reported daily smoking were also more likely to report sleep problems (Holmen, Barrett-Connor, Holmen, & Bjermer, 2000). Several prospective studies have also linked poor sleep with an increased risk of substance use. For instance, mother-reported sleep difficulties at child age 3-5 years predicted child-reported substance use at 12-14 years (Wong, Brower, Fitzgerald, & Zucker, 2004). In addition, adolescents' self-reported sleep problems at 16 years predicted more alcohol-related problems (e.g., binge drinking, regretted sexual activity, driving under the influence) one year and five years later (Wong, Robertson, & Dyson, 2015). Sleep problems have also been implicated as a risk factor for relapse after treatment for substance abuse (Bootzin & Stevens, 2005). Sleep problems can increase the likelihood of substance use through several mechanisms. Sleep disturbances, along with the accompanying daytime sleepiness and academic problems, may contribute to self-medication using substances (Bootzin & Stevens, 2005). For example, adolescents might use stimulants to combat daytime sleepiness or alcohol to reduce sleep problems (Stevens & Murphy, 2000). Unfortunately, alcohol use after insufficient sleep actually increases daytime sleepiness (Lumley et al., 1987), possibly contributing to a vicious cycle between sleep problems and substance use.

As noted above for aggression, the relationship between sleep and substance use may be bi-directional. In addition to sleep problems predicting substance use over time,

adolescents who use or abuse substances may be more likely to experience sleep problems. While research supports this bi-directional relationship in adulthood, especially among clinical populations (Brower, 2001), few studies have investigated it among adolescents, and those that do appear inconsistent. In one study, for example, self-reported sleep problems predicted self-reported substance use one year later, but only alcohol (and not other substances) predicted sleep problems over time and, contrary to hypotheses, more alcohol use predicted fewer sleep problems (Pieters et al., 2015).

Hyperactivity and Inattention

Research on the relationship between sleep and hyperactivity/inattention is relatively scarce and, like much of the research on sleep and other behavioral outcomes, involves mostly cross-sectional studies. Most of this research has focused on adolescents diagnosed with attention-deficit/hyperactivity disorder (ADHD), who exhibit clinical levels of hyperactivity and/or inattention (American Psychiatric Association, 2013a). Parent and self-reports of sleep problems tend to be higher in youth with vs. without ADHD, although these results do not replicate across all studies, particularly those using objective sleep measures such as actigraphy or polysomnography (Yoon, Jain, & Shapiro, 2012). However, a recent meta-analysis focusing on studies comparing non-medicated children with ADHD to controls concluded that children with ADHD experience more sleep problems, as assessed through both subjective (e.g., number of reported wakings, reported difficulties sleeping) and objective (e.g., sleep efficiency and duration as measured by actigraphy) measures (Cortese, Faraone, Konofal, & Lecendreux, 2009).

Few prospective studies have been conducted, but one such study found that more severe ADHD symptoms predicted more persistent sleep problems over a one-year period (Lycett, Mensah, Hiscock, & Sciberras, 2014). Little research has investigated the potential effects of sleep problems on ADHD symptoms. However, the nature of ADHD suggests that it could be aggravated by sleep problems. Poor sleep might contribute to problems in mood or motivation (both of which are ADHD symptoms) while other symptoms of ADHD (e.g., poor organization and time management) might contribute to lack of sleep, which could then continue to exacerbate mood and motivation problems (Yoon et al., 2012). No empirical research has yet investigated the potential bi-directional relationships between sleep problems and hyperactivity or inattention symptoms. In addition, most of the research conducted in this area has focused on comparing clinical ADHD samples with healthy controls, providing limited insight into the role of continuous distributions of ADHD symptoms (e.g., hyperactivity and inattention) as they occur in the general population of youth.

Depression

Research supports a cross-sectional relationship between sleep problems and depression. For example, in a community sample of adolescents, insomnia symptoms were associated with concurrent depression, suicidal ideation, and suicide attempts (Roane & Taylor, 2008). Prospectively, self-reported insomnia problems during adolescence predicted a depression diagnosis at a 6 to 7-year follow-up (Roane & Taylor, 2008), although parent reports of sleep problems at ages 5, 7, and 9 did not predict self-reported depressive symptoms in adulthood (Gregory et al., 2005). It is possible that

sleep problems in adolescence have a stronger effect on later depression than sleep problems in childhood, or that these effects do not persist for longer time periods. The causal effect of insufficient sleep on depression was also supported by an intervention study, where sleep hygiene education and a schedule of gradually advancing bed times increased the duration of sleep and reduced depressive symptoms compared to a control group (Dewald-Kaufmann, Oort, & Meijer, 2014).

Again, research investigating bi-directionality of the relationship between sleep problems and depression is scarce and inconsistent. In one study with twins, parent-reported sleep problems at age 8 predicted self-reported depression at age 10, but depression did not predict sleep problems (Gregory et al., 2009). Another study with adolescents found that shorter duration of sleep predicted an increased risk of major depressive symptoms over two years, and that higher levels of depressive symptoms predicted more sleep problems (Roberts & Duong, 2013). However, this relationship was not found across all time points and sleep problems were defined strictly as insomnia.

In a recent review of nine studies exploring the bi-directional links between insomnia and depression (Alvaro, Roberts, & Harris, 2013), a majority of the studies provided at least some evidence for bi-directionality. However, in studies involving only children or adolescents, early sleep problems generally predicted higher levels of depression, but depression was not predictive of sleep problems. Similarly, a meta-analysis of 23 studies found support for significant cross-sectional relationships between sleep problems and depression, as well as for sleep problems predicting depression over time, but not for depression predicting later sleep problems (Lovato & Gradisar, 2014). However, this last nonsignificant result may be due to the small number of studies testing

this relationship (3 vs. 13 and 7 for the other two effects). In fact, the authors still proposed a bi-directional framework for the development of depression, with lower sleep quality increasing rumination which, in turn, may promote depressive symptoms that make sleep more difficult.

Anxiety

Cross-sectional findings demonstrated a positive relationship between sleep problems and anxiety symptoms across ages 9 to 16 (Shanahan, Copeland, Angold, Bondy, & Costello, 2014). Longitudinally, sleep problems predicted increased anxiety both in childhood and adolescence (Jansen et al., 2011; Shanahan et al., 2014). Meanwhile, in comorbid cases of anxiety and insomnia, 73% of retrospective informants reported that the anxiety symptoms came first (Gregory & Sadeh, 2012). Compared to depression, there is stronger evidence for a bi-directional relationship between sleep and anxiety (Alvaro et al., 2013; Shanahan et al., 2014). However, sleep appears to be a more consistent predictor of anxiety, as only certain aspects of anxiety (e.g., generalized anxiety symptoms) predicted poorer quality sleep (Gregory & Sadeh, 2012).

Many studies investigating the relationship between sleep and anxiety have included samples with clinical levels of anxiety, which raises questions about the applicability of these findings to the general population. In a recent study using a community sample of children aged 8-14 years, poorer quality and shorter duration of sleep predicted higher levels of anxiety symptoms over 5 years (Kelly & El-Sheikh, 2014). Conversely, anxiety also predicted poorer sleep, although the relationships were not as strong.

Overall, the literature suggests that various behavioral and emotional problems are associated with both poor quality and short duration of sleep. However, the temporal nature of these relationships, including possible bi-directionality, is less clear and warrants further study.

Sleep in African American Youth

Past research has demonstrated racial disparities between African American and Caucasian individuals for a variety of medical conditions, and these disparities may also extend to sleep outcomes (Cukor et al., 2016). While there is still relatively little research in this area, results indicate that African Americans experience overall poorer sleep than Caucasians, including higher rates of obstructive sleep apnea (Jean-Louis et al., 2008), more sleep problems, greater latency to sleep, lower sleep duration, lower sleep quality (Chen et al., 2015), and greater daytime sleepiness (Patel, Grandner, Xie, Branas, & Gooneratne, 2010). Even less research has focused on the effects of sleep in African American adolescents.

Understanding the relationships between sleep and behavioral and emotional outcomes is particularly important among African American adolescents, because ethnic minorities are less aware of severe sleep issues (Cukor et al., 2016) and are at increased risk for both sleep problems and behavioral and emotional dysfunction. Increased risk of sleep problems may come, in part, from living in urban environments, which present unique challenges for healthy sleep behaviors such as noise pollution (Cukor et al., 2016; Hale & Do, 2007). Living in distressed urban communities is also related to increased risk for behavioral and emotional problems among minority adolescents (S. Anderson,

Donlan, McDermott, & Zaff, 2015; Leventhal & Brooks-Gunn, 2011). Compared to Caucasian adolescents, African American youth are more likely to initiate alcohol and marijuana use earlier (Lanza, Vasilenko, Dziak, & Butera, 2015) and suffer more negative long-term effects of substance use (Mercado-Crespo & Mbah, 2013; Wallace Jr et al., 2002). Although the results are mixed, some studies find that African American adolescents are more likely than Caucasians to experience symptoms of depression and/or anxiety (E. R. Anderson & Mayes, 2010). Minority youth are also typically underserved by mental health services, especially in cases of internalizing disorders (Gudiño, Lau, Yeh, McCabe, & Hough, 2009).

Limitations of Past Research

Sleep researchers have long made the distinction between sleep *duration* and sleep *regularity*. However, much research on the effects of sleep tends to focus on duration, without great consideration for regularity (Acebo & Carskadon, 2002). This may be especially problematic when studying adolescent sleep, given that adolescents frequently report irregular sleep, with large differences between weekend and weekday sleep schedules (Szymczak, Jasińska, Pawlak, & Zwierzykowska, 1993; Wolfson & Carskadon, 1998). To investigate effects of sleep regularity, reported bed and wake times can be used to calculate *weekend delay* (the difference between weekend and weekday bedtime) and *weekend oversleep* (the difference between weekend and weekday total sleep time; Wolfson & Carskadon, 1998). In adolescents, these irregularity variables have been linked to lower academic achievement, behavior problems (Wolfson & Carskadon, 1998), and depression (Acebo & Carskadon, 2002). Additionally, when sleep

duration and irregularity variables were included in the same studies, they predicted different outcomes (Acebo & Carskadon, 2002). This suggests that a combination of both sleep duration and sleep regularity variables—like weekend delay and weekend oversleep—may provide more comprehensive explanations for the relationships between sleep and various behavioral and emotional outcomes.

As reviewed above, previous studies have several other limitations which interfere with our ability to fully understand the relationship between sleep problems and behavioral and emotional problems in adolescence. Many studies were cross-sectional (Pieters et al., 2015), not allowing for the assessment of the temporal relationships between sleep and emotional and behavioral problems. In addition, relatively few studies to date have considered the possible bi-directionality of these relationships, and their results have not always been consistent. In general, the evidence is stronger for sleep as a predictor of adjustment problems than vice versa, and reciprocal relationships between sleep and behavioral and emotional problems have been found more consistently in adults than children or adolescents. For those studies focusing on younger youth, several factors may limit generalizability of their findings. First, some of the few studies investigating these bi-directional relationships have restricted definitions of sleep problems and behavioral or emotional problems to clinical populations. However, the most commonly reported sleep problems in adolescence are difficulties getting to and staying asleep (Pieters et al., 2015), which typically do not meet clinical cut-offs for insomnia or other sleep disorders. Similarly, many adolescents suffer behavioral or emotional difficulties which are insufficient to warrant a clinical diagnosis, but which nonetheless negatively impact developmental outcomes (Brière, Janosz, Fallu, &

Morizot, 2015; Dekker et al., 2007; Fernandez Castelao & Kröner-herwig, 2013; Weeks et al., 2014). Thus, a prospective study using a community sample of adolescents could provide valuable insights into the possible bi-directionality of the relationships between sleep problems and both behavioral and emotional issues during this critical period of development.

Current Study

The proposed study seeks to address current gaps in the literature and to advance our understanding of the relationship between sleep and psychosocial adjustment in adolescence in several ways. First, we will utilize an urban community sample comprised of a majority of African American adolescents. These adolescents are more likely to experience sleep problems (Jansen et al., 2011; Leahy & Gradisar, 2012) and to experience more negative outcomes as a result of poor quality sleep (Kelly & El-Sheikh, 2014), but have been underrepresented in many studies of sleep (Gregory et al., 2011). Second, we will use a prospective design including three waves of data collection, which will enable us to examine prospective, bi-directional relationships between sleep and emotional and behavioral problems across multiple points during adolescence. We hypothesize that more sleep problems, more weekend delay, more weekend oversleep and shorter sleep duration will be associated with behavioral and emotional problems within each wave; that sleep problems, weekend delay, weekend oversleep, behavioral problems, and emotional problems will increase over time, whereas sleep duration will decrease; that more sleep problems, weekend delay, and/or weekend oversleep and shorter sleep duration will predict increased behavioral and emotional problems over

time; and that more behavioral and emotional problems will predict increased sleep problems, weekend delay, and/or weekend oversleep and shorter sleep duration over time. We further hypothesize that these relationships will be significant after controlling for covariates including gender, pubertal development, age, overall household income, and parental education, all of which have been related to adolescent sleep problems and/or behavioral and emotional problems (Arber, Bote, & Meadows, 2009; Crowley, Acebo, & Carskadon, 2007; El-Sheikh et al., 2013; Gregory & O'Connor, 2002; Johnson & Breslau, 2001; Marceau, Ram, Houts, Grimm, & Susman, 2011; Wong, Brower, & Zucker, 2009).

