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EMPIRICAL RESEARCH

Sleep Deprivation, Low Self-Control, and Delinquency: A Test of the Strength Model of Self-Control

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Abstract Recent work provides evidence that sleep deprivation is positively related to delinquency. In this study, we draw on Baumeister and colleagues' strength model of self-control to propose an explanation for this association. Specifically, we argue that low self-control is the construct that bridges the relationship between sleep deprivation and delinquency. To test the proposed model, we examine survey data drawn from a longitudinal multi-city cohort study of adolescents who were followed from birth through age 15 (N = 825; 50 % female; 82 % non-Hispanic white, 59 % two-parent nuclear family). The results from regression models using latent factors indicate: sleep deprivation is positively related to low self-control; low self-control is positively related to delinquency; and the relationship between sleep deprivation and delinquency is indirect and operates through low self-control. Impressively, these relationships emerged when accounting for potential background sources of spuriousness, including neighborhood context, depressive symptoms, parenting practices, unstructured socializing with peers, and prior delinquency. Implications and directions for future research are discussed.

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Introduction

An impressive body of research finds that low self-control is related to a variety of maladaptive behaviors (e.g., de Ridder et al. 2012; Hagger et al. 2010; Moffitt et al. 2011; Pratt and Cullen 2000; Tangney et al. 2004). Among the various models of self-control, the strength model developed by Baumeister et al. (1994) and commented on elsewhere (Baumeister et al. 2007; Baumeister and Tierney 2011) has received extensive empirical attention and support (Hagger et al. 2010). The basic premise is that self-control is a limited resource that individuals expend to regulate thoughts, feelings, and actions. Employing a metaphor to illustrate this idea, Muraven and Baumeister (2000) equate self-control to a muscle that can be depleted by tasks and situations that require self-control, but also replenished through rest and strengthened through practice.

Many studies evaluating the strength model have focused on testing the argument that self-control can be depleted (e.g., Muraven et al. 1998; Schmeichel et al. 2003) and strengthened over time (Baumeister et al. 2006). Implicit in this model is the idea that the ability to regulate one's behavior in part relies upon periods of rest and recovery. As stated by Muraven and Baumeister (2000, 248), "…a strength model entails that the available stock of resources is depleted by exertion and must be replenished before the full measure is available again." Informatively, research finds that providing a rest period between tasks requiring self-control results in a replenishment of self-control (Oaten et al. 2008; Tyler and Burns 2008). While such tests have generally focused upon short-

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term self-control tasks and periods of rest in laboratory settings, recent research has started to consider these processes in the broader context of the day-to-day exertion of self-control. In particular, studies indicate that inadequate periods of rest and recovery, operationalized as poor sleep quality, are significantly related to deficiencies in self-control capacity and cognitive functioning (Altena et al. 2008; Walker 2008).

At the same time that research has started to reveal a link between sleep quality and self-control, a separate line of inquiry has begun documenting the relationship between sleep quality and delinquency. In particular, recent findings indicate that adolescents who do not get adequate, quality sleep are at an increased risk for involvement in various forms of delinquency and risk-taking behaviors (Catrett and Gaultney 2009; Clinkinbeard et al. 2011; O'Brien and Mindell 2005; Peach and Gaultney 2013). Taken together, these two lines of inquiry linking sleep to reduced self-control and delinquency raise the question as to whether the relationship between sleep deprivation and delinquency might be mediated by low self-control. Given the arguments of the strength model, we submit there is good reason to believe that such a process could be taking place—adolescents who fail to get adequate, restful sleep on a consistent basis may be less able to regulate their behavior and therefore be more likely to engage in delinquent behavior.

This study seeks to advance the literature by testing the tenability of the model of mediation just described. Given the emerging body of research examining the link between sleep deprivation and delinquency, uncovering the processes through which this relationship emerges is an important consideration (Peach and Gaultney 2013). In addition, the idea that self-control might be influenced by sleep quality speaks to the possibility that the sources of and the ability to exercise self-control might be more varied than what has been described by some theorists (e.g., Gottfredson and Hirschi 1990). We test our ideas using data from a multi-site study of US adolescents. The data are well suited to investigating the relationships of interest in that they include multi-item indicators of sleep deprivation, low self-control, and delinquency. Furthermore, we are able to address a key limitation of past research on the relationship between sleep and delinquency by accounting for prior delinquency, which could drive contemporaneous associations between sleep deprivation and delinquency. Thus, this study is able to advance this area of research in several different ways.

Prior Theory and Research on Sleep and Behavior

Until recently, the harmful implications of sleep deprivation have been relatively neglected by social scientists; indeed, some scholars have deemed sleep "the great forgotten aspect of human life" (Nutt 2012, 9). Although sleep occupies roughly a third of our time, neurologists are only now beginning to understand its function. Most notably, sleep offers the central nervous system an opportunity for recuperation and restoration. This is essential to people of all ages, but is especially important for developmental processes in children and adolescents (Steinberg et al. 2011). Sleep also is central to the processing of information, with the brain using periods of sleep to reinforce learning and consolidate memory (Kopasz et al. 2010). In this sense, sleep is critical to the organization of cognitions that are experienced while awake.

