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Sleep Quality, ADHD Symptomatology, and Executive Functioning in College Students

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SLEEP QUALITY, ADHD SYMPTOMATOLOGY, AND EXECUTIVE FUNCTIONING IN COLLEGE STUDENTS

BY

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Abstract

Previous research has suggested that college students often experience poor quality of sleep (Lund, Reider, Whiting, & Prichard, 2010), and self-reported poor quality of sleep is associated with poorer EF performance in college students (Benitez & Gunstad, 2012). Preliminary research has also found that college students who report higher levels of ADHD symptoms also report poorer quality of sleep based on the PSQI (Becker, Luebbe & Langberg, 2014; Gau et al., 2007). Therefore, the first purpose of the present study was to investigate whether college students who reported higher levels of ADHD symptoms also manifested poorer EF and if sleep quality moderated this relationship. The second purpose of the present study was to explore whether sleep quality was predictive of self-reported EF before and after controlling for mental health condition and ADHD symptomatology. Specifically, it was hypothesized that higher levels of self-reported ADHD symptomatology would be predictive of poorer self-reported EF. It was also hypothesized that poorer sleep quality would be predictive of poorer self-reported EF. In addition, it was hypothesized that sleep quality would moderate the association between self-reported ADHD symptoms and self-reported EF, specifically college students manifesting poorer sleep quality in addition to higher levels of ADHD symptomatology would be predictive of even poorer self-reported EF. Lastly, it was hypothesized that poorer self-reported sleep quality would be predictive of poorer EF performance after controlling for both mental health condition and ADHD symptomatology. Results from a hierarchical multiple regression revealed that sleep quality was not a significant moderator between ADHD symptomatology and self-reported EF. It was also found

that poorer sleep quality and higher levels of ADHD symptomatology, specifically inattention, predicted poorer EF performance. Although sleep quality was a significant predictor of EF, sleep quality was not a significant predictor of EF after controlling for both mental health condition and ADHD symptomatology. Although ADHD symptoms and EF appear to be related, the present study is limited in the inferences between these variables due to their near equivalency statistically and that no pilot testing was conducted. In summary, universities should be encouraged to develop programs that stress the importance of good sleep hygiene for college students.

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Table of Contents

List of Tables

1. Statement of the Problem

Attention-deficit/hyperactivity disorder (ADHD) is characterized by developmentally inappropriate levels of inattention and/or hyperactive-impulsive behavior that cause significant impairment in multiple settings (American Psychiatric Association, 2013). ADHD affects about 7 % of the school age population (Thomas, Sanders, Doust, Beller, & Glasziou, 2015) and clinically significant symptoms are typically exhibited across the life span (Barkley, 2006; Biederman, Mick, & Faraone, 2000; Rasmussen & Gillberg, 2000). Recent findings suggest that young adults with ADHD are attending college at higher rates than in previous decades (Wolf, Simkowitz, & Carlson, 2009). Preliminary findings suggest that students with ADHD are at greater risk for deficits in executive functioning (EF) as are students who report significant ADHD symptoms but have not been formally diagnosed with ADHD (Altgassen et al., 2014; Barkley, Murphy, & Fischer, 2008; Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; Boonstra, Kooij, Oosterlaan, Sergeant, & Buitelaar, 2010; DuPaul, Weyandt, O'Dell, & Varejao, 2009; Garnier-Dykstra, Pinchevsky, Caldeira, Vincent, & Arria, 2010; Hervey, Epstein, & Curry, 2004; Rohlf et al., 2012; Weyandt & DuPaul, 2006; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005).

Executive functioning (EF) is a multifaceted construct, and a variety of definitions exist in the literature. For example, Jurado & Rosselli (2007) defined EF as cognitive processes consisting of response inhibition, planning, working memory, motivational inhibition, self-monitoring, and set shifting. Alternatively, Weyandt (2009) postulated that, "Executive functioning (EF) is a complex construct that encompasses a variety of cognitive abilities that allow for strategic planning, impulse control, cognitive flexibility, and goal directed behavior" (p. 1). The present study operationally defined EF as cognitive processes consisting of inhibition, shifting, emotional control, self-monitoring, initiation, working memory, planning/organization, task monitoring, and organization of materials (Roth, Lance, Isquith, Fischer, & Giancola, 2013). Executive functions play an important role for college students due to EF's role in planning of schoolwork, organization of schoolwork, academic adjustment, and academic procrastination (Rabin, Fogel, & Nutter-Upham, 2011; Sheehan & Iarocci, 2015). Preliminary research suggests that EF in adults is affected by poor sleep quality (Benitez & Gunstand, 2012; Couyoumdjian et al., 2010; Wilckens, Woo, Erickson, & Wheeler, 2014) and numerous studies have found that many healthy college students experience poor quality of sleep (Lund, Reider, Whiting, & Prichard, 2010). Quality of sleep has been measured in terms of sleep duration, sleep latency, sleep disturbance, habitual sleep efficiency, use of sleeping medication, and daytime dysfunction (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). These findings raise important issues concerning the relationship between ADHD symptoms, sleep quality, and EF. Recent research has found that college students who report higher levels of ADHD symptoms also report poorer quality of sleep based on the Pittsburgh Sleep Quality Index (PSQI) (Becker, Luebbe & Langberg, 2014; Gau et al., 2007). Furthermore, self-reported poor quality of sleep on the PSQI is associated with poorer executive function performance on tasks such as set shifting and verbal fluency in healthy college students (Benitez & Gunstad, 2012).