CHAPTER TWO

METHOD

Participants and Procedures

The sample included 84 adolescents and their caregivers who participated in the Coping with Violence study, conducted between 2011 and 2015. Adolescents were recruited from four middle schools (grades 6 to 8 or 9) serving low income, urban communities in the Birmingham, AL area. The sampled schools included 83.4 to 96.8% African American students and 83 to 87% of the students were eligible to receive free or reduced price lunch at school (Alabama State Department of Education, 2016).

Students were given information packets which described the study and included a contact information form and the assent and consent forms for the study. Families interested in participating returned their contact information to their school and were later contacted by study personnel to schedule an interview at a university laboratory. From approximately 240 invited students, 129 (54%) provided their contact information and 84 of those (65%) completed the Wave 1 interview. The youth had a mean age of 13.3 years and included 50% females; 95% identified as African American, 4% as Caucasian, and 1% as Hispanic. Seventy-six (90%) of those adolescents returned approximately a year and a half later to complete a Wave 2 interview (Mean age=14.7 years) and 75 (89%) completed a Wave 3 interview after another year and a half (Mean age=16.1 years). The

sample reflected the demographic composition of the sampled schools; the average annual income was between $20,000 and $25,000 (range <$5000 to $70,000-$90,000).

At each wave, informed consent was obtained from the parent and assent from the adolescent. The adolescent and his or her primary caregiver were then interviewed separately in private rooms by trained study staff using computer assisted technology. Sensitive questions (e.g., about adolescent substance use and emotional and behavioral problems) were completed privately through audio assisted self-interview. At the end of the approximately 1.5 hour interview, both parent and adolescent received a $50 compensation for their time. All study procedures were approved by the university's Institutional Review Board (IRB).

Measures

Sleep Problems

Adolescent's sleep problems were assessed using a 22-item scale from the Sleep History section of the Adolescent Sleep Habit Survey (Owens, 2002). At each wave, both adolescent and parent rated the frequency with which the adolescent experienced various sleep problems during the course of a typical week on a 5-point scale ranging from 'Never' (1) to 'Every day' (5). These sleep problems included disruption to the sleep-wake cycle (e.g., staying up late), insomnia (e.g., difficulty staying or falling asleep), daytime sleepiness (e.g., falling asleep during school classes), parasomnias (e.g., nightmares or sleepwalking), sleep disordered breathing (e.g., snoring, waking up gasping for breath), and general quality of sleep (e.g., feeling satisfied with sleep; reverse coded). Factor analyses confirmed that all items loaded on a single dimension, consistent with previous research that combined responses to similar items (Gregory et al., 2011).

The 22 items were averaged separately for each informant (child and parent) to create a mean sleep problems score, with higher values indicating more sleep problems.

The child-reported sleep problems scale had acceptable reliability in this study, which improved with the removal at all waves of an item assessing snoring ($.70 \leq \alpha \leq .75$). However, the parent-reported sleep problems scale did not have acceptable reliability ($.56 \leq \alpha \leq .64$). Investigation of modification indices suggested no consistent pattern of change that could improve reliability to acceptable levels. Thus, the parent-report of sleep problems was not used in this study.

Sleep Duration

At each wave, the adolescent and their parent were asked to report the adolescent's typical bedtime and wake time, separately for weekdays and weekends. These reports were used to compute typical weekday sleep duration and typical weekend sleep duration. Then, average daily amount of sleep was calculated based on a typical week including five weekdays and two weekend days, separately for parent and adolescent reports.

Weekend Delay

At each wave, reported weekday bedtime was subtracted from reported weekend bedtime (Wolfson & Carskadon, 1998). This difference represents the amount of time adolescents delay going to bed on the weekends and is reported in minutes. A separate measure of weekend delay was computed from both parent and adolescent reports of bed times.

Weekend Oversleep

At each wave, total reported weekday sleep duration was subtracted from total weekend sleep duration (Wolfson & Carskadon, 1998). This difference is the amount of time adolescents oversleep on weekends and is expressed in minutes. A separate measure of weekend oversleep was computed from both parent and adolescent reports of sleep duration.

Behavioral and Emotional Problems

Parent report

At each wave, parents completed the 25-item Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). Parents were asked to rate how true various statements were about their child on a 3-point scale ranging from 'Not true' (1) to 'Certainly true' (3). This study only utilized three of the five 5-item subscales: conduct problems (e.g., "Steals from home, school, or elsewhere"), hyperactivity/inattention problems (e.g., "Easily distracted, concentration wanders"), and emotional problems (e.g., "Many worries or often seems worried"; three items assessed anxiety, one somatization, and one depression). For each scale, higher scores indicate higher levels of problem behaviors.

Both the conduct problems and hyperactivity/inattention subscales had acceptable reliability in this study ($\alpha > .70$). Reliability of the parent-reported emotional problems scale was somewhat below desired levels ($.60 \leq \alpha \leq .67$). Given that this scale represented three different types of emotional difficulties, with three anxiety items, one depression item, and one somatization item, we initially thought that reliability might improve by only using the three anxiety items. However, that did not prove to be true.

But, given that this scale is one of only two measures in the study to explicitly assess emotional symptoms, we opted to include it in further analyses in its original form, despite slightly lowered reliability.

Youth report

Physical aggression. At each wave, adolescents completed the Problem Behavior Frequency Scale (PBFS; Farrell, Kung, White, & Valois, 2000). Only the 7-item Physical Aggression subscale was used in this study. Youth rated the frequency of various physically aggressive behaviors during the past 30 days (e.g., "How many times have you thrown something at someone to hurt them?") from 'Never' (1) to '6 or more times' (4). The items were averaged to create a composite measure of physical aggression, with higher scores indicating more physical aggression. This measure had acceptable reliability at all time points in this study ($\alpha > .70$).

Depression. At each wave, adolescents completed the 20-item Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977), rating the frequency of depressive symptoms over the last 2 weeks (e.g., "I did not feel like eating; my appetite was poor"). The rating scale ranged from 'Less than 1 day' (1) to '5-7 days' (4). After reverse coding positively phrased items (e.g., "I enjoyed life"), the 20 items were averaged to create a composite depression score, with higher values indicating higher levels of depression.

This measure had acceptable reliability at the first two time points after the exclusion of one item ("I felt like everything I did was an effort;" $\alpha = .77$). However,

there was a dramatic decrease in reliability at Wave 3 ($\alpha = .48$). Further analysis showed that the two reverse coded items of the scale (e.g., "I felt happy") had higher means and variability at this wave, suggesting that subjects failed to respond to the change in question valence. After dropping the reverse coded items from the scale at Wave 3, reliability rebounded to acceptable levels ($\alpha = .72$).

Substance use. At each wave, adolescents reported on whether they had ever used tobacco, alcohol, marijuana, inhalants, or other drugs, with each item coded as 'Yes' (1) or 'No' (0). We summed these items to create a total substance use score ranging from zero to five, with higher scores indicating more lifetime substance use.

Covariates

Pubertal Development

At each wave, adolescents self-reported on their pubertal status using the Pubertal Development Scale (Petersen, Crockett, Richards, & Boxer, 1988). Adolescents responded to five (for girls) or six (for boys) items indicating stages of pubertal development (growth in height, body hair, and skin changes for both genders; breast growth for girls; and facial hair growth and deepening of voice for boys). The ratings for each item ranged from 'Has Not Yet Started' (1) to 'Seems Completed' (4). The items were averaged, with higher scores indicating more advanced pubertal development.

Reliability for this scale was somewhat low in this study ($.61 \leq \alpha \leq .69$ for girls; $.42 \leq \alpha \leq .67$ for boys). However, no clear patterns for improvement could be discerned. We therefore maintained the scale in its original form for consideration as a covariate.

Gender

Gender was reported by the parent at Wave 1, with a score of '0' indicating 'male' and '1' indicating 'female'.

Age

Child's date of birth was reported by the parent at Wave 1 and used to compute exact age at each interview.

Household Income

Parents reported average household income at Wave 1 using a 13-point scale ranging from '<$50,000 per year' (1) to '>$90,000 per year (13)'.

Parental Education

Parents reported on their highest level of achieved education at Wave 1, ranging from 'Less than 9th grade' (1) to 'Graduate or professional degree' (8).

Data Analytic Plan

Preliminary Analyses

Descriptive statistics examined overall levels, variability, and distributions of all variables. Correlations tested bivariate associations among variables within each time point and stability of each measure over time, as well as relationships of sleep variables with behavioral and emotional functioning. Correlations also determined whether or not parent and child reports of sleep duration were sufficiently correlated ($r > .50$) to warrant

creation of a composite measure for use in main analyses and what covariates should be included in the main analyses. Paired samples t-tests examined whether sleep, emotional, and behavioral problems changed over time.

Main Analyses

Autoregressive cross-lagged structural equation models were run using Mplus version 7.11 to test the hypothesized reciprocal relationships between sleep problems, sleep duration, weekend delay, weekend oversleep, and behavioral and emotional problems across successive waves. Because of the small sample size, separate models were run for each outcome variable of interest, and each model only included sleep variables correlated with that particular outcome in preliminary analyses. All paths were adjusted for covariates that were related to both sleep and behavioral or emotional variables included in a given model. Because some variables were not normally distributed, the robust maximum likelihood estimation (MLR) method was used. Modification indices were examined for all models for theoretically meaningful suggestions which might improve model fit.

Developmental differences in the relationships between sleep and behavioral or emotional functioning were tested with constraints imposed on the cross-lagged pathways. Specifically, each cross-lagged path (e.g., sleep problems to aggression) was set to be identical across the two time intervals (Wave 1 to Wave 2, and Wave 2 to Wave 3). Differences between the free and constrained models were tested with the Satorra-Bentler chi-square difference test (Muthèn & Muthèn, 2010). If significant differences

between the models were detected, follow up analyses constrained one pathway at a time to identify the specific relationships that vary across development.

CHAPTER THREE

RESULTS

Preliminary Results

Descriptive Analyses

Means and standard deviations for the main variables of interest are listed in Table 1. Significant changes over time, identified through paired samples t tests, are indicated in the table. Adolescents reported a consistently low level of sleep problems (under 2 on a 5 point scale) at all time points. Average sleep duration reported by the youth decreased over time, from 8.73 hours at age 13 to 8.05 hours at age 16. Parents, in contrast, reported somewhat higher sleep duration that did not change across time (between 8.87 and 8.64 hours).

Weekend delay and weekend oversleep also did not change across time, for either adolescent or parent reporters, with adolescents reporting that they stay up about 2 hours later and sleep in over an hour more on weekends and parents reporting that their children stay up about 1 ½ hours later and sleep in about the same length of time on weekends. However, there was very high variability in both child and parent reports of weekend delay and oversleep.

In this community sample of adolescents, levels of physical aggression, conduct problems, depression, emotional problems, substance use, and hyperactivity/inattention were low across time on average. Aggression, conduct problems, and

hyperactivity/inattention decreased from age 13 to age 16, whereas substance use increased across the three waves. Child-reported depression increased from age 15 to age 16, but parent-reported emotional problems decreased across the same time period.