With much still to learn about the exact neurological processes involved in sleep, behavioral scientists have directed increasing attention to a clear pattern: Many individuals do not get enough sleep. In fact, the US Centers for Disease Control and Prevention has deemed insufficient sleep a public health epidemic—their research indicates that roughly 35 % of adults reported unintentionally falling asleep at least once during the prior month; roughly 5 % did so while driving (Centers for Disease Control and Prevention 2013). Moreover, the prevalence of sleep deprivation is higher among adolescents. Compared to preadolescence, adolescence is marked by later bed times, earlier school start times, and pubertal shifts thought to *increase* the number of needed hours of sleep (Colten and Altevogt 2006). In connection, the National Sleep Foundation (2013) indicates that adolescents need roughly 8.5–9.25 h of sleep per night, yet this is achieved by <15 % of the adolescent population. Indeed, by some estimates, roughly one-fourth of adolescents sleep 6 h or less per night (Wolfson and Carskadon 1998).

Sleep deprivation has notable implications for health and behavior (for reviews, see Colten and Altevogt 2006; Fredriksen et al. 2004). With respect to physical and mental health, insufficient sleep has been linked to such things as high cholesterol (Gangwisch et al. 2010), depression and suicidal ideation (Roane and Taylor 2008), and heightened anxiety (Talbot et al. 2010). For example, in a laboratory setting, Talbot and her colleagues found that participants assigned to a sleep-deprived state were more likely to rate aversive experiences as catastrophic. Similar results have emerged in community-based studies. For example, Fredriksen et al. (2004) tracked roughly 2,200 Illinois sixth graders for more than 2 years and found that those who experienced less sleep and greater reductions in sleep from the sixth through eighth grades experienced heightened depression and reduced self-esteem. Sleep deprivation also has been linked to academic outcomes and learning difficulties (Carskadon et al. 2004; Roberts et al. 2001). In a recent two-wave prospective study of roughly 3,000 adolescents, Roberts et al. (2009) found that sleep deprivation

(measured as six or less hours of sleep per night) significantly affected a range of negative outcomes reported 1 year later, including increased problems at school and poor grades.

Our interest in sleep deprivation focuses specifically on how it may increase delinquency in particular, and whether it does so through a process that involves impeding one's ability to engage in self-control. These potential outcomes of sleep deprivation—reduced self-control and increased delinquency—have received less attention in the literature, but the limited research suggests the value in considering them. A number of studies reveal effects of sleep deprivation on aggression, a key facet of delinquency. As Kamphuis et al. (2012) indicate in their review, research in this area often has involved laboratory experiments in which subjects assigned to a sleep-deprived state were compared to control groups on a range of aggression and antisocial inventories. These studies generally reveal higher levels of hostility, anger, suspicion of others, and externalizing aggression (e.g., Kahn-Greene et al. 2006). Lemola et al. (2012) reached a related conclusion in a community sample of early adolescents. Specifically, irregular sleep (differences in sleep duration between weekdays and weekends) amplified the effects of parental conflict on aggression—parental conflict was more likely to lead to aggression among those adolescents experiencing irregular sleep.

Some studies have gone beyond aggression to more directly consider delinquent or deviant behaviors (Catrett and Gaultney 2009; Clinkinbeard et al. 2011; O'Brien and Mindell 2005; Peach and Gaultney 2013). For example, in a cross-sectional study of Philadelphia high school students, O'Brien and Mindell (2005) found consistent relationships between these outcomes and various measures of sleep deprivation and poor sleep habits. Clinkinbeard et al. (2011) reached a similar conclusion using data from the first wave of the National Longitudinal Study of Adolescent Health—sleeping <7 h per night was associated with greater involvement in property delinquency, while sleeping <5 h per night was associated with greater involvement in violent delinquency. In addition, a recent study by Peach and Gaultney (2013) built on the work of Clinkinbeard et al. (2011) and examined the effect of sleep duration on delinquency across waves three, four, and five of the National Longitudinal Study of Adolescent Health. The authors found direct, positive effects of sleep deprivation on delinquency during adolescence, although these effects waned during adulthood.

Applying the Self-Control Strength Model

This prior research suggests that sleep deprivation may increase delinquency, but work in this area has yet to give adequate attention to the variables that may mediate this association. As noted above, we approach this issue in terms of the self-control strength model. According to this framework, sleep-deprived adolescents should be at greater risk for delinquency through a process in which insufficient sleep contributes to deficits in self-control. From this perspective, self-control is a limited resource used to regulate actions, emotions, and thoughts. This resource is analogous to a muscle in the sense that its strength can be depleted but also replenished from rest and strengthened from practice. A number of studies support the basic tenets of this model (see Hagger et al. 2010). For example, laboratory experiments have found that tasks designed to tax self-control resources produce within-individual reductions in self-control that exceed what is observed for control groups (Muraven et al. 1998). In short, the exercise of self-control in one instance produces at least a short-term increase in the chances that subsequent attempts at self-regulation will fail. As Vohs et al. (2011, 167) point out, a central theme to this finding is the idea that "dormant urges become unleashed after people have earlier engaged in self-regulation." This limited resource model therefore can explain findings in which such things as overeating, impulsive buying, and alcohol intake increase in the wake of demanding tasks that require self-regulation (see Baumeister et al. 2007).

From this perspective, sleep deprivation should increase delinquency in a very specific way: It should reduce daily self-control strength. This occurs because the level of sleep needed to restore one's self-regulation resources is not being achieved. Barber and Munz (2011, 315) describe this position well in noting the importance of sufficient sleep: "Sleep may provide individuals with the opportunity to replenish self-regulatory resources. These resources get depleted during the normal course of the day… [Thus,] rest and recovery are required to return to optimal self-regulatory functioning." Barber and Munz's own analysis of data from 96 college students supports the sleep-self-control connection—sufficient and consistent sleep over the course of a week produced increases in self-regulation performance in a laboratory test. Abe et al. (2010) reached a similar conclusion in their community study of junior high students in Japan, as did Ireland and Culpin (2006) in a study of incarcerated adolescent males. It also bears emphasizing that this position is consistent with research that explores the link between activity in the prefrontal cortex (PFC) of the brain and self-regulation. As Kamphuis et al. (2012) indicate, neuroimaging research shows that sleep deprivation impairs PFC functioning, which in turn interferes with self-regulation efforts.