Given previous work that suggests that ADHD symptoms, EF, and sleep quality may be related, the first purpose of the present study was to investigate whether college students who reported higher levels of ADHD symptoms also manifested poorer EF deficits and if sleep quality moderated this relationship. The second purpose of the present study was to explore whether sleep quality was predictive of EF performance before and after controlling for mental health condition and ADHD symptomatology.

2. Justification and Significance of the Study

2.1 ADHD Symptomatology in College Students

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder typically diagnosed in childhood and the majority of children continue to display symptoms into adulthood (Barkley, 2006). An increasing number of students with ADHD are currently entering college compared to past decades (Wolf, Simkowitz, & Carlson, 2009) and as a result, college students are a growing demographic in the ADHD literature (DuPaul & Weyandt, 2009). Studies have consistently indicated that college students with a diagnosis of ADHD tend to have a lower grade point average (Heiligenstein, Guenther, Levy, Savino, & Fulwiler, 1999) and experience more academic impairments than their non-ADHD peers (Lewandowski, Lovett, Codding, & Gordon, 2008; Weyandt, Swentosky, & Gudmundsdottir, 2013).

A growing body of research supports that college students who report significant ADHD symptoms also manifest similar impairments as those with ADHD in terms of academic functioning. For example, research has found that college students with elevated ADHD symptoms are at risk for lower levels of college adjustment and lower GPA than their peers with low symptoms (Pope et al., 2007). Research also suggests that two to eight percent of college students exhibit clinically significant ADHD symptoms (DuPaul, Weyandt, O'Dell, & Varejao, 2009) with up to ten percent of college students reporting various levels of ADHD symptoms (Garnier-Dykstra, Pinchevsky, Caldeira, Vincent, & Arria, 2010). Brown (2008) postulated that, "ADHD is essentially a cognitive disorder, a developmental impairment of executive functions (EFs), the self-management system of the brain" (p. 407). Self-reported EF was found to be a significant predictor of academic adjustment and academic procrastination in college students (Rabin, Fogel, & Nutter-Upham, 2011; Sheehan & Iarocci, 2015). Therefore, the importance of EF for academic success warrants further investigation of EF in college students with self-reported ADHD symptomatology (Wolf, Simkowitz, & Carlson, 2009).

2.2 Laboratory EF Performance in Students with ADHD and ADHD Symptoms

Only a handful of studies have investigated EF in college students with documented ADHD. Preliminary results suggest that these students tend to report problems with some aspects of EF performance, although laboratory tasks of EF have produced inconsistent findings. For example, Weyandt, Rice, Linterman, Mitzlaff, & Emert (1998) did not find differences in EF performance between college students with ADHD, students with a developmental reading disorder, and controls on the Tower of Hanoi, Tests of Variables of Attention (TOVA), Wisconsin Card Sorting Test, and the Ravens Standard Progressive Matrices. Weyandt and colleagues (2002) also investigated college students with ADHD and their non-ADHD peers on the TOVA and the freedom from distractibility factor of the Wechsler Adult Intelligence Scales-Revised (WAIS-R). Results revealed that students with ADHD made more errors of omission on the TOVA than the control group. No differences, however, were found between groups on the WAIS-R freedom from distractibility factor, errors of commission on the TOVA, mean response time, or variability. It is possible, although speculative, that the results may be explained by the TOVA's relatively low cognitive demand compared to other neuropsychological tasks. Work by Semrud-

Clikeman & Harder (2011) found that college students with ADHD performed similarly to non-diagnosed peers on the California Verbal Learning Test. Recent working memory studies have yielded modest deficits on measures of auditory-verbal and visual-spatial working memory in college students (Gropper & Tannock, 2009; Kim, Lieu, Glizer, Tannock, & Woltering, 2013; Woltering, Lieu, Rokeach, & Tannock, 2013). In general, research findings concerning the performance of college students on laboratory EF tasks are inconsistent.

Several studies have found that college students who report significant ADHD symptomatology also exhibit EF deficits; however, other studies have not substantiated these findings (Dehili, Prevatt, & Coffman, 2013; Murtagh & Elworthy, 2014). As noted previously, approximately 10% of college students report various levels of ADHD symptoms (DuPaul, Weyandt, O'Dell, & Varejao, 2009; Garnier-Dykstra, Pinchevsky, Caldeira, Vincent, & Arria, 2010; Weyandt & DuPaul, 2006). A recent study by Murtagh & Elworthy (2014) used the Stroop Test and the Wisconsin Card Sorting Test to measure inhibition in college students with various levels of ADHD symptoms. Findings revealed no group differences in behavioral inhibition between low, moderate, and high self-reported ADHD symptoms. This study only measured behavioral inhibition, one aspect of EF; therefore, it is not reflective of global EF. A lack of group differences may be reflective of a small sample size, low statistical power, and that the measure of ADHD symptoms was not based on the DSM-IV. Overall, findings suggest that laboratory tasks may not be sensitive to the daily EF deficits displayed by college students with ADHD, and that additional EF measures may be needed to explore this construct.