Table 1

Mean and Standard Deviation of Variables

	Wave 1 *N*=84 Mean (SD)	Wave 2 *N*=76 Mean (SD)	Wave 3 *N*=75 Mean (SD)
Age	13.36 (0.95)	14.76 (0.97)	16.14 (1.11)
BMI Percentile	74.15 (26.43)		
Pubertal Development	$2.64\ (0.65)_{a}$	$2.84\ (0.55)_{b}$	$3.09\ (0.49)_{c}$
Sleep Problems (C)	$1.89\ (0.43)_{a}$	$1.86\ (0.35)_{a}$	$1.87\ (0.35)_{a}$
Sleep Duration (C)	$8.73\ (1.12)_{a}$	$8.38\ (1.23)_{b}$	$8.05\ (1.14)_{c}$
Sleep Duration (P)	$8.87\ (1.15)_{a}$	$8.64\ (1.36)_{a}$	$8.77\ (1.17)_{a}$
Weekend Delay (C)	$134.23\ (93.58)_{a}$	$124.14\ (82.73)_{a}$	$123.43\ (76.37)_{a}$
Weekend Delay (P)	$109.34\ (67.63)_{a}$	$101.00\ (78.19)_{a}$	$97.40\ (72.42)_{a}$
Weekend Oversleep (C)	$81.39\ (145.83)_{a}$	$71.89\ (130.53)_{a}$	$74.03\ (141.55)_{a}$
Weekend Oversleep (P)	$81.02\ (105.47)_{a}$	$106.57\ (154.67)_{a}$	$100.96\ (103.73)_{a}$
Physical Aggression (C)	$1.30\ (0.43)_{a}$	$1.24\ (0.35)_{ab}$	$1.19\ (0.27)_{b}$
Conduct Problems (P)	$1.37\ (0.43)_{a}$	$1.29\ (0.36)_{ab}$	$1.25\ (0.36)_{b}$
Depression (C)	$1.41\ (0.52)_{ab}$	$1.36\ (0.47)_{a}$	$1.41\ (0.43)_{b}$
Emotional Problems (P)	$1.47\ (0.40)_{a}$	$1.40\ (0.36)_{a}$	$1.32\ (0.30)_{b}$
Substance Use (C)	$0.32\ (0.62)_{a}$	$0.53\ (0.87)_{ab}$	$0.67\ (0.87)_{b}$
Hyperactivity/Inattention (P)	$1.65\ (0.55)_{a}$	$1.63\ (0.52)_{a}$	$1.55\ (0.48)_{b}$

Note. (C) indicates child-report measure; (P) indicates parent-report measure. Means with differing subscripts are significantly different at $p < .05$ based on paired samples t-test comparisons across time points.

Determining Covariates

Bivariate correlations investigated the relationships between possible covariates and behavioral outcomes, emotional outcomes, and sleep duration (for both child and parent reports) and child-reported sleep problems. As can be seen in Table 2, consistent patterns of associations with key variables emerged only for child BMI percentile,

maternal education, and family income. Specifically, youth with higher BMI percentile experienced fewer sleep problems, as well as emotional and behavioral problems. Since BMI percentile remained stable over time ($.84 < r < .93$, $p < .001$), only Wave 1 BMI percentile was included in the main models. In addition, higher family income and/or maternal education were related to shorter sleep duration and fewer emotional and behavioral problems. Because family income and maternal education were moderately correlated ($r = .63$, $p < .001$), they were transformed into Z-scores and averaged to create a composite socioeconomic status (SES) variable, which was then used as a covariate in the main models.

Determining Sleep Variables for Individual Models

The correlations among different indicators of behavioral or emotional problems were not sufficiently high to warrant creation of latent or composite variables (*r*s ranged from -.01 to .39 for behavioral and -.12 to .07 for emotional problems). To reduce model complexity and ensure convergence of the main models given the modest sample size ($N = 84$), each model included only one behavioral or emotional variable and sleep variables which were correlated with this outcome variable. Results of correlations between sleep variables and outcome variables can be seen in Tables 3 and 4. Sleep variables ultimately included in individual structural equation models can be seen in Table 5. In addition, since parent and child-reports of sleep duration were only found to be significantly correlated at Wave 1 ($r = .32$, $p < .01$), they were not combined. Consistent with the correlations, child-report of sleep duration was used in models of child-reported

outcomes and parent-reported sleep duration was used in models with parent-reported outcomes.

Testing Assumptions for Multivariate Analyses

Linear relationships among variables

Curve estimations of the relationships between many of our variables suggested the presence of nonlinear relationships. However, since the sample size was too small to support non-linear analyses, we decided to continue with the proposed SEM analyses, acknowledging the possible nonlinearity of some of the data as a limitation.

Multivariate normality

Skewness and kurtosis values, as well as Shapiro-Wilk's coefficients for several of our variables also indicated that our data are skewed and may violate the assumption of normality. To address this, we used the MLR estimator when conducting our main analyses. This estimator provides maximum likelihood estimation with robust standard errors, making it more appropriate for analyzing non-normally distributed data (Muthèn & Muthèn, 2010)

Multicollinearity

Regression equations including collinearity diagnostics were run for all models with multiple endogenous or exogenous variables. For all such cases, VIF was under two, suggesting no issues with multicollinearity.

Table 2

Relationships between Covariates, Sleep Variables, Emotional Variables, and Behavioral Variables

					BMI Percentile			*Puberty*		
	Gender	W1 Age	Income	Maternal Education	W1	W2	W3	W1	W2	W3
W1 sleep duration (P)	--	-.29**	-.30**	--	--	--	--	--	--	--
W2 sleep duration (P)	.28*	--	--	--	--	--	--	--	.26*	--
W3 sleep duration (P)	.26*	--	--	--	--	--	--	--	--	--
W1 sleep duration (C)	--	-.25*	-.24	--	--	--	--	--	--	--
W2 sleep duration (C)	--	--	--	--	--	--	--	--	--	--
W3 sleep duration (C)	--	--	--	--	--	--	--	--	--	--
W1 sleep problems (C)	--	--	--	--	-.31**	-.33**	-.24*	--	--	-.28*
W2 sleep problems (C)	--	--	--	--	--	--	--	--	--	--
W3 sleep problems (C)	--	--	--	--	-.26*	-.29*	--	--	--	--
W3 Aggression (C)	--	--	--	--	--	--	--	--	--	.27*
W1 Depression (C)	--	--	--	--	--	--	--	--	--	--
W2 Depression (C)	--	--	--	--	-.24*	-.27*	--	--	--	--
W3 Depression (C)	--	--	--	--	--	--	--	--	--	--
W1 Emotional Problems (P)	--	--	-.22*	-.33**	--	--	--	--	--	-.25*
W2 Emotional Problems (P)	--	--	-.23*	--	-.32**	-.33**	-.31**	--	--	--
W3 Emotional Problems (P)	--	--	-.25*	-.26*	--	--	--	--	--	--
W1 Conduct Problems (P)	--	--	-.25*	-.36**	-.23*	--	--	--	--	.28*
W2 Conduct Problems (P)	--	--	-.31**	-.31**	--	--	--	--	-.24*	-.29*
W3 Conduct Problems (P)	--	--	-.28*	-.42**	-.25*	--	--	--	--	--
W1 Hyperactivity(P)	-.24*	--	--	--	--	--	--	--	--	--
W2 Hyperactivity(P)	--	--	--	--	--	--	--	--	--	-.27*
W3 Hyperactivity(P)	--	--	--	--	--	--	--	--	--	--

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. Nonsignificant correlations are not shown. (C) indicates child-report measure; (P) indicates parent-report measure.

Table 3

Correlations between Child-Reported Behavioral and Emotional Variables and Sleep Variables

		Physical Aggression			Substance Use			Depression		
		W1	W2	W3	W1	W2	W3	W1	W2	W3
Sleep Problems (C)	W1	0.50**	0.33**	0.31**	0.18	0.25*	0.28*	0.35**	0.25*	0.90
	W2	0.28*	0.29*	0.04	0.18	0.19	0.20	0.12	0.20	-0.03
	W3	0.24*	0.06	0.32**	0.06	0.09	0.14	0.00	0.22	0.32**
Sleep Duration (C)	W1	-0.02	0.04	-0.18	-0.11	-0.19	-0.04	-0.21	-0.03	-0.05
	W2	0.08	0.08	-0.07	-0.19	-0.12	-0.01	-0.19	0.02	-0.06
	W3	-0.05	-0.02	-0.24*	-0.18	-0.05	-0.03	-0.06	-0.08	-0.32**
Weekend Delay (C)	W1	0.02	-0.05	-0.02	0.17	0.18	0.16	-0.04	-0.12	-0.19
	W2	-0.11	0.14	-0.01	0.16	0.36**	0.12	0.07	0.21	-0.12
	W3	0.02	-0.11	-0.04	-0.15	-0.08	-0.05	-0.19	-0.11	0.03
Weekend Oversleep (C)	W1	0.05	0.21	0.15	0.08	0.05	0.14	0.10	0.28*	-0.06
	W2	0.23*	-0.05	0.07	-0.07	-0.04	0.07	0.03	0.07	-0.02
	W3	0.13	0.14	0.16	0.11	0.12	0.27*	0.00	0.10	-0.01
Sleep Duration (P)	W1	0.21	0.25*	0.20	-0.10	0.02	0.16	-0.02	-0.00	0.02
	W2	0.24*	0.02	0.03	0.08	0.03	0.16	0.12	0.13	0.20
	W3	0.08	0.07	-0.10	-0.12	-0.08	-0.13	-0.08	0.07	0.14
Weekend Delay (P)	W1	-0.15	-0.07	0.00	-0.17	-0.01	0.03	-0.04	0.13	0.09
	W2	-0.12	-0.13	-0.16	-0.04	0.14	0.00	0.15	0.19	-0.12
	W3	-0.03	0.16	0.05	0.04	0.12	0.06	-0.02	0.00	-0.06
Weekend Oversleep (P)	W1	0.16	0.11	0.21	0.22*	0.09	0.38**	0.14	-0.04	0.02
	W2	0.19	0.10	0.15	-0.09	-0.03	0.08	-0.05	0.08	-0.09
	W3	0.08	0.06	0.32**	0.01	0.18	0.13	-0.12	0.12	0.13

Note. * correlation is significant at $p < .05$; ** correlation is significant at $p < .01$. (C) indicates child-report measure; (P) indicates parent-report measure

Table 4

Correlations between Parent-Reported Behavioral and Emotional Variables and Sleep Variables

		Conduct Problems			Hyperactivity/Inattention			Emotional Problems		
		W1	W2	W3	W1	W2	W3	W1	W2	W3
Sleep Duration (P)	W1	-0.26*	0.03	-0.12	-0.13	-0.14	-0.12	0.01	-0.04	0.00
	W2	-0.07	0.07	-0.09	0.09	0.07	0.14	0.03	0.08	0.03
	W3	-0.25*	-0.28*	-0.33**	-0.01	-0.20	-0.19	0.09	-0.06	0.04
Weekend Delay (P)	W1	0.20	0.08	0.12	0.08	-0.06	0.06	0.09	0.06	0.18
	W2	0.14	0.16	0.19	0.15	0.04	0.14	0.21	0.00	0.10
	W3	0.20	0.13	0.09	0.15	0.04	0.04	0.29*	-0.12	0.17
Weekend Oversleep (P)	W1	0.09	0.20	0.22	0.08	0.11	0.16	0.07	-0.25*	-0.11
	W2	0.18	0.05	0.10	-0.05	-0.04	-0.08	0.03	-0.10	-0.08
	W3	0.12	0.28*	0.37**	0.16	0.16	0.19	0.08	0.25*	0.20
Sleep Duration (C)	W1	-0.13	-0.11	-0.14	0.02	-0.12	0.02	0.01	-0.07	0.00
	W2	-0.11	0.00	-0.01	-0.11	-0.16	-0.07	0.02	0.06	0.02
	W3	0.01	-0.01	-0.05	-0.01	-0.22	-0.13	0.09	0.19	0.14
Weekend Delay (C)	W1	0.19	0.29*	0.18	0.19	0.22	0.31**	0.13	0.17	0.16
	W2	0.11	0.32**	0.26*	0.19	0.24*	0.12	0.17	0.35**	0.46**
	W3	0.09	0.03	0.05	0.11	-0.01	-0.11	0.26*	0.35**	0.30*
Weekend Oversleep (C)	W1	0.08	0.17	0.14	0.50	0.02	0.02	0.04	-0.05	-0.12
	W2	0.04	0.04	0.06	-0.08	0.03	0.18	-0.20	-0.18	-0.21
	W3	0.29*	0.37**	0.31**	0.12	0.15	0.26*	-0.05	-0.06	-0.11
Sleep Problems (C)	W1	0.24*	0.40**	0.33**	0.19	0.11	0.08	0.11	0.08	0.04
	W2	0.30*	0.24*	0.21	0.26*	0.13	-0.04	0.23*	0.18	0.07
	W3	0.31**	0.30*	0.31**	0.14	0.10	-0.02	0.10	0.24*	0.09

Note. * correlation is signification at $p < .05$; ** correlation is significant at $p < .01$. (P) indicates child-report measure; (C) indicates parent-report measure

Table 5

Sleep Variables used to Predict Behavioral and Emotional Variables

Outcome	*Sleep Variables*
Aggression (C)	Sleep problems (C)
Substance Use (C)	Sleep problems (C)
	Weekend delay (C)
Depression (C)	Sleep problems (C)
	Weekend oversleep (C)
Conduct Problems (P)	Sleep duration (P)
	Sleep problems (C)
Emotional Problems (P)	Weekend oversleep (P)
	Weekend delay (C)
Hyperactivity/Inattention P)	Sleep duration (P)
	Sleep problems (C)

Note. (C) indicates child-report measure; (P) indicates parent-report measure

Main Analyses

Altogether, six models were fit to the data. Only one of the six models produced theoretically meaningful modification indices which resulted in the addition of paths to the emotional problems model (see Figure 5 and Table 11). However, none of the models had excellent fit to the data (see model fit indices in Table 6), with all RMSEA values exceeding 0.07, none of the CFI values reaching 0.95, and most SRMR values (with the exception of depression and substance use) exceeding 0.08 (Hooper, Coughlan, & Mullen, 2008). The relatively best fitting model was for depression with acceptable fit, followed by substance use with borderline fit.