Taken together, the research reviewed suggests a process in which sleep deprivation leads to deficits in daily self-control strength, which in turn increases delinquency.

It bears emphasizing, however, that such a model has yet to be fully tested—little research has examined whether the relationship between sleep deprivation and delinquency is mediated by low self-control. To our knowledge only one study has considered this issue in an indirect manner. Specifically, Peach and Gaultney (2013) examined whether impulse control and sensation-seeking mediate the effect of sleep deprivation on delinquency in cross-sectional models using data from the National Longitudinal Study of Adolescent Health. Their analysis did provide some evidence to suggest that the effect of sleep deprivation on delinquency is partially mediated by impulse control and sensation-seeking. Yet, as the authors note, the study relied on limited measures of impulse control and sensation-seeking. Moreover, each of the studies that have examined the effect of sleep deprivation on delinquency in settings outside of the laboratory has been limited in their ability to account for background sources of spuriousness and, in particular, prior delinquency. These observations raise attention to the goals of the current study.

Hypotheses

In an effort to build upon prior research, this study seeks to examine whether the sleep deprivation—delinquency association revealed through prior work operates through the intervening mechanism of low self-control. Given the research suggesting a link between sleep deprivation and diminished self-control, coupled with the literature linking low self-control to delinquency (e.g., de Ridder et al. 2012; Pratt and Cullen 2000), testing a model of mediation would assist in advancing and bridging together these two areas of research. Accordingly, we hypothesize that the relationship between sleep deprivation and delinquency should be mediated by low self-control. This hypothesis also implies, then, that sleep deprivation should be positively related to low self-control, and that low self-control should be positively related to delinquency. The model to be tested is presented in Fig. 1.

In testing the proposed model, we are able to advance the literature in a number of ways. Beyond attempting to illuminate the process through which sleep deprivation influences delinquency, there are three additional ways in which the current study advances the literature. First, whereas prior studies examining the relationship between sleep deprivation and delinquency have focused on a limited set of delinquent behaviors, the current study is able to consider the effect of sleep deprivation on a measure of delinquency that includes a range of behaviors tapping into violence, substance use, property offending and other non-violent behaviors. Given the limited research on this relationship, the ability to examine the generalizability of this association is important. Second, to our knowledge research investigating the sources of self-control has given little consideration to whether sleep may serve as an important source of self-control. Thus, the current study not only contributes to the literature on delinquency in particular but also contributes to the body of research that has sought to delineate the sources of self-control.

Third, past research investigating the relationship between sleep deprivation and delinquency has been limited in that it has been unable to rule out the possibility that prior delinquency and other potential confounding variables may account for observed associations. Exposure to sleep deprivation does not occur randomly—key background variables can affect the likelihood of being sleep deprived. Further, many of these same background variables may also influence self-control and involvement in delinquency. Thus, research of this kind must account for such things as the child's emotions, prior behavior, and exposure to prosocial or antisocial opportunities and contexts to guard against the possibility that the effects of sleep deprivation on low self-control and delinquency are spurious. To address this need, we control for adolescent depressive symptoms, parenting practices, the quality of the neighborhood environment, and time spent in unstructured and unsupervised socializing with peers, each of which are correlated with sleep deprivation, self-control, and/or delinquency (e.g., Beyers and Loeber 2003; Brand et al. 2009; Clinkinbeard et al. 2011; Hay 2001; Hay and Forrest 2006; Hoeve et al. 2009; Osgood et al. 1996; Roberts et al. 2001). In addition, we control for prior delinquency to capture preexisting individual differences in behavior that may influence later patterns of sleep, self-control, and delinquency. As others have noted (Haynie and Osgood 2005), because of strong intercorrelations between prior delinquency, future delinquency, and the various causes of delinquency (including low self-control), controlling for prior delinquency provides a rigorous examination of the effects of potential causes of delinquency (including sleep deprivation). Although no social scientific study can fully rule out concerns with spuriousness, the factors that we

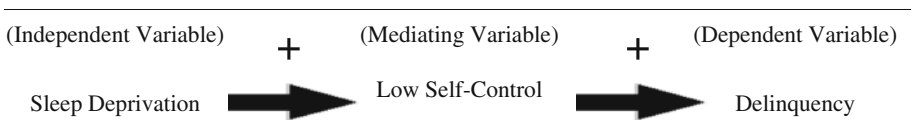

Fig. 1 Proposed theoretical model

account for exceed that seen in the prior studies in this area of research.

Methods

Participants and Procedure

The data used in this study come from the National Institute of Child Health and Human Development's Study of Early Child Care and Youth Development (SECCYD), which was conducted from 1991 through 2007. The main purpose of the SECCYD was to examine how variations in early childcare are related to developmental outcomes. However, as the study progressed, attention was also given to the collection of data on child and adolescent development, family dynamics, personality characteristics, and delinquency. Study families were recruited for inclusion in the SECCYD at hospitals in ten cities that were selected after the lead investigators reviewed applications submitted by researchers at major universities across the continental United States. The sites were selected on the basis of the quality of the applications received and not as a part of a random sampling procedure. Although the data cannot be considered nationally-representative, the selected sites represent a diverse set of cities: Little Rock, AR; Irvine, CA; Lawrence, KS; Wellesley, MA; Philadelphia, PA; Pittsburgh, PA; Morganton, NC; Charlottesville, VA; Seattle, WA; and Madison, WI.