2.3 Self-Reported EF in College Students with ADHD and ADHD Symptoms

Despite conflicting results on laboratory-based EF tasks, self-report measures of EF tend to produce consistent findings. For example, Weyandt, DuPaul, Verdi, Rossi, Swentosky, Vilardo, O'Dell, & Carson (2013) examined academic, neuropsychological, and psychological functioning in college students with ADHD. They found that students with ADHD reported EF impairments compared to their peers without ADHD on all specific and global aspects of EF on the Behavior Rating Inventory of Executive Function for Adults (BRIEF-A). These impairments included Inhibition, Shifting, Emotional Control, Self-Monitoring, Initiating, Working Memory, Planning/Organization, Task Management, and Organization of Materials. Although it was hypothesized that students with ADHD would exhibit significantly greater difficulties on all measures of EF, no significant group differences were obtained for the California Verbal Learning Test II (CVLT-II), a laboratory task for measuring sustained attention and impulse control. Similar to Weyandt et al. (2013), Chang, Davies, & Gavin (2009) examined error monitoring in college students with ADHD using the BRIEF-A. Students with ADHD reported significantly more difficulties in both the Self-Monitor and Task Monitor subscales of the BRIEF-A. A longitudinal study by Dvorsky & Langberg (2014) investigated the academic outcomes such as GPA, overall functional impairment, self-reported EF, and parent-reported EF in college students with ADHD. Results revealed that ADHD symptoms were positively associated with self-reported EF deficits including time management, organization, self-restraint, motivation, and emotional regulation. In a related study, Gray & colleagues (2015) explored self-reported EF and academic impairment in college students with ADHD. Both male and female students with ADHD reported marked impairments on the Barkley Deficits in Executive Functioning Scale (BDEFS) for time management, organization, problem solving, self-restraint, self-motivation, and self-regulation of emotions. A significant proportion of the college students with ADHD (67%) obtained scores greater than the 95th percentile, indicating moderate to severe deficits in EF. The participants classified as ADHD were recruited from the disability services at the university, however their diagnoses were not confirmed. Collectively, these studies suggest that college students with ADHD tend to report deficits on global and specific self-report measures of EF.

Self-reported ADHD symptomatology measures have also successfully predicted self-reported measures of EF in healthy college students. Dehili, Prevatt, & Coffman (2013), for example, explored self-reported EF, a visual search task of EF, and both measures' predictive validity of ADHD symptomatology in 116 undergraduates. EF deficits in college students were measured with the Barkley Deficits in Executive Functioning Scale (BDEFS) and ADHD symptomatology was measured with the Barkley Adult ADHD Rating Scale-IV (BAARS-IV). The BDEFS total score accounted for a significant proportion of variance ($R^2 = 0.53$) in predicting total ADHD symptoms, while the visual search task accounted for no significant variance. However, comorbidity was not controlled for in this study, which may have affected the results. A similar study in college students by Jarrett and colleagues (2014) investigated the relationship between ADHD symptoms, sluggish cognitive tempo symptoms, self-reported EF, laboratory EF performance, and sleep disturbances. The study found self-reported EF deficits were strongly associated with self-reported ADHD symptoms, and inattention was the strongest predictor of time management and motivation. Relationships were not found between self-reported symptoms and laboratory tasks of EF. Collectively, these studies suggest that EF deficits in college students with ADHD symptomatology are detectable using self-report measures of EF, however laboratory tasks may not be sensitive to these deficits. Inconsistencies across studies may be due in part to methodological problems, small sample sizes, or perhaps college students who report ADHD symptoms do not have EF deficits (Weyandt & DuPaul, 2012). Future research is needed to clarify whether college students with higher levels of ADHD symptoms also perform poorly on EF tasks.

2.4 Sleep Quality and Executive Functioning

A number of studies have reported that a significant proportion of healthy college students (36-60%) experience poor quality of sleep including restricted total sleep time, low enthusiasm, long sleep latencies, insomnia, restless legs syndrome, and periodic limb movement disorder (Lund, Reider, Whiting, & Prichard, 2010; Petrov, Lichstein, & Baldwin, 2014). Sleep, specifically rapid eye movement (REM) sleep, has been found to enhance learning, memory consolidation (Stickgold & Walker, 2008), and sustained attention (Lim, J. & Dinges, D.F., 2010; Lufi, D, 2014). Research supports that poor sleep quality impairs set shifting and task switching in college students (Benitez & Gunstand, 2012; Couyoumdjian et al., 2010). A recent study by Wilckens, Woo, Kirk, Erickson, & Wheeler (2014) also found that longer total sleep time and shorter wake time after sleep onset were associated with improved working memory, inhibition, and verbal fluency performance in young and middle-aged adults.

Although these participants were not college students, it is plausible that similar results would be found in the college population. Overall, these findings suggest that poor sleep quality in college students may result in poorer performance on EF tasks.