Table 6

Model Fit Indices of Structural Equation Models

Dependent Variable	χ^2 Test of Model Fit (df)	RMSEA	CFI	SRMR
Physical Aggression (C)	24.74* (12)	0.11	0.89	0.084
Substance Use (C)	37.70* (21)	0.10	0.86	0.071
Depression (C)	32.66 (21)	0.08	0.91	0.060
Conduct Problems (P)	77.85*** (21)	0.18	0.70	0.090
Emotional Problems (P)	63.15* (20)	0.16	0.71	0.085
Hyperactivity/Inattention (P)	70.04*** (21)	0.17	0.76	0.090

Note. + p <.10, * p < .05, *** p < .01, *** p < .001; (C) indicates child-report measure; (P) indicates parent-report measure

Aggression

The model predicting child-reported aggression can be seen in Figure 1, with standardized coefficient estimates listed in Table 7. Aggression and sleep problems were moderately stable over time (β = 0.39 to 0.53, p <.001). Although none of the cross-lagged paths reached significance, higher levels of aggression were concurrently associated with more sleep problems at ages 13 and 16 (β = 0.50 and 0.41, p <.001), but not at age 15.

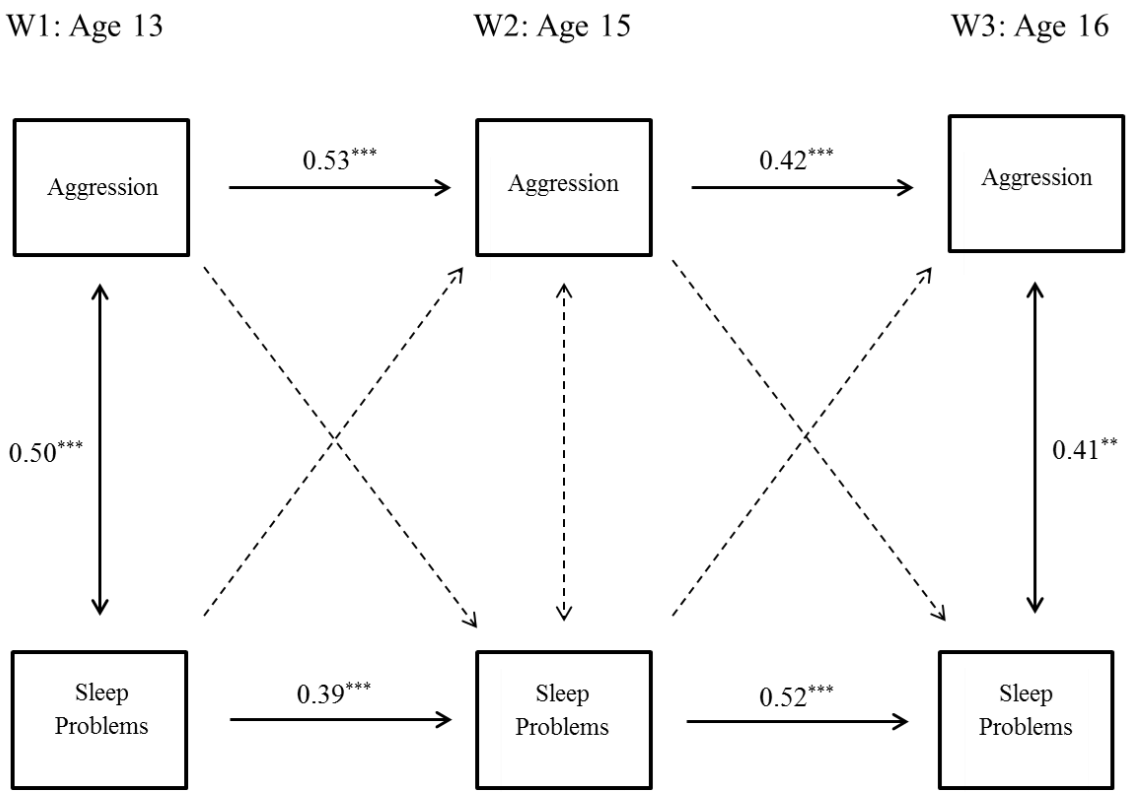

Figure 1. Model predicting child-reported aggression.
$^{+}$= p <.10, * = p < .05, ** = p < .01, *** = p < .001; Dashed lines indicate no significant path between two variables. All variables were adjusted at age 13 for BMI and SES.

Table 7

Standardized Estimates for Aggression Model

Type of Effect	*Parameter Estimate*	*MLR Estimated β*
Covariates	SES → W1 aggression	0.07
	BMI → W1 aggression	-0.11
	SES → W1 sleep problems	-0.07
	BMI → W1 sleep problems	-0.14
Autoregressive	W1 aggression →W2 aggression	0.53***
	W2 aggression → W3 aggression	0.42***
	W1 sleep problems → W2 sleep problems	0.39***
	W2 sleep problems → W3 sleep problems	0.52***
Cross-lagged	W1 sleep problems → W2 aggression	0.06
	W1 aggression → W2 sleep problems	0.09
	W2 sleep problems → W3 aggression	-0.08
	W2 aggression →W3 sleep problems	-0.08
Covariances	W1 aggression and W1 sleep problems	0.50***
	W2 aggression and W2 sleep problems	0.15
	W3 aggression and W3 sleep problems	0.41**
	BMI and SES	0.06

Note. + p <.10, * p < .05, *** p < .01, *** p < .001

Substance Use

The model predicting child-reported substance use can be seen in Figure 2, with standardized coefficients displayed in Table 8. Substance use, sleep problems, and weekend delay were all stable over time (β = 0.29 to .070, $p < .05$). More sleep problems were marginally associated with higher levels of concurrent substance use at age 13 (β = 0.19, $p < .10$). Greater amounts of weekend delay were concurrently associated with higher levels of substance use at age 15 (β = 0.29, $p < .05$) and marginally with more sleep problems at both age 15 and 16 (β = 0.25 and 0.18, $p < .10$). Cross-lagged paths in this model approached significance, with greater weekend delay at age 13 marginally predicting higher levels of substance use at age 15 (β = 0.16, $p < .10$) which, in turn, marginally predicted less weekend delay at age 16 (β = -0.19, $p < .10$). Further, greater weekend delay at age 15 marginally predicted *less* overall substance use at age 16 (β = -0.18, $p < .10$).

Depression

The model predicting child-reported depression can be seen in Figure 3, with standardized coefficients displayed in Table 9. Depression and sleep problems were moderately stable over time (β = 0.44 to 0.63, $p < .001$), but weekend oversleep was stable only between ages 15 and 16. Concurrently, higher levels of sleep problems were associated with more depression at all waves (β = 0.14 to .035, $p < .10$). One cross-lagged path was significant, with higher levels of weekend oversleep at age 13 predicting higher levels of age 15 depression (β = 0.18, $p < .05$).

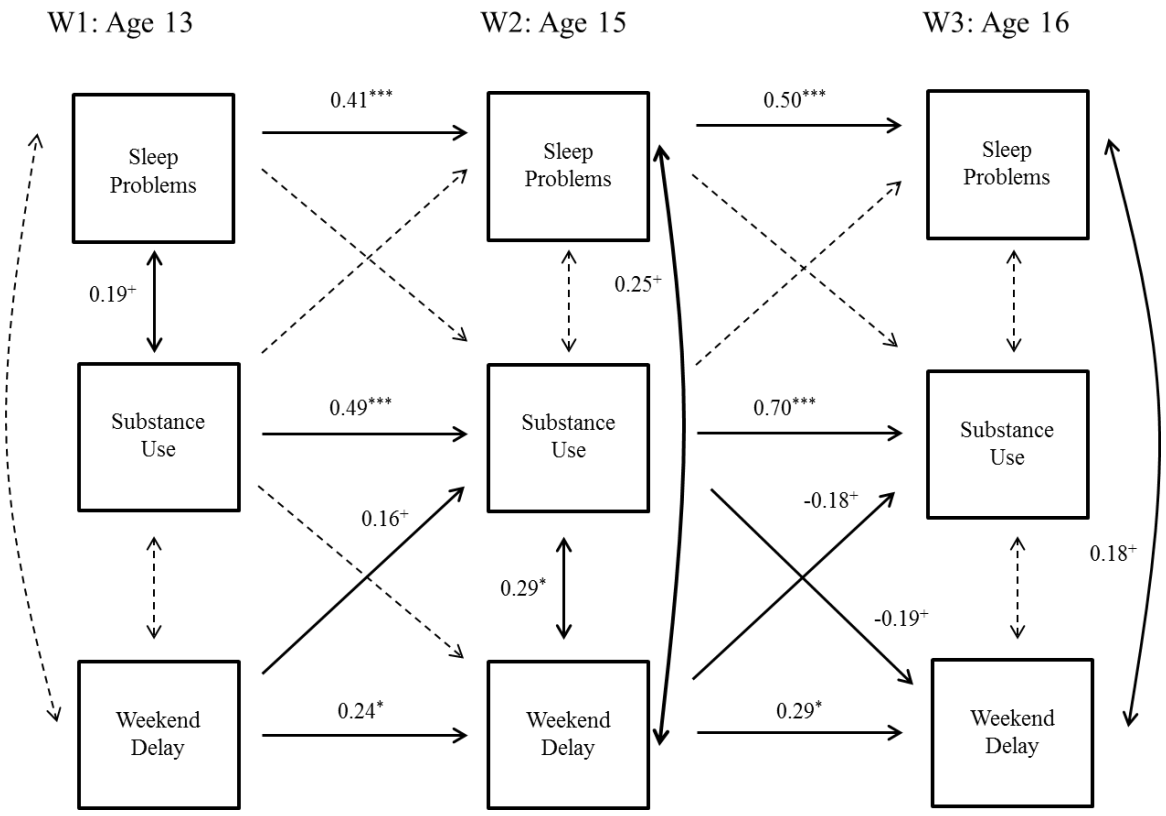

Figure 2. Model predicting child-reported substance use.
+= p <.10, * = p < .05, ** = p < .01, *** = p < .001; Dashed lines indicate no significant path between two variables. All cross-lagged pathways between sleep variables were also modelled, but only significant paths are included here. All variables were adjusted at age 13 for BMI and SES.