Recruitment of the study families in 1991 focused on roughly 5,400 eligible families who were identified based on recent births at various hospitals in the ten cities. Of the families eligible for inclusion in the study, 3,015 were conditionally randomly sampled and contacted for an interview 2 weeks after the birth of the child [the conditioning assured representation (at least 10 % marginally) of single parent households, mothers with less than a high school education, and ethnic minority mothers]. However, certain families could not be reached, refused to participate, or experienced circumstances that interfered with their ability to participate in the study (e.g., the child remained in the hospital for an extended period). The total number of families that could be located and were able to participate in the study was 1,526. One month after the birth of their child, each family was contacted for the first major interview. Of the 1,526 families, 1,364 (89 %) completed the 1-month interview and were enrolled in the long-term study. The resulting sample was relatively diverse: 20 % of the children were non-white, 10 % had mothers who had not completed high school, and 13 % of the mothers were not married at the time of the child's birth.

Data were collected from the study child, their family, and other individuals, such as childcare workers and teachers, a number of times in the ensuing years, with the final assessment occurring when the study children were 15 years old. The current study largely relies on data collected at the final assessment at age 15, as this was the only point in time when all items measuring constructs central to the current investigation, particularly sleep deprivation, were available. However, as noted above, we are able to address limitations of prior work by accounting for prior delinquency that was assessed at the prior wave of data collection (age 12), as well as several other variables at age 15 that prior research has established are linked to sleep, self-control, and delinquency.

Of the 1,364 study families that completed the initial interview when their child was 1 month old, complete data for the variables used in the current study were available for 825 adolescents. To consider whether sample attrition was selective, the current sample's composition was examined relative to study families who had dropped out of the SECCYD before its completion when adolescents were 15 years old (or who had missing data on variables included in current study). We made comparisons with respect to five demographic/social status variables—sex, race, maternal education, family structure, and family income—for which data were collected during the 1-month interview (i.e., the first wave of data collection). While there was no evidence of selective attrition with regard to the sex ($\chi^2 = 3.73$, $p > .05$) and race ($\chi^2 = 2.14$, $p > .05$) of study adolescents, families who dropped out or who had missing data reported lower levels of maternal education ($t = 4.46$, $p < .05$), lower total family income ($t = 2.50$, $p < .05$), and were less likely to have a nuclear two-parent family structure at the 1-month interview ($\chi^2 = 11.76$, $p < .05$) as compared to respondents in the analytic sample. Attrition of this kind is not uncommon in longitudinal panel studies, and we include controls for each of these variables in our statistical models. Additional information about the SECCYD is available from the National Institute of Child Health and Human Development Early Child Care Research Network (2001).

Primary Measures

Delinquency

The study data contained information on a variety of delinquent behaviors reported by study adolescents at age 15, adapted from Conger and Elder (1994). In reference to these behaviors, adolescents were asked, "How many times in the past year have you…[act]?" "Never" (=0), "once or twice" (=1), and "more than twice" (=2) were offered as response options. The 11 items considered here included the use of different substances, non-violent behaviors such as trespassing, vandalism, and theft, and violent behaviors

such as threatening to beat someone up and attacking someone with a weapon ($\alpha = 0.82$). As will be discussed in the "Analysis Plan" section, the delinquency scale was estimated as a latent factor score in a structural equation model.

Low Self-Control

Low self-control at age 15 was measured with eight items drawn from the Weinberger adjustment inventory (Weinberger and Schwartz 1990). The WAI is a validated instrument (see Farrell and Sullivan 2000) used to measure psychosocial development and maturity, and recent studies have employed the WAI as an indicator of self-control (e.g., DeLisi et al. 2010). The eight items included in the SECCYD data compose the impulse control subscale of the WAI, and include potential responses of "False" (=1), "Somewhat False" (=2), "Not Sure" (=3), "Somewhat True" (=4), and "True" (=5) to each of the following statements: "I'm the kind of person who will try anything once, even if it's not that safe"; "I should try harder to control myself when I'm having fun"; "I do things without giving them enough thought"; "I become wild and crazy and do things other people might not like"; "If someone does something I really don't like, I yell at them about it"; "When I'm doing something fun, I tend to get carried away and go too far"; "I say the first thing that comes into my mind without thinking about it"; "I stop and think things through before I act" (reverse coded). Each of the items were coded so that higher scores reflected *lower* self-control ($\alpha = 0.82$). The low self-control scale was estimated as a latent factor score.

It is worth noting that the SECCYD also included an adolescent self-report version of the Child Behavior Checklist (see Achenbach 1991) at age 15, which contains items that have been used to measure adolescent self-control in prior research (e.g., Chapple 2005; Hay and Forrest 2006). To consider the robustness of the relationships of interest, we conducted a secondary analysis using the CBCL items appearing in past research on self-control (e.g., I act without stopping to think; I have a hot temper; I have trouble concentrating or paying attention). The results of the analysis using the CBCL items mirrored those which we discuss using the WAI items, and so we only present the set of results using the WAI items rather than both sets of results.