2.5 ADHD Symptomatology and Sleep Quality

In addition to healthy college students, students with higher levels of ADHD symptomatology have also been found to exhibit similar or exacerbated quality of sleep. For example, Gau et al. (2007) surveyed college students on sleep quality and symptoms of ADHD using a sleep schedule questionnaire, sleep problems questionnaire, and the Adult ADHD Self-Report Scale. For both inattentive and hyperactive symptoms, the highly likely ADHD and probable ADHD groups were more likely than the non-ADHD group to have a variety of current and lifetime sleep problems. For example, self-reported inattention symptoms were associated with a greater sleep need and a greater difference between sleep need and self-estimated nocturnal sleep duration. Self-reported hyperactivity symptoms were associated with decreased nocturnal sleep duration. Similarly, Becker, Luebbe & Langberg (2014) investigated 288 college students on inattentive, hyperactive, and impulsive dimensions of ADHD in relation to sleep quality. For example, 63% of participants were classified as "poor sleepers" and had higher rates of ADHD than "good sleepers". When controlling for ADHD status and psychiatric medication use, hyperactive symptoms of ADHD were significantly associated with worse sleep quality, longer sleep latency, shorter sleep duration, and more use of sleep medications. Inattention was also found to be associated with greater daytime dysfunction. In summary, preliminary research suggests that college students who report higher levels of ADHD symptoms are at greater risk for manifesting poor sleep quality.

3. Purpose of the Study

Previous research has suggested that healthy college students experience poor quality of sleep (Lund, Reider, Whiting, & Prichard, 2010) and self-reported poor quality of sleep is associated with poorer EF performance in healthy college students (Benitez & Gunstad, 2012). Preliminary research has also found that college students who reported significant ADHD symptoms also reported poor quality of sleep based on the PSQI (Becker, Luebbe & Langberg, 2014; Gau et al., 2007). Therefore, the first purpose of the present study was to investigate whether college students who reported higher levels of ADHD symptoms also manifested poorer EF and if sleep quality moderated this relationship. The second purpose of the present study was to explore whether sleep quality was predictive of EF performance before and after controlling for mental health condition and ADHD symptomatology.

Specifically, it was hypothesized that (1) Higher levels of self-reported ADHD symptomatology and poorer sleep quality would be predictive of poorer EF performance, (2) Sleep quality would moderate the association between self-reported ADHD symptoms and EF performance, specifically college students manifesting poorer sleep quality in addition to higher levels of ADHD symptoms would be predictive of even poorer EF performance (3) Poorer self-reported sleep quality would be predictive of poorer EF performance after controlling for both mental health condition and ADHD symptomatology.

4. Methodology

4.1 Procedure

Participants for the proposed study were a convenience sample of volunteers from undergraduate introductory psychology and communication courses from a public university located in the Northeast region of the United States. Students were recruited via campus flyers and classroom announcements that included information about the study as well as instructions and contact information for questions about the study. After a potential participant contacted the investigator, the investigator scheduled the time and location (classrooms) for participants to participate in the study. Participants who provided consent were then presented with paper and pencil forms of the Brief Rating Inventory of Executive Function-Adult Version (Roth, Isquith, & Gioia, 2005), Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), Barkley Adult ADHD Rating Scale-IV (Barkley, 2011) & a demographic questionnaire. Participants were informed that the response items would be different for each survey. Participants received the questionnaires in counterbalanced order to reduce potential testing effects. The participants completed materials in a room with minimal distractions supervised by the researcher. Assigning a random 3-digit number instead of names on the study materials of participants ensured confidentiality. The data collected was free of personal identifiers and completed copies were stored in a locked filing cabinet in a secure laboratory located on campus. Participants in introductory psychology and communication courses received extra credit for participation in the study. After completing the study, the participants were debriefed and received a receipt that could be given to their introductory psychology or communication professors. There was no pilot testing of this study. The study procedures were reviewed and approved by the IRB at the university.

4.2 Participants

After conducting a statistical power analysis, the number of participants required to achieve a Cohen's *f* effect size of 0.02 (small), 0.15 (medium), and 0.35 (large) for 80% power was 395, 55, and 25, respectively. In the present study, a convenience sample of 66 participants consisted of college students from a public university located in the Northeast region of the United States. To be able to participate in the study, students needed to be at least 18 years of age, a full time student at the university, and be able to read and write in English. Participants confirmed these inclusion criteria by reading and signing the consent form. Those who did not fulfill these criteria were excluded from participating in the study. Participants were not excluded for having ADHD or any other mental health conditions.

4.3 Informed Consent

The consent form detailed the aims and requirements of the study, any potential for harm, confidentiality, and benefits of participating. Potential participants were required to document having read the consent form before responding to the surveys, by signing a statement of endorsement. The form contained the student investigator's contact information in case participants had any questions or concerns. Participants were made aware that they had the opportunity to discontinue participation in the study at any time. Participants were also debriefed after participation and provided with information regarding how to contact the investigator if desired.

4.4 Measures

4.4.1 Demographic Questionnaire: Demographic information was obtained via a brief self-report questionnaire that included questions concerning participant age, gender/sex, race/ethnicity, year in school, and history of mental health conditions. Mental health condition was dummy coded as 1 (yes) and 0 (no) for the independent variable in the second hierarchical multiple regression.