Table 8

Standardized Estimates for Substance Use Model

Type of Effect	*Parameter Estimate*	*MLR Estimated β*
Covariates	SES → W1 substance use	0.14
	BMI → W1 substance use	-0.01
	SES → W1 sleep problems	-0.07
	BMI → W1 sleep problems	-0.14
	SES → W1 weekend delay	-0.03
	BMI → W1 weekend delay	0.17
Autoregressive	W1 substance use → W2 substance use	0.49***
	W2 substance use → W3 substance use	0.70***
	W1 sleep problems → W2 sleep problems	0.41***
	W2 sleep problems → W3 sleep problems	0.50***
	W1 weekend delay → W2 weekend delay	0.24*
	W2 weekend delay → W3 weekend delay	0.29*
Cross-lagged	W1 sleep problems → W2 substance use	0.12
	W1 weekend delay → W2 substance use	0.16+
	W1 substance use → W2 sleep problems	0.10
	W1 substance use → W2 weekend delay	0.11
	W1 weekend delay → W2 sleep problems	0.13
	W1 sleep problems → W2 weekend delay	0.03
	W2 sleep problems → W3 substance use	0.12
	W2 weekend delay → W3 substance use	-0.18+
	W2 substance use → W3 sleep problems	0.01
	W2 substance use → W3 weekend delay	-0.19+
	W2 weekend delay → W3 sleep problems	0.01
	W2 sleep problems → W3 sleep delay	0.04
Covariances	W1 substance use with W1 sleep problems	0.19+
	W1 substance use with W1 weekend delay	0.18
	W1 sleep problems with W1 weekend delay	0.11
	W2 substance use with W2 sleep problems	0.03
	W2 substance use with W2 weekend delay	0.29*
	W2 sleep problems with W2 weekend delay	0.25+
	W3 substance use with W3 sleep problems	0.08
	W3 substance use with W3 weekend delay	0.04
	W3 sleep problems with W3 weekend delay	0.18+
	BMI with SES	0.06

Note. + p <.10, * p < .05, *** p < .01, *** p < .001

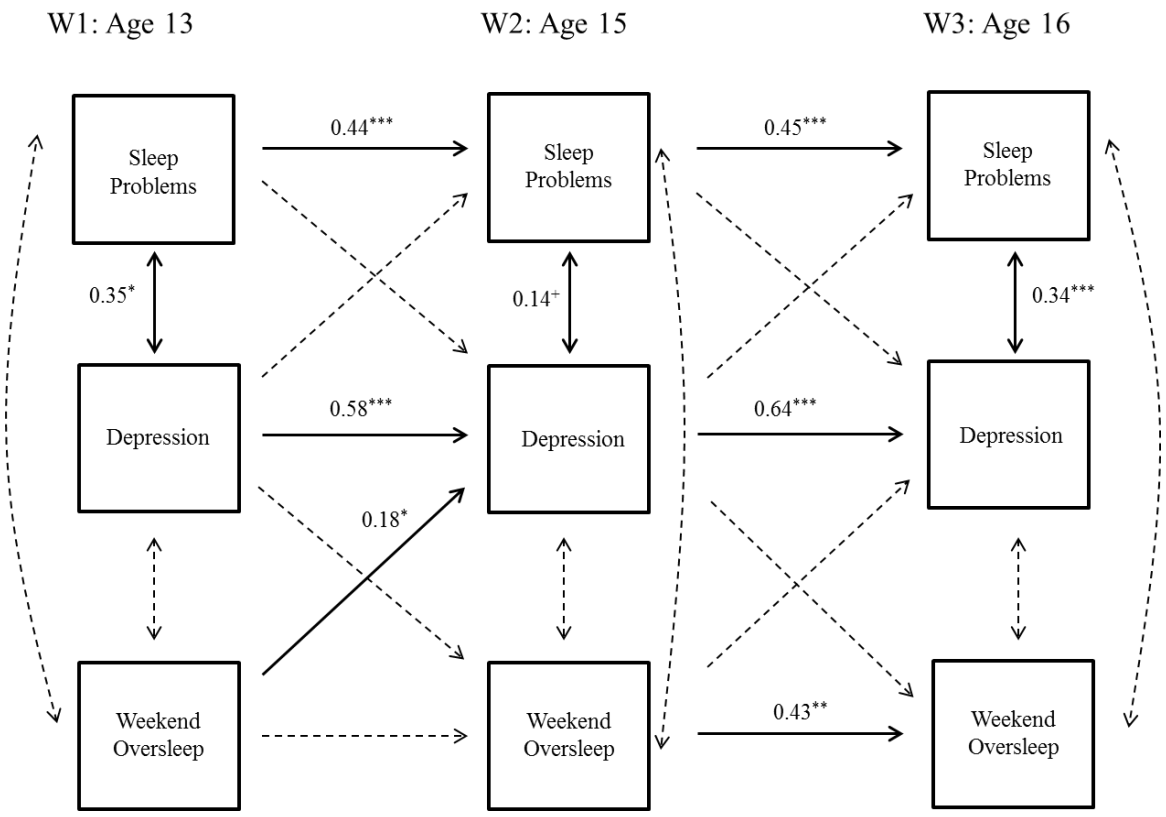

Figure 3. Model predicting child-reported depression.
$^{+}$= p <.10, * = p < .05, ** = p < .01, *** = p < .001; Dashed lines indicate no significant path between two variables. All cross-lagged pathways between sleep variables were also modelled, but only significant paths are included here. All variables were adjusted at age 13 for BMI and SES.

Table 9

Standardized Estimates for Depression Model

Type of Effect	*Parameter Estimate*	*MLR Estimated β*
Covariates	SES → W1 depression	0.04
	BMI → W1 depression	-0.03
	SES → W1 sleep problems	-0.07
	BMI → W1 sleep problems	-0.14
	SES → W1 weekend oversleep	-0.29***
	BMI → W1 weekend oversleep	-0.02
Autoregressive	W1 depression → W2 depression	0.58***
	W2 depression → W3 depression	0.64***
	W1 sleep problems →W2 sleep problems	0.44***
	W2 sleep problems → W3 sleep problems	0.45***
	W1 weekend oversleep → W2 weekend oversleep	0.21
	W2 weekend oversleep → W3 weekend oversleep	0.43**
Cross-lagged	W1 sleep problems → W2 depression	0.02
	W1 weekend oversleep → W2 depression	0.18*
	W1 depression → W2 sleep problems	-0.04
	W1 depression → W2 weekend oversleep	-0.02
	W1 weekend oversleep → W2 sleep problems	0.11
	W1 sleep problems → W2 weekend oversleep	0.01
	W2 sleep problems → W3 depression	-0.08
	W2 weekend oversleep → W3 depression	-0.04
	W2 depression → W3 sleep problems	0.25
	W2 depression → W3 weekend oversleep	0.11
	W2 weekend oversleep → W2 sleep problems	-0.04
	W2 sleep problems → W3 weekend oversleep	0.26
Covariances	W1 depression with W1 sleep problems	0.35*
	W1 depression with W1 weekend oversleep	0.12
	W1 sleep problems with W1 weekend oversleep	0.17
	W2 depression with W2 sleep problems	0.14+
	W2 depression with W2 weekend oversleep	0.03
	W2 sleep problems with W2 weekend oversleep	-0.18
	W3 depression with W3 sleep problems	0.34***
	W3 depression with W3 weekend oversleep	-0.03
	W3 sleep problems with W3 weekend oversleep	0.11
	BMI with SES	0.06

Note. + p <.10, * p < .05, *** p < .01, *** p < .001

Conduct Problems

The model predicting parent-reported conduct problems can be seen in Figure 4, with standardized coefficients displayed in Table 10. Conduct problems, sleep problems, and sleep duration all remained stable across time ($\beta = 0.21$ to 0.74, $p < .001$). No variables were concurrently related to one another during the first or second wave. However, at age 16 greater sleep duration was related to both fewer sleep problems and fewer conduct problems ($\beta = -0.25$ to -0.23, $p < .05$). Two of the hypothesized reciprocal effects emerged in this model. First, shorter parent-reported sleep duration at age 13 predicted more parent-reported conduct problems at age 15 ($\beta = -0.26$, $p < .05$), which in turn predicted shorter sleep duration at age 16 ($\beta = -0.31$, $p < .01$). Second, more child-reported sleep problems at age 13 predicted more parent-reported conduct problems at age15 ($\beta = 0.24$, $p < .05$), which then predicted more sleep problems at age 16 ($\beta = 0.20$, $p < .05$). In addition, more sleep problems at age 15 predicted greater sleep duration at age 16 ($\beta = 0.29$, $p < .05$) and greater age 15 sleep duration marginally predicted more age 16 conduct problems ($\beta = 0.13$, $p < .10$).

Emotional Problems

The model predicting parent-reported emotional problems can be seen in Figure 5, with standardized coefficients displayed in Table 11. Weekend delay was stable over time ($\beta = 0.45$ to 0.48, $p < .001$), but weekend oversleep was stable only between ages 13 and 15 and emotional problems were stable only between ages 15 and 16. Concurrently, greater weekend delay was associated with more weekend oversleep at all ages ($\beta = -0.26$ to -0.49, $p < 0.01$). At age 16, more emotional problems were associated concurrently

with lower levels of weekend delay (β = -0.21, $p < .05$) and higher levels of weekend oversleep (β = 0.28, $p < .05$). Higher levels of weekend delay at age 13 predicted greater amounts of weekend oversleep at age 15 (β = 0.17, $p < .05$). Based on modification indices, age 13 weekend oversleep was added as a direct predictor of age 16 emotional problems, in addition to age 15 weekend oversleep. This added path was significant, with higher levels of weekend oversleep at age 13 predicting *fewer* emotional problems at age 16 (β = -0.35, $p < .001$), while age 15 weekend oversleep was not significantly predictive of age 16 emotional problems (β = -0.01, p = n.s.). No other cross-lagged paths reached significance.

Hyperactivity/Inattention

The model predicting parent-reported hyperactivity/inattention can be seen in Figure 6, with standardized coefficients listed in Table 12. Levels of hyperactivity/inattention, sleep problems, and sleep duration were moderately stable over time (β= 0.30 to 0.71, $p < .001$). Concurrently, greater sleep duration was related to less hyperactivity/inattention at both age 13 and age 16 (β = -0.30 and -0.26, $p < .05$), but marginally to *more* hyperactivity/inattention at age 15 (β = 0.20, $p < .10$). More sleep problems were concurrently related to greater hyperactivity/inattention at age 13 (β = 0.36, $p < .01$) and to shorter sleep duration at age 16 (β = -0.28, $p < .01$). Among cross-lagged paths, more sleep problems at age 15 predicted greater sleep duration at age 16 (β = 0.25, $p < .05$). Finally, more hyperactivity/inattention at age 13 marginally predicted lower sleep duration at age 15 (β = -0.14, $p < .10$).

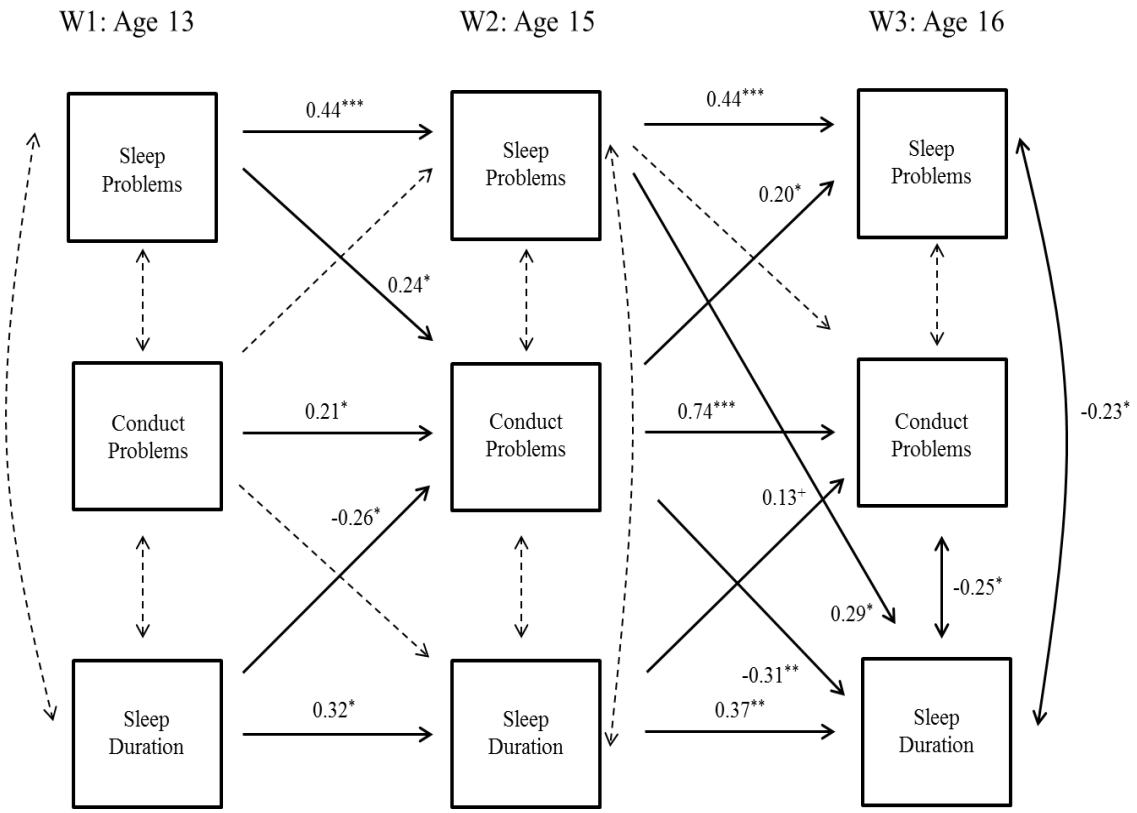

Figure 4. Model predicting parent-reported conduct problems.
$^{+}$= p <.10, * = p < .05, ** = p < .01, *** = p < .001; Dashed lines indicate no significant path between two variables. All cross-lagged pathways between sleep variables were also modelled, but only significant paths are included here. All variables were adjusted at age 13 for BMI and SES.