Sleep Deprivation

Measures of sleep examined in relation to delinquency in past research have included self-reports of such things as the average number of hours slept per night (Clinkinbeard et al. 2011; Peach and Gaultney 2013), daytime sleepiness and sleep-wake problems (O'Brien and Mindell 2005), and troubled sleep (Catrett and Gaultney 2009). For this study we used a 6-item measure based on self-report responses when adolescents were 15 years old to the following items: "How often do you feel tired on school days?"; "How often do you have trouble falling asleep on school nights?"; "How often do you wake up in the middle of the night and have trouble falling back to sleep?"; "How often do you have trouble getting up on time in the morning on school days?"; "How often do you wish you could get more sleep?"; and "How often do you wake up early in the morning and have trouble falling back asleep?" For each of the six items, responses ranged from "Never" (=1) to "Always" (=5) so that higher scores reflected greater sleep deprivation when combined together ($\alpha = 0.68$). As with the measures for delinquency and low self-control, the sleep deprivation scale was estimated as a latent factor score for the analysis.

Control and Demographic Measures

Prior Delinquency

Prior delinquency at age 12 was measured with a 14-item scale that reflects items that are substantively similar to those discussed above representing delinquency measured at age 15. The prior delinquency measure was coded as a frequency scale that ranged between 0 and 5 where higher values reflected greater involvement in delinquency ($\alpha = 0.70$). The scale originally ranged between possible values 0 and 28 [28 indicating that a respondent reported a score of 2 (engaged in a behavior 2 or more times in past 12 months) for each of the 14 items]. Only a handful of respondents scored above 5. Thus, to limit the influence of outliers we capped the scale at 5.

Depressive Symptoms

Self-reported depressive symptoms at age 15 were measured with a 10-item scale in which adolescents responded to items from the Child's Depression Inventory (Kovacs 1992) that assessed such things as whether they feel lonely, if they feel sad, and whether anyone loves them. Each of the ten items ranged on a 3-point scale, and some items were reverse-coded so that higher values consistently indicated more severe depressive symptoms ($\alpha = 0.81$). The depressive symptoms scale was estimated as a latent factor score for the analysis.

Effective Parenting

A measure of effective parenting tapping dimensions of parental monitoring and warmth taken at age 15 was

included. The scale was adapted from Stattin and Kerr (2000) and Conger et al. (2002). Adolescents were asked to respond to 15 items such as "How much does your mother know about whom you spend free time with?" (monitoring) and "How often does your mother act loving and affectionate toward you?" (warmth). Each of the 15 items were coded so that higher values represent higher quality parenting ($\alpha = 0.91$). The effective parenting measure was estimated as a latent factor score for the analysis.

Neighborhood Risk

A measure of neighborhood structural conditions was included based upon year 2000 census neighborhood block data that corresponded with the 2006 residential address of each of the study adolescents at age 15. The measure included in the analysis was based on 5 items tapping the: percent of households headed by single-mothers; percent of households that are not owner occupied; percent of males that are unemployed; percent of residents age 25 and older having less than a high school education; and percent of households having an income that is below the poverty line. Each of the items were coded so that higher values for each of the 5 items represent greater neighborhood risk ($\alpha = 0.80$). The neighborhood risk variable was estimated as a latent factor score for the analysis. We can also report that alternative measures for neighborhood risk were available in the data based on adolescent and maternal reports, and that the use of these items in place of the census-based items produced identical results.

Unstructured Socializing

We included measures for time spent in unstructured socializing with peers during the week and on the weekend when the study adolescents were 15 years old. Study adolescents were asked to report the typical number of weekdays in which they spend >30 min with friends when no adults are around, with response options ranging from 0 to 5 days. A corresponding item asked adolescents about the typical number of hours they spend with friends when no adult is around on the weekend, with response options ranging from 1 (none at all) to 6 (more than 7 h).

Additional Controls

We included six additional variables in the analysis, each measured when the adolescents were 15 years old. First, we included an item asking adolescents to report who decides how late they can stay up on a school night. Response options for this item were as follows: 1 for "my parents decide"; 2 for "my parents decide after discussing it with me"; 3 for "we decide together"; 4 for "I decide after discussing it with my parents"; 5 for "I decide all by myself." Second, we included a dichotomous indicator for whether or not study adolescents lived in a household with both of their biological parents (Yes = 1; No = 0). Third, we included maternal reports for total family income (in dollars, transformed with natural logarithm) and maternal education (1 = less than H.S.; 10 = doctoral degree). Last, the race (nonwhite = 1; white = 0) and sex (male = 1; female = 0) of study adolescents are also accounted for in the analyses. Given the birth cohort design of the study, age is treated as a constant. Table 1 provides the descriptive statistics for the analytic sample, including the latent variables that were estimated in a measurement model that did not partial out the influence of the covariates (see below). The latent variables represent the *estimated* factor that was extracted from the analysis and, therefore, the means and variances deviate slightly from the model imposed constraints of 0 and 1.00, respectively.

Table 1 Descriptive statistics for study variables (N = 825)

Variable	Mean	SD	Min	Max
Latent factors				
Delinquency	0.07	0.60	−1.29	2.47
Sleep deprivation	0.01	0.49	−1.65	1.75
Low self-control	0.02	0.55	−1.40	1.89
Depressive symptoms	0.06	0.66	−1.35	2.91
Effective parenting	−0.01	0.63	−2.04	1.62
Neighborhood risk	0.00	0.67	−0.81	3.72
Observed covariates				
Male	0.50	0.50	0	1
Non-white	0.18	0.39	0	1
Two-parent nuclear family	0.59	0.49	0	1
Family income (natural log)	11.17	0.92	7.82	13.82
Maternal education	4.25	1.93	1	10
Weekday unstructured socializing	1.98	1.89	0	5
Weekend unstructured socializing	3.52	1.65	1	6
Weeknight sleep decision-making	3.08	1.44	1	5
Prior delinquency	0.66	1.19	0	5