4.4.2 Pittsburgh Sleep Quality Index (PSQI): The PSQI (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) is a self-administered questionnaire and consists of 19 items in addition to five questions (not used in the present study) for the bed companion. The 19 items measure different factors determining sleep quality, grouped into seven components: quality, latency, duration, efficiency and sleep alterations, use of sleeping pills, and daytime dysfunction. Each component is scored from 0 to 3. The total score of the PSQI is obtained from the sum of the seven components and ranges from 0 to 21 points (the higher the score, the worse the sleep quality). The PSQI has been found to have adequate validity (sensitivity and specificity was 89.6% and 86.5% for poor sleep quality, respectively) and reliability (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Buysee proposed a cutoff of 5 (score greater than or equal to five defining poor sleep quality and scores four or less defining good sleep quality). The PSQI is appropriate for heirarchical multiple regression, since this measure met statistical assumptions for a similarly designed study with healthy college students (Lund, Reider, Whiting, & Prichard, 2010). The global index score served as the independent variable.

4.4.3 Barkley Adult ADHD Rating Scale-IV (BAARS-IV): The BAARS-IV (Barkley, 2011) is a behavior rating scale for adult ADHD symptoms that consists of the 18 DSM-IV symptoms (9 for inattention, 5 for hyperactivity and 4 for impulsivity) together with 9 additional items for evaluating the symptoms of sluggish cognitive tempo (SCT). Higher scores indicate a higher number of symptoms, and symptoms must be present in two or more settings. Internal consistency has been reported as 0.870 for Inattention, 0.754 for Hyperactivity, 0.870 for Impulsivity, and 0.852 for SCT subscales, respectively (Barkley, 2011). A normal distribution for the BAARS-IV was found for each ADHD subscale among healthy college students and college students with ADHD (Becker, Langberg, Luebbe, Dvorsky, & Flannery, 2014). Construct and discriminant validity of the measure has been supported by several studies (Barkley et al., 2008; Caterino et al., 2009; Kooij et al., 2005; Kooij et al., 2008; Lewandowski, Lovett, Codding, & Gordon, 2008). The global score served as the independent variable in the first hierarchical multiple regression, and the three ADHD subscales served as the independent variables in the second regression.

4.4.4 Behavior Rating Inventory of Executive Function-Adult Version (BRIEF-A): The BRIEF-A (Roth, Isquith, & Gioia, 2005) is a standardized self-report measure of executive functioning. The rating scale is intended for individuals between the ages of 18 and 90 years of age with a minimum of a fifth grade reading level. The BRIEF-A is composed of 75 items within nine overlapping theoretically and empirically derived clinical scales that measure different aspects of executive functioning: Inhibit, Shift, Emotional Control, Self-Monitor, Initiate, Working Memory, Plan/Organize, Task Monitor, and Organization of Materials. Higher scores indicate poorer EF performance. The BRIEF-A has demonstrated good internal consistency with alpha coefficients ranging from .73 to .90 for the BRI and MI scales. Test-retest reliability was also adequate, ranging from .82 to .93 over a 4-week period (Roth, Isquith, & Gioia, 2005). A normal distribution for the BRIEF-A has been validated among healthy adults and adults with ADHD in previous studies (Roth, Lance, Isquith, Fisher, & Giancola, 2013). The global score served as the dependent variable.

4.5 Statistical Analyses

Descriptive statistics were conducted on the regression model and met the assumptions of normality, multicollinearity, linearity, and homoscedasticity (Table 2). There were no significant outliers in the data set. To address the first two hypotheses of the study, pearson product-moment correlations and a hierarchical multiple regression were conducted with global EF as the dependent variable and sleep quality and global ADHD symptomatology as the independent variables. Residual analyses were conducted and it was found that the regression models met the assumptions of the general linear model. The global score for the BAARS-IV was the first variable entered into the multiple regression. The global score for the PSQI was entered in the second step. The interaction term (sleep quality x ADHD symptomatology) was entered in the third step. The presence of a significant interaction indicated that there was a significant moderation.

To address the third hypothesis, a second hierarchical multiple regression was conducted. Global score for the PSQI, mental health condition, impulsivity total score, hyperactivity total score, and inattention total score were sequentially entered into the second regression as the independent variables, respectively. Global EF served as the dependent variable. No interaction terms were included in the second multiple regression analysis given the lack of adequate power to detect a small effect.

5. Results

5.1 Demographics and Descriptive Statistics

Sixty-six students participated in the study and were between 18 and 23 years of age (*M*=19.27, *SD*=1.22) and were primarily female (69.7%), White/Caucasian (75.8%), in their freshman year of college (50%), and were never diagnosed with a mental health condition (78.8%). Table 1 provides demographic information for the participants. As depicted in Table 2, the mean total sleep quality score for participants was 7.11 (*SD*=3.21), indicating poor sleep quality. The mean total score for global ADHD symptomatology and EF for this sample was 31.45 (*SD*=8.25) and 112.88 (*SD*=22.46), respectively. Neither mean ADHD symptomatology nor EF scores indicated clinically significant impairments.

5.2 Hypothesis 1

A Pearson product-moment correlation was used to explore the relationships between global ADHD symptomatology, sleep quality, and EF among college students. As depicted in Table 3, higher levels of global ADHD symptomatology were associated with poorer global self-reported EF ($r = 0.848$, $p \leq 0.001$). Poorer sleep quality was also associated with poorer global self-reported EF ($r = 0.430$, $p \leq 0.01$). In addition, higher levels of global ADHD symptomatology were associated with poorer sleep quality ($r = 0.415$, $p \leq 0.01$).