Table 10

Standardized Estimates for Conduct Problems Model

Type of Effect	*Parameter Estimate*	*MLR Estimated β*
Covariates	SES → W1 conduct problems	-0.27**
	BMI → W1 conduct problems	-0.16
	SES → W1 sleep duration	-0.21*
	BMI → W1 sleep duration	-0.00
	SES → W1 sleep problems	-0.07
	BMI → W1 sleep problems	-0.14
Autoregressive	W1 conduct problems → W2 conduct problems	0.21*
	W2 conduct problems → W3 conduct problems	0.74***
	W1 sleep problems → W2 sleep problems	0.44***
	W2 sleep problems → W3 sleep problems	0.44***
	W1 sleep duration → W2 sleep duration	0.32*
	W2 sleep duration → W3 sleep duration	0.37**
Cross-lagged	W1 sleep problems → W2 conduct problems	0.24*
	W1 sleep duration → W2 conduct problems	-0.26*
	W1 conduct problems → W2 sleep problems	0.06
	W1 conduct problems → W2 sleep duration	0.05
	W1 sleep duration → W2 sleep problems	-0.04
	W1 sleep problems → W2 sleep duration	0.05
	W2 sleep problems → W3 conduct problems	0.04
	W2 sleep duration → W3 conduct problems	0.13+
	W2 conduct problems → W3 sleep problems	0.20*
	W2 conduct problems → W3 sleep duration	-0.31**
	W2 sleep duration → W3 sleep problems	0.12
	W2 sleep problems → W3 sleep duration	0.29*
Covariances	W1 conduct problems with W1 sleep duration	-0.11
	W1 conduct problems with W1 sleep problems	-0.01
	W1 sleep duration with W1 sleep problems	0.01
	W2 conduct problems with W2 sleep duration	-0.09
	W2 conduct problems with W2 sleep problems	0.18
	W2 sleep duration with W2 sleep problems	-0.10
	W3 conduct problems with W3 sleep duration	-0.25*
	W3 conduct problems with W3 sleep problems	0.05
	W3 sleep duration with W3 sleep problems	-0.23*
	BMI with SES	0.05

Note. + p <.10, * p < .05, *** p < .01, *** p < .001; changes to patterns of significance between estimators are highlighted.

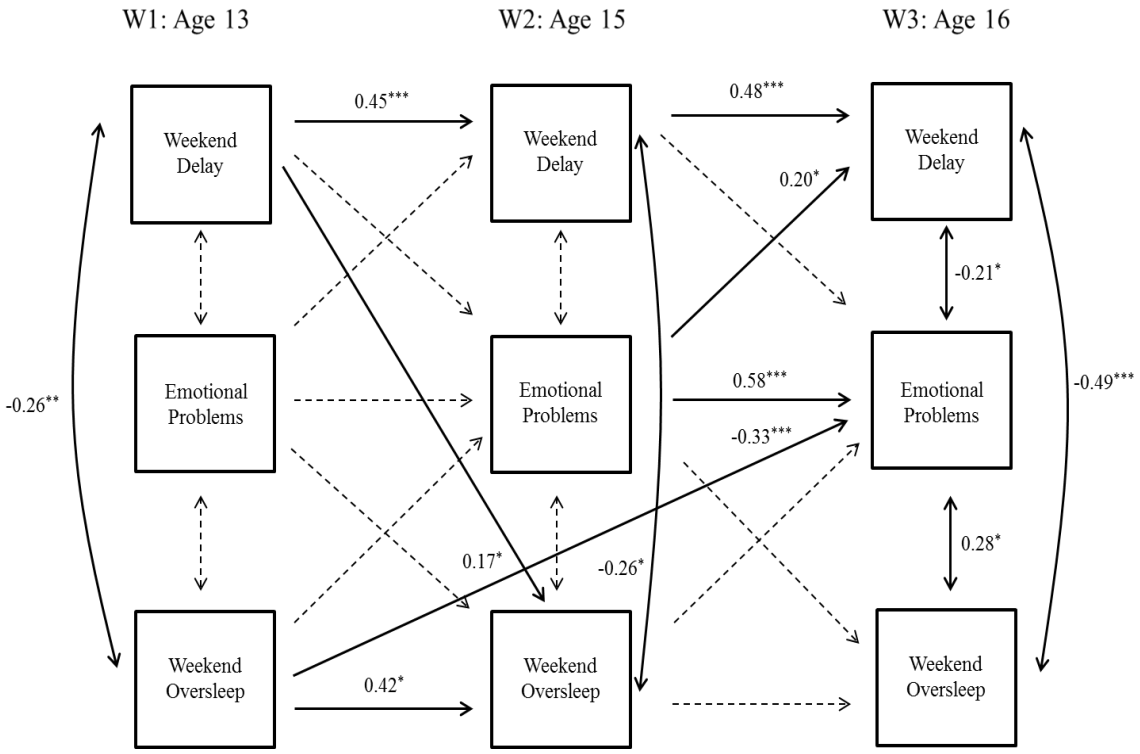

Figure 5. Model predicting parent-reported emotional problems.
$^{+}$= p <.10, * = p < .05, ** = p < .01, *** = p < .001; Dashed lines indicate no significant path between two variables. All cross-lagged pathways between sleep variables were also modelled, but only significant paths are included here. All variables were adjusted at age 13 for BMI and SES.

Table 11

Standardized Estimates for Emotional Problems Model

Type of Effect	*Parameter Estimate*	*MLR Estimated β*
Covariates	SES → W1 emotional problems	0.03
	BMI → W1 emotional problems	-0.20*
	SES → W1 weekend delay	-0.30**
	BMI → W1 weekend delay	-0.13
	SES → W1 weekend oversleep	-0.15
	BMI → W1 weekend oversleep	0.02
Autoregressive	W1 emotional problems → W2 emotional problems	0.20
	W2 emotional problems → W3 emotional problems	0.58***
	W1 weekend delay → W2 weekend delay	0.45***
	W2 weekend delay → W3 weekend delay	0.48***
	W1 weekend oversleep → W2 weekend oversleep	0.42**
	W2 weekend oversleep → W3 weekend oversleep	0.20
Cross-lagged	W1 weekend delay → W2 emotional problems	0.10
	W1 weekend oversleep → W2 emotional problems	0.07
	W1 emotional problems → W2 weekend delay	0.10
	W1 emotional problems → W2 weekend oversleep	-0.14
	W1 weekend oversleep → W2 weekend delay	0.03
	W1 weekend delay → W2 weekend oversleep	0.17*
	W2 weekend delay→ W3 emotional problems	-0.13
	W1 weekend oversleep → W3 emotional problems[1]	-0.33***
	W2 weekend oversleep → W3 emotional problems	-0.01
	W2 emotional problems → W3 weekend delay	0.13
	W2 emotional problems → W3 weekend oversleep	0.11
	W2 weekend oversleep → W3 weekend delay	0.05
	W2 weekend delay → W3 weekend oversleep	-0.06
Covariances	W1 emotional problems with W1 weekend delay	0.03
	W1 emotional problems with W1 oversleep	0.15
	W1 weekend delay with W1 oversleep	-0.26***
	W2 emotional problems with W2 weekend delay	0.19
	W2 emotional problems with W2 oversleep	-0.04
	W2 weekend delay with W2 oversleep	-0.26*
	W3 emotional problems with W3 weekend delay	-0.21*
	W3 emotional problems with W3 oversleep	0.28*
	W3 weekend delay withW3 oversleep	-0.49***
	BMI with SES	0.05

Note. + p <.10, * p < .05, *** p < .01, *** p < .001; 1 = pathway addition suggested by modification indices

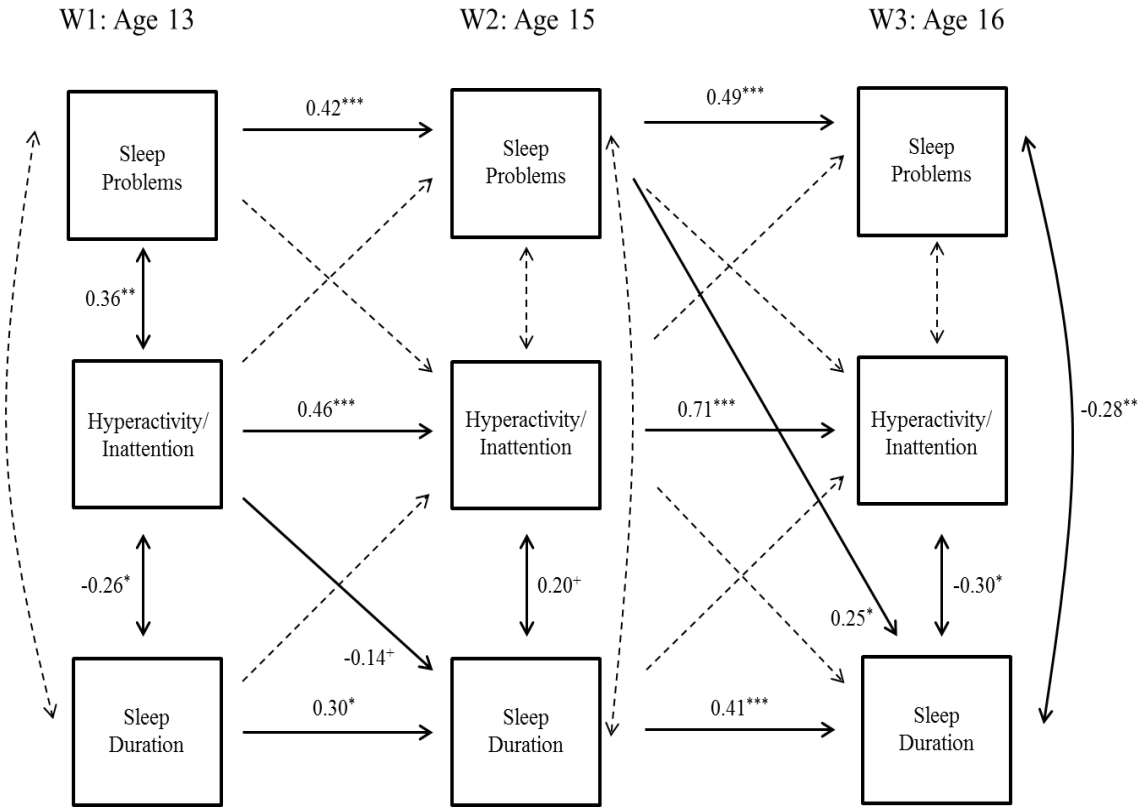

Figure 6. Model predicting parent-reported hyperactivity/inattention.
+= p <.10, * = p < .05, ** = p < .01, *** = p < .001; Dashed lines indicate no significant path between two variables. All cross-lagged pathways between sleep variables were also modelled, but only significant paths are included here. All variables were adjusted at age 13 for BMI and SES.

Table 12

Standardized Estimates for Hyperactivity/Inattention Model

Type of Effect	*Parameter Estimate*	*MLR Estimated β*
Covariates	SES → W1 hyperactivity	-0.33***
	BMI → W1 hyperactivity	-0.29***
	SES → W1 sleep duration	-0.21*
	BMI → W1 sleep duration	0.01
	SES → W1 sleep problems	-0.07
	BMI → W1 sleep problems	-0.14
Autoregressive	W1 hyperactivity → W2 hyperactivity	0.46***
	W2 hyperactivity → W3 hyperactivity	0.71***
	W1 sleep problems → W2 sleep problems	0.42***
	W2 sleep problems → W3 sleep problems	0.49***
	W1 sleep duration → W2 sleep duration	0.30*
	W2 sleep duration → W3 sleep duration	0.41***
Cross-lagged	W1 sleep problems → W2 hyperactivity	0.02
	W1 sleep duration → W2 hyperactivity	-0.06
	W1 hyperactivity → W2 sleep problems	0.08
	W1 hyperactivity → W2 sleep duration	-0.14+
	W1 sleep duration → W2 sleep problems	-0.02
	W1 sleep problems → W2 sleep duration	0.12
	W2 sleep problems → W3 hyperactivity	-0.07
	W2 sleep duration → W3 hyperactivity	-0.00
	W2 hyperactivity → W3 sleep problems	0.03
	W2 hyperactivity → W3 sleep duration	-0.11
	W2 sleep duration → W3 sleep problems	0.11
	W2 sleep problems → W3 sleep duration	0.25*
Covariances	W1 hyperactivity with W1 sleep duration	-0.26*
	W1 hyperactivity with W1 sleep problems	0.36**
	W1 sleep duration with W1 sleep problems	0.01
	W2 hyperactivity with W2 sleep duration	0.20+
	W2 hyperactivity with W2 sleep problems	0.17
	W2 sleep duration with W2 sleep problems	-0.09
	W3 hyperactivity with W3 sleep duration	-0.30*
	W3 hyperactivity with W3 sleep problems	-0.00
	W3 sleep duration with W3 sleep problems	-0.28**
	SES with BMI	0.06

Note. + p <.10, * p < .05, *** p < .01, *** p < .001

Developmental Differences

Results of chi-square difference tests of constrained versus free structural equation models are displayed in Table 13. The only model to show significant differences between the constrained and unconstrained models was the conduct problems model (p = .02; see Figure 4). Differences between the constrained and free parameters in all other models were nonsignificant, suggesting no developmental differences in cross-time associations between the sleep variables and emotional or behavioral problems. For the conduct problems model, follow up analyses revealed that only the pathway from sleep duration to conduct problems varied significantly over time (p =.003; see Table 14). Specifically, greater sleep duration at age 13 predicted fewer conduct problems at age 15; however, sleep duration at age 15 had a marginally positive effect on levels of conduct problems at age 16 (see Figure 4 and Table 10).