Analysis Plan

Structural equation modeling (SEM) was used to estimate the impact of sleep deprivation and self-control on delinquency and, further, to unpack the indirect relationship between sleep deprivation and self-control on delinquency. The analysis unfolded in two steps. The first step was to estimate a measurement model where each of the observed variables mentioned above—specifically, those for delinquency, low self-control, sleep deprivation, depressive symptoms, effective parenting, and neighborhood risk—were fit to separate latent factors using confirmatory factor

analysis after controlling for the influence of the observed covariates. It is important to note that the observed indicators for each of the latent variables, with the exception of the neighborhood risk items, were coded on an ordinal scale (e.g., 0, 1, or 2). Preliminary results suggested that modeling the observed variables as continuous outcomes was detrimental to the overall model fit. As a result, all observed indicators were modeled as categorical variables in *Mplus 7* by using the robust weighted least squares estimator with a diagonal weight matrix and delta parameterization. This estimator uses maximum likelihood with robust standard errors and is an appropriate strategy for fitting SEMs to non-continuous data.

The second step to the analysis built on the first step by estimating the structural portion of the overall SEM. In particular, the impact of sleep deprivation on low self-control was estimated while simultaneously estimating the impact of low self-control and the other covariates on delinquency. It is important to keep in mind as we move to the results that the SEM allows for the estimation of the indirect relationship between sleep deprivation and delinquency that works through (i.e., is mediated by) low self-control. This estimate is of particular interest for the present study given our focus on the possible mediating role of low self-control in the relationship between sleep deprivation and delinquency. To evaluate model fit we report the weighted root mean square residual (WRMSR), the root mean squared error of approximation (RMSEA) (Steiger 1990), the comparative fit index (CFI) (Bentler 1990), and the Tucker-Lewis index (TLI).

Results

The first step to the analysis was to estimate the measurement model to generate scores on the latent factors for each observation. Additionally, the measurement model provides a correlation matrix such that the relationships among each of the latent factors can be assessed. We also present the paths from the observed covariates on each of the latent factors. As was noted above, the observed indicators for each of the latent factors, with the exception of the neighborhood risk items, were specified as categorical variables and, therefore, the weighted least squares estimator was employed to fit the model. Parameter estimates from the measurement model are presented in Table 2. Model fit indices showed a relatively good fit of the measurement model: WRMSR = 1.55, RMSEA = .04, CFI = .92, TLI = .92. Further, though the results are not shown in a table, the constituent indicators for each of the six latent factors all loaded positively and significantly ($p < .001$), with the standardized loadings ranging from .51 to .92 and a majority of the items loading at or above .70 for each factor.

Of particular interest are the correlations among the latent factors of sleep deprivation, low self-control, and delinquency estimated by the measurement model (note that we elected not to present the intercorrelations among the observed covariates given our primary focus on how the latent factors relate to one another). First, the correlation between sleep deprivation and delinquency is positive and statistically significant ($r = .20$, $p < .001$). This is consistent with prior work and indicates that individuals who are sleep deprived are more likely to engage in greater amounts of delinquency. Second, low self-control is strongly correlated with delinquency; the coefficient is positive and statistically significant ($r = .51$, $p < .001$). This indicates that respondents with lower levels of self-control (coded as higher values) reported greater involvement in delinquency. The third observation to note from Table 2 is that the correlation between sleep deprivation and low self-control is of moderate size, positive, and statistically significant ($r = .31$, $p < .001$). These three correlations that are positive and moderate-to-large in size suggest that the SEM analyses could reveal an indirect relationship between sleep deprivation and delinquency that is mediated by low self-control.

Presented in Table 3 are the results from the full SEM. Each of the latent factors presented in Table 2 were again estimated as latent factors in the full SEM results presented in Table 3. We initially estimated a model where the latent factor for low self-control was omitted from the analysis to confirm the association between sleep deprivation and delinquency revealed through prior work. Importantly, the estimates from this model revealed that the relationship between sleep deprivation and delinquency was positive and statistically significant when controlling for all factors and covariates other than low self-control ($b = .23$, SE = .06, $\beta = .17$, $p < .001$). However, given that our primary hypothesis centers on the indirect effect of sleep deprivation on delinquency and how low self-control may mediate this association, this model is not presented in Table 3. Having said this, the estimates presented in the first column from the full SEM in Table 3 provide initial support for our hypothesis and reveal a relationship between sleep deprivation and low self-control that is positive and statistically significant ($\beta = .29$, $p < .001$). In addition, the covariates of depressive symptoms, male, weekend unstructured socializing, and prior delinquency are positively related with low self-control, while effective parenting is negatively related with low self-control. Thus, this portion of the model reveals strong support for the contention that sleep deprivation is associated with reductions in self-control, even when accounting for prior delinquency and a number of other relevant covariates.