Table 1

Participant Demographic Information

Demographic Variables	**N**	**%**	**Mean**	**SD**
Age in years	66		19.27	1.22
Year in college				
Freshman	33	50.0		
Sophomore	14	21.2		
Junior	14	21.2		
Senior	5	7.6		
Gender				
Male	20	30.3		
Female	46	69.7		
Ethnicity				
White/Caucasian	50	75.8		
African American	7	10.6		
Hispanic	4	6.1		
Asian/Pacific Islander	4	6.1		
Other	1	1.5		
Previous mental health condition				
Yes	14	21.2		
No	52	78.8		
Mental health conditions reported	14			
ADHD	5	7.6		
Depression	1	1.5		
Generalized Anxiety Disorder (GAD)	1	1.5		
GAD/ADHD	2	3.0		
GAD/Depression	2	3.0		
GAD/Depression/PTSD/OCD	1	1.6		
GAD/OCD	1	1.6		
GAD/Tourette Syndrome	1	1.6		

Table 2

Descriptive analysis of global ADHD symptomatology, sleep quality, mental health condition, impulsivity, hyperactivity, inattention, and EF

Variable	Mean	SD	Min	Max	Skewness	Kurtosis
Global ADHD Symptomatology	31.45	8.254	18	59	1.019	1.137
Sleep Quality	7.11	3.206	2	18	0.629	0.653
Mental Health Condition	-	-	-	-	1.441	0.079
Impulsivity	6.50	2.445	4	14	1.375	1.571
Hyperactivity	8.85	3.100	5	17	0.808	-0.128
Inattention	15.95	4.975	9	31	1.089	0.978
Executive Functioning	112.88	22.455	74	190	0.887	1.060

5.3 Hypothesis 2

As depicted in Table 4, a hierarchical multiple regression was conducted. For model 1, global ADHD symptomatology was entered into the regression analysis. Global ADHD symptomatology explained 71.9% ($R^2 = .719$, $p \leq 0.001$) of the variance in global EF. In model 2, sleep quality was entered into the hierarchical regression. Findings from this model revealed that sleep quality was not a predictor of EF after controlling for global ADHD symptomatology (B = 0.664, $p = 0.195$). For model 2, global ADHD symptomatology remained a predictor of EF (B = 2.200, $p \leq 0.001$).

In model 3, the interaction term (sleep quality x global ADHD symptomatology) was added to the regression. As depicted in Table 4, sleep quality did not moderate the relationship between global ADHD symptomatology and EF, since the interaction term was not significant (B = 0.055, $p = 0.352$).

Table 3

Correlations between global ADHD symptomatology, sleep quality, impulsivity, hyperactivity, inattention, and EF

Variables	**BAARS-IV Total Score**	**PSQI Total Score**	**Impulsivity Total Score**	**Hyperactivity Total Score**	**Inattention Total Score**	**BRIEF-A Total Score**
BAARS-IV Total Score	1.0	-	-	-	-	-
PSQI Total Score	0.415***	1.0	-	-	-	-
Impulsivity Total Score	0.608***	0.154	1.0	-	-	-
Hyperactivity Total Score	0.785***	0.494***	0.339**	1.0	-	-
Inattention Total Score	0.865***	0.354**	0.300**	0.531***	1.0	-
BRIEF-A Total Score	0.848***	0.430***	0.492***	0.566***	0.849***	1.0

Note: **. $p \leq 0.05$, ***. $p \leq 0.001$

Table 4

Hierarchical multiple regression of the moderating effect of sleep quality on the relationship between ADHD symptomatology and EF

	B	SE	P value	R^2	Adjusted R^2	F
Model 1				0.719	0.715	163.779
Global ADHD Symptomatology	2.307	0.180	0.001			
Model 2				0.726	0.718	83.657
Global ADHD Symptomatology	2.200	0.197	0.001			
Sleep Quality	0.664	0.507	0.195			
Model 3				0.730	0.717	55.959
Global ADHD Symptomatology	1.767	0.502	0.001			
Sleep Quality	-1.136	1.984	0.569			
Global ADHD Symptomatology X Sleep Quality	0.055	0.058	0.352			

5.4 Hypothesis 3

As depicted in Table 5, a second hierarchical multiple regression was conducted. No significant interactions were found among the independent variables. For model 1, sleep quality was entered into the regression. Poorer sleep quality predicted poorer self-reported EF (B = 3.014, $p \leq$ 0.001). After the addition of mental health condition in model 2, sleep quality was still a predictor of EF (B = 2.293, $p \leq$ 0.05). Self-reporting a mental health condition also predicted poorer self-reported EF (B = 20.468, $p \leq$ 0.001). In model 2, these variables explained 31.6% (R^2 = 0.316) of the variance for EF.