Table 13

Chi square difference tests for constrained versus free models

Model	Constrained χ^2 (df)	Free χ^2 (df)	p value of difference test
Aggression (C)	29.96 (14)	24.74 (12)	.33
Substance Use (C)	48.00 (27)	37.70 (21)	.11
Depression (C)	41.35 (27)	32.66 (21)	.19
Conduct Problems (P)	91.56 (27)	77.85 (21)	***.02***
Emotional Problems (P)	54.30 (27)	42.97 (20)	.12
Hyperactivity/Inattention (P)	69.85 (27)	70.04 (21)	.85

Note: (C) indicates child-reported measure; (P) indicates parent-reported measure.

Table 14

Chi square difference tests for constrained versus free models of specific conduct problems model pathways

Pathway	Constrained χ^2 (df)	Free χ^2 (df)	*p* value of difference test
Sleep duration (P) → Conduct problems (P)	87.69 (22)	77.85 (21)	***.003***
Sleep problems (C) → Conduct problems (P)	80.42 (22)	77.85 (21)	.10
Sleep problems (C) → Sleep duration (P)	78.38 (22)	77.85 (21)	.18
Conduct problems (P) → Sleep duration (P)	81.47 (22)	77.85 (21)	.06
Sleep duration (P) → Sleep problems (C)	76.69 (22)	77.85 (21)	.41
Conduct problems (P) → Sleep problems (C)	78.96 (22)	77.85 (21)	.42

Note: (C) indicates child-reported measure; (P) indicates parent-reported measure.

CHAPTER FOUR

DISCUSSION

This study examined the prospective bi-directional relationships between a variety of sleep variables and multiple indicators of behavioral and emotional problems. The study also explored whether these relationships varied across early and middle adolescence. One particularly unique aspect of this study was its focus on a sample of predominantly African American, low-income, urban adolescents, a group at risk for both increased sleep difficulties (Cukor et al., 2016) and behavioral and emotional problems (E. R. Anderson & Mayes, 2010; Mercado-Crespo & Mbah, 2013; Walters, 2008). We hypothesized that poor sleep would be associated with both behavioral and emotional problems within each of three waves of data collection; that behavioral problems, emotional problems, sleep problems, weekend delay, and weekend oversleep would all increase over time, while sleep duration would decrease; and that poor sleep would show bi-directional relationships with behavioral and emotional problems over time.

Instead, we found that different types of sleep variables were related to different outcomes, with stronger relationships observed between sleep problems/duration variables and behavioral outcomes while sleep irregularity variables (e.g., weekend oversleep) were associated more with emotional problems. While sleep duration did decrease over time, all other sleep variables remained stable instead of increasing. In terms of bi-directional relationships, the results revealed that both shorter sleep duration

and more sleep problems predicted more conduct problems over time and, in turn, that conduct problems predicted more sleep problems and shorter sleep duration. Additionally, higher levels of weekend oversleep predicted more depression and emotional problems over time.

Concurrent Relationships Among Variables

Contrary to our first hypothesis, none of the sleep variables were consistently related to all behavioral and emotional variables over time. Both shorter sleep duration and more sleep problems were associated with more parent-reported conduct problems and youth-reported aggression and depression. Interestingly, the associations with sleep problems were more consistent over time, whereas sleep duration was most commonly related to behavioral and emotional problems at Wave 3 (age 16). Perhaps the more severe disturbances to sleep represented by sleep problems are sufficient for it to affect adjustment at all ages, while the effect of sleep duration must accumulate before it can be seen. Older adolescents also have more demands than younger adolescents at school, home, and work (Steinberg, 2014), so they might feel the effects of shorter sleep more at age 16 than they did a few years earlier. Finally, as older adolescents sleep less overall, the restricted range might make any variation in sleep duration more important than it had been at earlier periods.

Greater amount of weekend oversleep was related to more parent-reported conduct problems, more parent-reported hyperactivity/inattention, more youth-reported aggression, and more youth-reported substance use only at Wave 3 (age 16). However,

weekend delay was related consistently to parent-reported emotional problems. Meanwhile, weekend delay was only related to higher levels of substance use at Wave 2.

Consistent with our results, most past research has more closely linked behavioral and emotional outcomes with sleep duration and sleep problems than to weekend delay or weekend oversleep (e.g., Alvaro, Roberts, & Harris, 2013; Ireland & Culpin, 2006; Johnson, Breslau, Roehrs, & Roth, 1999; Yoon et al., 2012). However, past research also has posited that sleep duration measures and sleep variability measures might predict different outcomes (Acebo & Carskadon, 2002). We demonstrated the sleep problems are related consistently to behavioral outcomes throughout adolescence, but to emotional outcomes at isolated time points. However, sleep irregularity variables show the opposite pattern, being more closely related to emotional problems throughout adolescence, with inconsistent relationships with behavioral outcomes. Thus, our results support the idea that the most comprehensive explanations for the relationships between sleep and various behavioral and emotional outcomes can be found by considering a combination of both sleep duration and sleep regularity variables (Acebo & Carskadon, 2002).

Changes in Variables over Time

In support of our second hypothesis, child-reported sleep duration did decrease over time, from 8.73 hours at age 13 to 8.05 hours at age 16. However, contrary to our hypothesis, levels of all other sleep variables did not change over time. These results suggest that sleep problems, weekend delay, and weekend oversleep may not systematically change in early to middle adolescence among low income, urban African American youth. Although these results are inconsistent with previous research that

showed insomnia symptoms, daytime sleepiness, and sleep problems are common and increase during adolescence, the populations studied in most large-scale studies of adolescent sleep behaviors may not be comparable to ours. While Johnson and Breslau (2006) assessed an urban sample of adolescents in our age range (13 to 16 years old), only 25% of their 1,014 participants were African American, and they were only measuring insomnia. Similarly, when Acebo and Carskadon (2002) investigated sleep habits of students at four public schools, only 14% of the 3,119 adolescents were African American. Matthews, Hall, and Dahl (2014) did use a majority African American population (57%, mean age 15.7 years) in a study of 250 high schoolers in a lower SES, urban setting. However, the study used actigraphy to record sleep times and was also cross-sectional, comparing sleep habits of different ethnic and gender groups. This study concluded that African American males had poorer sleep than other groups, but it could not address ethnic differences in changes in sleep over time. There is clearly a need for future studies to investigate the epidemiology of sleep and various sleep problems specifically in minority youth.

It is also possible that existing developmental differences in these aspects of sleep were not detected due to limitations of the self-report measures used, or because of limited statistical power due to the small sample size. Most epidemiological studies which reported increases in sleep problems were much larger in scale (e.g., Johnson, Roth, Schultz, & Breslau, 2006). However, these studies also suffer the same limitations mentioned previously; namely, they focus on clinical diagnoses of sleep disorders. The effect sizes observed in our study, although low (d = 0.07 to 0.30; Cohen, 1988), are comparable to other studies assessing sub-clinical levels of sleep problems in community

adolescent samples (see Table 15; Wolfson & Carskadon, 1998). We also observed discrepancies between child and parent-reported sleep duration, with adolescents reporting a decrease over time, whereas parents reported consistently higher levels that did not decrease over time. This discrepancy could reflect a decrease in parents' control over children's bed times and sleep behaviors, as well as lower awareness of their children's sleep habits (Steinberg, 2014).

Table 15

Comparison of effect sizes observed for sleep variables in current study vs.Wolfson & Carskadon (1998)

Variable	Cohen's D (Effect-size Correlation)			
	Current Study		*Wolfson & Carskadon (1998)*	
	Ages 13-15	Ages 15-16	Ages 13/14-15	Ages 15-16
Sleep Problems (C)	0.08 (0.04)	0.03 (0.01)		
Sleep Duration (C)	0.30 (0.15)	0.28 (0.14)	0.08 (0.04)	0.11 (0.06)
Weekend Delay (C)	0.11 (0.06)	0.01 (0.00)	0.01 (0.01)	0.06 (0.03)
Weekend Oversleep (C)	0.07 (0.03)	0.02 (0.01)	0.10 (0.05)	0.02 (0.01)
Sleep Duration (P)	0.18 (0.09)	0.10 (0.05)		
Weekend Delay (P)	0.11 (0.06)	0.05 (0.02)		
Weekend Oversleep (P)	0.19 (0.10)	0.04 (0.02)		

Note: (C) indicates child-report measure; (P) indicates parent-report measure

Unlike sleep problems, behavioral and emotional outcomes showed more systematic differences over time. Both child-reported physical aggression and parent-reported conduct problems and hyperactivity/inattention decreased from age 13 to age 16, whereas substance use increased. These trends are consistent with findings from other studies which demonstrate that levels of hyperactivity, aggression, conduct problems, and oppositional behavior all decrease throughout adolescence (Biederman, Mick, & Faraone,

2000; Bongers, Koot, van der Ende, & Verhulst, 2004; Brame, Nagin, & Tremblay, 2001; Lahey et al., 2000) while substance use increases (A. L. Bryant, Schulenberg, O'Malley, Bachman, & Johnston, 2003).

Among emotional outcomes, both child-reported depression and emotional problems were stable from ages 13 to 15 and then decreased at age 16. This pattern is contrary to past epidemiological findings of increasing rates of depression in middle adolescence (see Hankin et al., 2015 for a review), but is generally consistent with several recent studies which have observed decreases in multiple types of anxiety symptoms across adolescence (McLaughlin & King, 2015; Van Oort, Greaves-Lord, Verhulst, Ormel, & Huizink, 2009).

Support for Reciprocal Relationships

Several models revealed significant links between sleep and behavior or emotions over time. Sleep was more closely related to behavioral than emotional functioning. Specifically, more hyperactivity/inattention at age 13 predicted shorter sleep duration at age 15. In addition, shorter sleep duration and more sleep problems at age 13 predicted more conduct problems at age 15 which, in turn, predicted shorter sleep duration and more sleep problems at age 16. These relationships between sleep and conduct problems provided the only instance of true reciprocal relationships. Adolescents who have short duration or poor quality of sleep may be irritable or low in cognitive resources such as impulse control (Dahl & Harvey, 2007), which may make them more likely to engage in things like fighting, lying, bullying, and cheating. These behaviors, in turn, could lead to physical arousal which makes sleep more difficult (Ireland & Culpin, 2006), and the act

of committing the behaviors themselves could keep adolescents out later at night, contributing to shorter sleep duration.

Among emotional outcomes, more weekend oversleep at age 13 predicted more depression at age 15 and more emotional problems at age 16. It is difficult to say if these findings are consistent with previous studies, since most past research has examined the effects of sleep duration and sleep problems on depression and anxiety, rather than the role of sleep irregularity. Such studies tend to find cross-sectional support for relationships between low sleep duration and depression and anxiety (e.g., Roane & Taylor, 2008; Shanahan, Copeland, Angold, Bondy, & Costello, 2014), but more conflicting evidence for prospective or reciprocal relationships (Alvaro et al., 2013; Gregory et al., 2009). Only one study used weekend delay to predict depressive symptoms, and the results were nonsignificant (Acebo & Carskadon, 2002).

Weekend oversleep reflects the tendency of the adolescent to engage in more total sleep time on the weekends than during the week. It could be a result of youth attempting to catch up on sleep debt which they have accumulated during the week. This sleep debt could be a consequence of multiple social, familial, work, and school obligations, coupled with early school start times (Steinberg, 2014). Any combination of these stressors, in addition to promoting a tendency for weekend oversleep, could also put youth at risk for developing depression or emotional problems. The fact that these stressors typically increase with the transition to high school could help explain why age 13 weekend oversleep (but not later time points) predicted subsequent emotional problems in this study.