Reported in the second column of Table 3 are the estimates of the latent factors and the observed covariates on

Table 2 Measurement model correlation matrix for latent factors and fit statistics

	Latent factor					
	Delinquency	Sleep deprivation	Low self-control	Depressive symptoms	Effective parenting	Neighborhood risk
Latent factor correlations						
Sleep deprivation	0.20***					
Low self-control	0.51***	0.31***				
Depressive symptoms	0.29***	0.42***	0.34***			
Effective parenting	−0.29***	−0.24***	−0.32***	−0.26***		
Neighborhood risk	−0.07	0.05	−0.001	−0.02	0.08*	
Correlations between observed covariates and latent factors						
Male	0.05	−0.18***	0.02	−0.29***	−0.05	−0.02
Non-white	0.03	−0.04	−0.02	−0.07	0.02	0.28***
Two-parent nuclear family	−0.12**	−0.09*	−0.03	−0.11*	0.09*	−0.06
Family income (natural log)	−0.05	−0.05	−0.09*	−0.05	0.01	−0.32***
Maternal education	−0.01	0.00	−0.07	0.03	0.003	−0.01
Weekday unstructured socializing	0.15***	0.13**	0.09*	0.03	−0.07	0.07*
Weekend unstructured socializing	0.22***	0.08	0.14***	0.00	−0.05	−0.04
Weeknight sleep decision-making	0.16***	−0.00	0.02	0.05	−0.12***	−0.02
Prior delinquency	0.26***	0.14***	0.26***	0.15***	−0.17***	0.01
Fit statistics						
WRMSR	1.55					
RMSEA	0.04					
CFI	0.92					
TLI	0.92					
N	825					

All paths are standardized

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

delinquency (all variables were specified as having a direct effect on delinquency). We begin by noting that the strongest estimate in the model is that of low self-control ($\beta = .35$, $p < .001$), which establishes that the mediating variable in our proposed theoretical model is strongly related to the outcome of delinquency. Further, given our theoretical argument that sleep deprivation should operate through low self-control, we anticipated that the direct effect of sleep deprivation on delinquency would be close to zero and statistically insignificant. Informatively, this is what is observed in the data—the Beta coefficient for the relationship between sleep deprivation and delinquency is .08 and fails to reach statistical significance ($p > .05$).

In addition, the model produces an estimate for the indirect association between sleep deprivation and delinquency that operates through low self-control (displayed near the bottom of the table). Providing additional support for our theoretical stance, this estimate is positive and statistically significant ($\beta = .10$, $p < .001$). Taken together, the results of the SEM provide strong support for our primary hypothesis and theoretical argument—sleep deprivation is strongly and positively related to low self-control, low self-control is strongly and positively related to delinquency, and the relationship between sleep deprivation and delinquency is mediated by low self-control.

It is worth noting that two alternative models were estimated and that results were substantively identical to those presented here. First, a baseline model that included only the observed indicators involved in the mediation pathway was estimated. Specifically, we estimated the measurement model and the full SEM by including only the variables necessary to estimate the latent variables for delinquency, self-control, and sleep deprivation (i.e., all control variables were omitted). The results from this analysis indicated that the effect of sleep deprivation on delinquency was completely mediated by the self-control factor (indirect effect $\beta = .19$, $p < .001$). Second, and as a further point of emphasis, recall that we replicated the

Table 3 Structural equation model results

	Dependent variable	
	Low self-control *b* (SE) [β]	Delinquency *b* (SE) [β]
Covariates		
Sleep deprivation	.29*** (.04) [.29]	.11 (.07) [.08]
Low self-control		.51*** (.09) [.35]
Depressive symptoms	.23*** (.03) [.33]	.15** (.05) [.15]
Effective parenting	−.27*** (.03) [−.31]	−.19*** (.05) [−.15]
Neighborhood risk	−.00 (.03) [−.02]	−.09 (.05) [−.07]
Male	.18*** (.05) [.15]	.16* (.08) [.09]
Non-white	.04 (.05) [.03]	.15 (.09) [.07]
Two-parent nuclear family	.07 (.05) [.06]	−.13 (.08) [−.08]
Family income (natural log)	−.04 (.03) [−.06]	−.02 (.04) [−.02]
Maternal education	−.02* (.01) [−.08]	.01 (.02) [.01]
Weekday unstructured socializing	.01 (.01) [.02]	.05* (.02) [.10]
Weekend unstructured socializing	.04** (.01) [.11]	.08*** (.02) [.15]
Weeknight sleep decision-making	−.01 (.01) [−.03]	.08** (.02) [.13]
Prior delinquency	.06** (.02) [.11]	.08** (.02) [.11]
Indirect effect		
(Sleep deprivation → Low self-control → Delinquency)		.15*** (.03) [.10]
Fit statistics		
WRMSR	1.88	
RMSEA	0.04	
CFI	0.89	
TLI	0.88	
N	825	

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

analysis and produced substantively identical results when using items from the Child Behavior Checklist to measure low self-control, indicating that the results are robust across various operationalizations of low self-control.

Discussion

This study sought to advance research on the relationship between sleep deprivation and delinquency by drawing on Baumeister et al.'s (1994) strength model of self-control and recent work in the area of sleep (e.g., Abe et al. 2010; Barber and Munz 2011). In particular, we investigated whether the relationship between sleep deprivation and delinquency is mediated by low self-control. In support of our theoretical model and hypothesis, the analysis revealed a relatively strong relationship between sleep deprivation and low self-control and between low self-control and delinquency. In addition, the observed relationship between sleep deprivation and delinquency was indirect and it operated through low self-control. These findings emerged when accounting for a number of competing sources of influence, including prior delinquency and contemporaneous measures for parenting, depressive symptoms, neighborhood risk, and unstructured socializing with peers. Furthermore, we were able to consider a measure of delinquency that included a wider variety of behaviors than prior work. Specifically, the latent factor of delinquency considered in this study included items pertaining to substance use (alcohol, tobacco, and marijuana), non-violent behaviors such as trespassing and theft, as well as violent behaviors, including threatening to beat someone up and attacking someone with a weapon. Thus, taken as a whole, the findings of this study add to a growing body of evidence that sleep quality and/or quantity is an important construct that merits additional attention on the part of researchers seeking to uncover the varied factors related to adolescent delinquency.