Table 5

Hierarchical multiple regression of sleep quality, mental health condition, and ADHD symptomatology subscales on EF

	B	SE	P value	R^2	Adjusted R^2	F
Model 1				0.185	0.172	14.544
Sleep Quality	3.014	0.790	0.001			
Model 2				0.316	0.294	14.525
Sleep Quality	2.293	0.759	0.004			
Mental Health Condition	20.468	5.907	0.001			
Model 3				0.429	0.402	15.555
Sleep Quality	1.067	0.781	0.177			
Mental Health Condition	16.266	5.567	0.005			
Hyperactivity	2.878	0.818	0.001			
Model 4				0.490	0.457	14.657
Sleep Quality	1.196	0.746	0.114			
Mental Health Condition	11.543	5.588	0.043			
Hyperactivity	2.333	0.806	0.005			
Impulsivity	2.533	0.940	0.009			
Model 5				0.801	0.785	48.352
Sleep Quality	0.857	0.471	0.074			
Mental Health Condition	-2.399	3.801	0.530			
Hyperactivity	0.345	0.547	0.531			
Impulsivity	2.351	0.592	0.001			
Inattention	3.275	0.338	0.001			

For model 3, hyperactivity was added to the regression. After this addition, sleep quality was no longer a predictor (B = 1.067, $p =$ 0.177) of EF, however mental health condition remained a predictor (B = 16.266, $p \leq$ 0.05) of EF. In this model, it was revealed that higher levels of hyperactivity predicted poorer self-reported EF (B = 2.878, $p \leq$ 0.001). The variance explained for model 3 was 42.9% ($R^2 = 0.429$). Impulsivity was added to the regression in model 4. Sleep quality was still not significant (B = 1.196, $p = 0.114$) in this model. Self-reporting a mental health condition (B = 11.543, $p \leq 0.05$), higher levels of hyperactivity (B = 2.333, $p \leq 0.05$), and higher levels of impulsivity (B = 2.533, $p \leq 0.05$) predicted poorer self-reported EF. The total variance explained in model 4 was 49% ($R^2 = 0.490$). In model 5, inattention was added to the regression. After this addition, sleep quality (B = 0.857, $p = 0.074$), hyperactivity (B = 0.345, $p = 0.531$), and mental health condition (B = -2.399, $p = 0.530$) were no longer significant. Higher levels of impulsivity (B = 2.351, $p \leq 0.001$) and inattention (B = 3.275, $p \leq 0.001$) were the only variables that predicted poorer self-reported EF. For model 5, 80% of the variance for EF was explained ($R^2 = 0.801$). In this model, it was revealed that inattention was the strongest predictor of EF after controlling for hyperactivity, impulsivity, mental health condition, and sleep quality. Additional post hoc analyses were performed to explore whether gender and ethnicity had an interaction effect with sleep quality and the results were non-significant.

6. Discussion

This study investigated self-reported sleep quality, ADHD symptomatology, and EF in college students. The obtained findings corroborated previous work showing that college students who reported higher levels of ADHD symptomatology and poorer sleep quality also reported worse self-reported EF. The present study aimed to extend the prior literature by examining the moderating effect of sleep quality on the relationship between ADHD symptomatology and EF. The study also explored whether sleep quality was predictive of EF performance after controlling for both mental health condition and ADHD symptomatology.

Consistent with the results of previous studies (Benitez & Gunstad, 2012; Couyoumdjian et al., 2010; Dehili, Prevatt, & Coffman, 2013; Dvorsky & Langberg, 2014; Jarrett et al., 2014), the first hypothesis that higher levels of self-reported ADHD symptomatology and poorer sleep quality would be predictive of poorer EF was supported. Specifically, ADHD symptomatology explained 71.9% of the variance in EF. This finding may be evidence of a robust relationship between ADHD symptoms and EF in college students. Alternatively, this result may be explained by the possibility that the ADHD symptomatology and EF surveys were measuring the same constructs. It is also possible, however, that college students with elevated ADHD symptomatology may perceive themselves as more impaired in relation to EF than they actually are. This finding would lead to quite different implications for students, universities, and mental health practitioners. As a result, these findings need to be replicated by other self-report and laboratory measures of EF.

In addition to ADHD symptomatology, sleep quality significantly predicted EF before and after controlling for mental health condition. These results are compelling since comorbid mental health conditions have been known to confound research investigating ADHD symptomatology and EF (Nigg, Hinshaw, Carte, & Treuting, 1998). For example, EF deficits are common in several mental health conditions such as ADHD (Weyandt et al., 2013), major depression and bipolar disorder (Thompson et al., 2009), obsessive compulsive disorder (Roth, Baribeau, Milovan, & O' Connor, 2004), Gilles de la Tourette syndrome (Muller et al., 2003), and many others (Weyandt, 2009). Sleep quality may be able to reverse these deficits in college students due to its modifiability and relationship to ADHD symptomatology and EF. For example, sleep hygiene education may be able to improve sleep quality and ADHD symptomatology in college students, since sleep hygiene education appeared to improve these variables in a similar study for children (Hiscock et al., 2015). As a result, future studies should implement educational hygiene programs for healthy college students to evaluate its potential benefits on EF and ADHD symptomatology.