Given that the sleep variability (vs. duration) measures were most strongly related to the emotional outcomes, the lack of reciprocal relationships is not entirely surprising. Most proposed bi-directional frameworks between sleep and depression and anxiety suggested that emotional difficulties would increase cognitive arousal (e.g., rumination) which makes sleep more difficult. If this is true, then emotional problems are more likely to affect sleep problems and sleep duration, not weekend delay or weekend oversleep. So, the aspects of sleep most likely to *affect* emotional functioning might not be the same aspects of sleep most likely to be *affected by* emotional functioning. The relationships between sleep and psychosocial functioning might be more complex than can be captured by a bi-directional relationship. The limited findings for the hypothesized reciprocal relationships between sleep and emotional variables may also be due to limited measurement of emotional problems. In particular, the parent report was a brief composite measure of depression, anxiety, and somatic complaints, which may have made it difficult to discern relationships between any of these specific domains and aspects of sleep. Future studies should consider including more comprehensive measures of specific emotional outcomes.

Altogether, these findings reflect the fact that different types of sleep variables are often related to different types of outcome variables (Acebo & Carskadon, 2002). Sleep problems and sleep duration were prospectively related to the behavioral outcomes, replicating previous findings (e.g., Haynes et al., 2006, Wong, Robertson, & Dyson, 2015). However, for emotional outcomes, where past research has been sparse and more contradictory (e.g., Gregory et al., 2005; Kelly & El-Sheikh, 2014; Roane & Taylor, 2008), sleep irregularity variables, such as weekend oversleep, may be more predictive.

For researchers, again, the implication is that considering both sleep duration and sleep regularity will provide the clearest picture of the overall effects of sleep on adolescent behavioral and emotional outcomes. For parents and others interacting directly with adolescents, these finding imply that interventions that target sleep duration may be more effective for improving behavioral outcomes, such as conduct problems, while improving regularity of sleep may be more helpful for emotional outcomes, such as depression. For conduct problems, where support for reciprocal relationships was found, it may also be that interventions that target sleep behaviors may improve behavior problems, and sleep-focused interventions may possibly be used to increase the effectiveness of other behavioral interventions.

Developmental Differences

Developmental differences were only observed for the links between sleep and conduct problems. Specifically, there was a relationship between decreased sleep duration and increased conduct problems in early adolescence, but not in later adolescence. It is possible that this reflects an increased importance of sleep variables for behavioral outcomes at the beginning of the physical changes and developmental shifts occurring in early adolescence (Carskadon, Vierira, & Acebo, 1993; Pieters et al., 2015). Alternatively, sleep duration may be a more important predictor of conduct problems during the vulnerable period of transitioning from middle school to high school. Many of our participants moved from middle to high school between Waves 1 and 2 of data collection, when the significant finding was observed. However, sleep duration may be less important later on when the youth are in a stable school environment. It is

surprising that we did not observe more developmental differences, given the number of developmental changes that occur, both to the sleep-wake cycle (Adair & Bauchner, 1993) and to behavioral and emotional functioning (Steinberg, 2014) in adolescence. However, the mean level of conduct problems in this sample decreased over time, meaning that there was less variability in the variable at the later developmental periods. This could partially explain the findings, along with our small sample size. Regardless, this finding underscores the importance of sufficient sleep in early adolescence.

Limitations and Future Directions

The major limitation of this study was the small sample size of 84 participants. With a larger sample size, some of our marginal findings, such as the bi-directional pathways in the substance use model, might have reached significance. In addition, there was some evidence for nonlinear relationships among some of the variables. A larger sample would help clarify the reliability of such nonlinear relationships. In the future, studies with larger samples should replicate our design with greater power in order to better understand the relationships between sleep and adolescents' psychological functioning.

In addition, this study included only self- and parent-reports of both sleep and behavioral and emotional outcomes, raising questions about the validity of these reports. Research has found that, when compared to objective measures like actigraphy, self-reports of sleep duration are inflated by an average of a half hour for each hour of additional reported sleep (Lauderdale, Knutson, Yan, Liu, & Rathouz, 2008). However, other studies have concluded that self-report survey measures tend to be reliable in

assessments of school-night total sleep time and wake-up time, but give early estimates of school-night bedtimes, longer estimates of weekend total sleep time, and later weekend wake up times (Wolfson & Carskadon, 1998). In general, self-report measures are considered valid for total sleep time, but caution should be used when interpreting more specific sleep variables (Gradisar, Gardner, & Dohnt, 2011). In this study, there was a discrepancy between adolescent and parent-reports of sleep duration, with a significant correlation between them only present at age 13. Among all sleep variables, only weekend oversleep was consistently correlated between both reporters at all three time points. Future studies should supplement subjective reports of sleep with objective measures, such as actigraphy.

A similar concern is whether parents can be considered valid sources of information on adolescent sleep behaviors. This might be a particular concern in this study, given that the strongest evidence for bi-directional relationships came from a parent-report model. Research does seem to suggest that parents tend to overestimate the amount of sleep their children receive, reporting near optimal amounts on both weekdays and weekends in the form of earlier bedtimes and later wake times (Short, Gradisar, Lack, Wright, & Chatburn, 2013). While some might argue that such discrepancies are a reason to only include adolescent-reports of sleep, others argue for the importance of using multiples sources within the same study, as we have done here (Wolfson & Carskadon, 2003). This echoes the concept of the "Grand Discrepancy"—the long held belief in research that multiple informants can provide valuable information about an individual's behavior, coupled with a tendency to still treat any disparity between informants as measurement error (De Los Reyes, Thomas, Goodman, & Kundey, 2013).

Rather than operating on the principle of Converging Operations (Garner, Hake, & Eriksen, 1956), which would argue that a multi-informant study's strength rests in whether all its results support the same conclusions, De Los Reyes and colleagues suggest that there is room for a framework which considers both converging and diverging research findings, and which places value on informant discrepancies (De Los Reyes, Thomas, Goodman, & Kundey, 2013). For example, future studies should consider the ways in which adolescent and parent reports of sleep and behavior/emotional functioning might be expected to disagree, given the disparate contexts and viewpoints from which adolescents and parents experience them (Achenbach, McConaughy, & Howell, 1987). These considerations may help elucidate why reports from some informants yield stronger associations between sleep and emotional or behavioral functioning than others.

Even if parental reports of adolescent sleep have lower validity, this perspective is important to study because parental perceptions of adolescents' behavior will affect their interactions with the child. Parents who perceived their children as sleeping less later perceived them as engaging in more problem behaviors. During the same time period, adolescents who reported more problems sleeping were acting in ways their parents judged to be more problematic. Whether or not the adolescents themselves would judge their behavior to be problematic, results of this study show that, within the family dynamic, sleep could be an excellent target behavior for intervention which may improve both parent and adolescent perceptions of the child's functioning.

Conclusions

Despite the limitations, this study makes several unique contributions to our understanding of the relationships between sleep and behavioral and emotional problems in adolescence. Importantly, this is one of few prospective studies of sleep in a community sample of adolescents that addresses the relationships between non-clinical variations in sleep and behavior. This study is also unique in its focus on low-income, urban African American adolescents who are at risk for both poor sleep and elevated behavioral and emotional problems. The findings add to the existing literature by demonstrating that sleep is an important predictor of adolescent behavior and emotions, but that behavioral functioning can also affect adolescent sleep. Shorter sleep duration and sleep problems appear to be better predictors of behavioral outcomes such as aggression and conduct problems, while irregularity of sleep seems to be a better predictor of emotional difficulties. There was evidence of bi-directional relationships between sleep duration, sleep problems, and conduct problems, at least when using parental reports of youth behavior. In conclusion, this study demonstrates that sleep is an important and complex phenomenon whose effects in adolescence we are just beginning to untangle and that future studies should continue to explore.

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APPENDIX A

IRB APPROVAL FORM

Project Revision/Amendment Form

Form version: June 26, 2012

In MS Word, click in the white boxes and type your text; double-click checkboxes to check/uncheck.

- **Federal regulations require IRB approval before implementing proposed changes. See Section 14 of the IRB Guidebook for Investigators for additional information.**
- **Change means any change, in content or form, to the protocol, consent form, or any supportive materials (such as the Investigator's Brochure, questionnaires, surveys, advertisements, etc.). See Item 4 for more examples.**

1. Today's Date	3/28/16

21879

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Department	Psychology	**Division (if applicable)**	
Office Address	HMB 195, zip 2100	**Office Phone**	5-9462
E-mail	smrug@uab.edu	**Fax Number**	5-2295

Contact person who should receive copies of IRB correspondence (Optional)

Name		**E-Mail**	
Phone		**Fax Number**	
Office Address (if different from PI)			

3. UAB IRB Protocol Identification

3.a. Protocol Number	**X110303001**
3.b. Protocol Title	Coping with Violence (Pathways to substance use and risky sexual behavior in youth exposed to violence)

3.c. Current Status of Protocol—Check ONE box at left; provide numbers and dates where applicable

- ☐ **Study has not yet begun** — **No participants, data, or specimens have been entered.**
- ☐ **In progress, open to accrual** — **Number of participants, data, or specimens entered:**
- ☐ **Enrollment temporarily suspended by sponsor**
- ☒ **Closed to accrual, but procedures continue as defined in the protocol (therapy, intervention, follow-up visits, etc.)**
  - **Date closed:** 9/15/2002
  - **Number of participants receiving interventions:** 0
  - **Number of participants in long-term follow-up only:** 84
- ☐ **Closed to accrual, and only data analysis continues**
  - **Date closed:**
  - **Total number of participants entered:**

4. Types of Change

Check all types of change that apply, and describe the changes in Item 5.c. or 5.d. as applicable. To help avoid delay in IRB review, please ensure that you provide the required materials and/or information for each type of change checked.

- ☐ **Protocol revision (change in the IRB-approved protocol)**
  In Item 5.c., if applicable, provide sponsor's protocol version number, amendment number, update number, etc.
- ☐ **Protocol amendment (addition to the IRB-approved protocol)**
  In Item 5.c., if applicable, provide funding application document from sponsor, as well as sponsor's protocol version number, amendment number, update number, etc.
- ☒ **Add or remove personnel**
  In Item 5.c., include name, title/degree, department/division, institutional affiliation, and role(s) in research, and address whether new personnel have any conflict of interest. See "Change in Principal Investigator" in the IRB Guidebook if the principal investigator is being changed.
  - ☒ **Add graduate student(s) or postdoctoral fellow(s) working toward thesis, dissertation, or publication**
    In Item 5.c., (a) identify these individuals by name; (b) provide the working title of the thesis, dissertation, or publication; and (c) indicate whether or not the student's analysis differs in any way from the purpose of the research described in the IRB-approved HSP (e.g., a secondary analysis of data obtained under this HSP).
- ☐ **Change in source of funding; change or add funding**
  In Item 5.c., describe the change or addition in detail, include the applicable OSP proposal number(s), and provide a copy of the application as funded (or as submitted to the sponsor if pending). Note that some changes in funding may require a new IRB application.

5. Description and Rationale

In Item 5.a. and 5.b, check Yes **or** No **and see instructions for** Yes **responses.**
In Item 5.c. and 5.d, describe—and explain the reason for—the change(s) noted in Item 4.

☐ Yes ☐ No **5.a. Are any of the participants enrolled as normal, healthy controls?**
If yes, describe in detail in Item 5.c. how this change will affect those participants.

☐ Yes ☐ No **5.b. Does the change affect subject participation, such as procedures, risks, costs, location of services, etc.?**
If yes, FAP-designated units complete a FAP submission and send to fap@uab.edu. Identify the FAP-designated unit in Item 5.c.
For more details on the UAB FAP, see www.uab.edu/cto.

5.c. Protocol Changes: In the space below, briefly describe—and explain the reason for—all change(s) to the protocol. ✓ Noted in IRB.

▶ Meredith Henry will use data from this study for her dissertation titled "Sleep tight, don't let the dysfunction bite! The relationship between sleep problems and behavioral and emotional problems in adolescence". The scope of the dissertation falls under the original goals of the study as approved in the IRB-approved HSP.

5.d. Consent and Recruitment Changes: In the space below,
(a) describe all changes to IRB-approved forms or recruitment materials and the reasons for them;
(b) describe the reasons for the addition of any materials (e.g., addendum consent, recruitment); and
(c) indicate either how and when you will reconsent enrolled participants or why reconsenting is not necessary (not applicable for recruitment materials).

Also, indicate the number of forms changed or added. For new forms, provide 1 copy. For revised documents, provide 3 copies:
- **a copy of the currently approved document (showing the IRB approval stamp, if applicable)**
- **a revised copy highlighting all proposed changes with "tracked" changes**
- **a revised copy for the IRB approval stamp.**

▶

Signature of Principal Investigator [signature] Date 3/28/16

FOR IRB USE ONLY

☐ Received & Noted ☑ Approved Expedited* ☐ To Convened IRB

Marilyn Davis 3-29-16
Signature (Chair, Vice-Chair, Designee) Date

DOLA 3/9/16

Change to Expedited Category **Y / N / NA**

*No change to IRB's previous determination of approval criteria at 45 CFR 46.111 or 21 CFR 56.111