We see these findings as having significant implications for knowledge on adolescent development. The key mediating variable in our study—low self-control—has long been considered a robust predictor of maladaptive behavior, but rarely is it studied as something that continues to evolve in adolescence. More commonly, self-control is approached as a personality construct caused by factors that have to some degree run their course by the time individuals advance to adolescence—such things as genetics and early childhood socialization lead an adolescent to either *have* or *not have* self-control by that point in the life course. Thus, researchers have neglected the ways in which self-control continues to be shaped by various aspects of health, development, and socialization. The findings here suggest that this is an important omission: a key aspect of adolescent health—how much sleep an adolescent receives—can affect behavior and do so by influencing self-control. We were drawn to this possibility through our attention to Baumeister's self-control strength model and its explicit emphasis on the malleability of self-control. The findings in this study support that model and

suggest that self-control is malleable in response to decisions that families and adolescents make regarding health and lifestyle. We see this finding as prioritizing future research on the ways in which sleep and other adolescent health and lifestyle variables (including nutrition, for example) can shape adolescent behavior at least in part by affecting key aspects of personality that are still evolving in adolescence.

Though the present study represents an important advancement, it is not without certain limitations. Four limitations are most notable. First, the current analysis was unable to rule out all sources of endogeneity. Endogeneity can arise for several reasons, including omitted variables and reverse-causation. For example, it is possible that early childhood differences in self-control affect sleep deprivation and delinquency, which may be reciprocally related to one another. Thus, even though the current analysis attempted to account for important potential sources of spuriousness, it cannot be stated with certainty that the analysis was able to perfectly specify the nature or direction of the association between sleep deprivation and low self-control/delinquency. That said, it bears emphasizing that in controlling for prior delinquency, we sought to capture many of the early childhood differences that might potentially explain self-control and delinquency at age 15. Also, our finding that sleep deprivation was associated with low self-control and delinquency is consistent with the results from experimental studies (e.g., Kahn-Greene et al. 2006).

Future research can be fruitfully directed to better establishing causality. This likely will require panel data with repeated identical measures of sleep deprivation, self-control, and delinquency. A useful approach with such data is to estimate hierarchical linear models in which different data collection points are nested within individuals; the analysis would focus on whether within-individual changes in sleep deprivation are associated with within-individual changes in self-control and delinquency. As others have noted (Brame et al. 1999), an advantage of this approach is that each individual serves as his or her own control, therefore accounting for unmeasured time-stable sources of spuriousness. It bears emphasizing, however, that this approach often reaches substantively similar conclusions to between-individual approaches—like that used here—that include strong statistical controls for key sources of spuriousness (e.g., Hay and Forrest 2006).

A second limitation highlights the difficulty of unpacking the "black box" when trying to specify the exact nature of the relationships between variables. The analysis revealed that sleep deprivation predicts greater delinquency and that this influence works through low self-control. This is consistent with theoretical expectations, yet we are unable to specify the exact neurological or psychological processes that bridge these associations. Does prolonged sleep deprivation lower patience and lead adolescents to simply *care less* about resisting temptations and restraining inhibitions? If so, this could amount to a reduction in what Tittle et al. (2004) have referred to as one's *interest* in self-control. Alternatively, prolonged sleep deprivation could produce more enduring neurological effects that substantially lower one's *capacity* for self-control. Such a pattern would be consistent with brain scan research showing that sleep deprivation can impair prefrontal cortex functioning, which in turn interferes with self-regulation. Although our analysis revealed that observed levels of self-control mediated the effects of self-deprivation on delinquency, we are not able to distinguish between these two different processes by which that could have occurred. Thus, while this study provides some answers, it also raises attention to other important questions.

Third, although the data were drawn from a multi-city sample of adolescents, it is not a nationally representative data set. As such, this shortcoming should be kept in mind when comparing the present results to those from prior or future research. And last, there are important and interesting issues that went beyond the scope of this study but that merit attention in future research. For example, it would be informative to examine how the relationships investigated might vary according to important demographic variables such as gender, as well as how sleep deprivation may operate to influence maladaptive behavior at different points in the life-course (see Peach and Gaultney 2013). Also, although we accounted for likely potential causes of sleep deprivation when estimating its effects, our analysis did not explicitly examine the causes of sleep deprivation. This merits attention in future research—to the extent that sleep deprivation contributes to an inability to exercise self-control and problem behavior, understanding the factors that contribute to sleep deprivation in the first place would be important for devising solutions to combat the issue.

Conclusion

This study provides an extension of prior work on the sleep deprivation–delinquency relationship by illuminating the intervening process that is in play. A key "lifestyle" attribute of adolescents (whether or not they are sleep deprived) is associated with a well-established individual characteristic (low self-control), which in turn affects involvement in delinquency. This study also provides a significant contribution to the area of research concerned with the factors that shape self-control by revealing that effective self-regulation is the result of a complex set of factors, one of which is sleep quality/quantity. Though far from being the definitive study on these subjects, we hope

that the findings produced will prompt additional research into the causes and consequences of sleep deprivation and self-control, and, ultimately, produce a more complete understanding of the etiology of adolescent delinquency.

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Author contributions RCM conceived of the study, acquired the data required for the analysis, drafted the introduction of the manuscript, drafted portions of the methods and discussion sections, and edited the complete manuscript; JCB conducted the statistical analysis, drafted portions of the results section and discussion section, and created the tables; CH drafted the literature review section of the manuscript and portions of the discussion section of the manuscript. All authors read, edited, and approved the final manuscript.

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