Sleep quality significantly predicted EF after controlling for mental health condition; however, sleep quality was not a significant predictor after controlling for both mental health condition and ADHD symptomatology. An explanation for this finding may be related to the previous observation that ADHD symptomatology predicted most of the variance in EF. However, sleep quality may be a significant predictor of EF after controlling for ADHD symptomatology in a larger sample size due to evidence from a similar study in college students. For example, Benitez & Gunstad (2012) found that poor sleep quality was associated with diminished EF performance after controlling for depression and anxiety symptoms. Given that ADHD and depression are both associated with EF deficits (Thompson et al., 2009; Weyandt et al., 2013), it is plausible that poor sleep quality may be associated with EF deficits after controlling for ADHD symptoms. Alternatively, it is also possible that sleep quality is a not a significant predictor of EF after controlling for ADHD symptoms in college students. Collectively, these findings suggest that sleep quality likely contributes to daily EF performance.

Although sleep quality was a significant predictor of EF, ADHD symptomatology emerged as the strongest predictor of EF. A second hierarchical regression revealed that inattention was the strongest predictor of EF after controlling for sleep quality, mental health condition, impulsivity, and hyperactivity. Similar to the present study, Jarrett and colleagues (2014) found that self-reported inattention was the strongest predictor of EF, specifically time management and motivation. The present study's results draw attention to potential importance of prioritizing the assessment of inattention (as opposed to impulsivity/hyperactivity) when examining ADHD symptoms and EF deficits. Some college students may experience elevated ADHD symptoms, but students exhibiting inattentive symptoms appear more likely to experience daily EF impairments. Therefore, it is plausible that college students with the inattentive subtype of ADHD may report daily EF impairments more often than the hyperactive/impulsive subtype. Future research is needed to explore this hypothesis.

Although it was not specifically hypothesized, the present study found that college students who reported higher levels of ADHD symptomatology reported poorer sleep quality. This finding is also consistent with previous studies in college students. For example, Gau et al. (2007) found that self-reported inattention symptoms were associated with a greater sleep need and a greater difference between sleep need and self-estimated nocturnal sleep duration. Self-reported hyperactivity symptoms were also associated with decreased nocturnal sleep duration. Similarly, Becker, Luebbe & Langberg (2014) found that while controlling for ADHD status and psychiatric medication use, hyperactive symptoms of ADHD were significantly associated with worse sleep quality, longer sleep latency, shorter sleep duration, and more use of sleep medications. Inattention was also found to be associated with greater daytime dysfunction. Collectively, these studies support the present study's findings and suggest that it may be important for future researchers to examine these separate ADHD dimensions when studying sleep quality.

Despite the strong relationships among these variables, sleep quality did not emerge as a significant moderator between self-reported ADHD symptomatology and self-reported EF. A possible explanation for this finding may be related to the previous result that ADHD symptomatology explained 71.9% of the variance in EF. Consequently, little variance was left in the model to be explained by the interaction term (ADHD symptomatology X sleep quality). However, although speculative, moderation may be found in college students reporting very poor levels of sleep quality (over 2 *SD* units above the mean) and clinically significant ADHD symptoms (93^{rd} percentile or higher). Instead of a moderator, sleep quality may be a mediator between ADHD symptomatology and EF due to evidence from a similar study in children. For example, Hiscock and colleagues (2015) found that at three and six months, 50% and 33% of the effect of a sleep intervention on severity of ADHD symptoms was mediated through improved sleep. As a result, it is plausible that college students may obtain these benefits as well. Although no moderation was found, this is the first study to the author's knowledge to examine sleep quality as a moderator among ADHD symptomatology and EF. Therefore, additional research is needed to better elucidate the factors that influence these relationships.

ADHD symptomatology, sleep quality, and EF may also explain daytime dysfunction and academic impairments in college students. For example, a prospective association between daytime sleepiness and academic impairment in college students with ADHD has recently been documented (Langberg, Dvorsky, Becker, & Molitor, 2013). According to Langberg and colleagues (2013), it is likewise possible that ADHD symptoms mediate the association between sleep and academic difficulties. Furthermore, ADHD may contribute to sleep problems, in turn contributing to more daytime dysfunction and possibly EF deficits. Given that EF is a significant predictor of academic adjustment and academic procrastination in college students (Rabin, Fogel, & Nutter-Upham, 2011; Sheehan & Iarocci, 2015), sleep quality likely contributes to the performance of college students' daily schoolwork.

In addition to predicting academic performance, the evidence gathered from this study may guide clinical interviewing when determining the etiology of observed EF deficits in healthy college students. This could diminish the likelihood of misattributing deficits to solely mental health conditions (e.g. ADHD) and promote the consideration of transient and reversible contributors (i.e. sleep quality). This is especially important when evaluating college students, as approximately two thirds of college students report poor sleep quality (Lund, Reider, Whiting, & Prichard, 2009), similar to the present study (77.3%). It is important to replicate the present study's results with clinical samples of college students with and without ADHD before specific recommendations to universities can be made.

6.1 Limitations

Several limitations of the present study should be acknowledged. Similar to prior studies, the number of participants was relatively small, which may have reduced statistical power in identifying smaller or subtle differences. Specifically, the present study did not have adequate statistical power to detect an interaction given the relatively small sample size. The primary limitation of the present study involves the correlational and cross-sectional design that prohibits causal inferences from being made. Future studies would benefit from using a longitudinal or cross-sequential design to help determine the direction of the relationship between EF and ADHD symptomatology. Furthermore, ideally the study would have included multiple EF and sleep measures (multi-trait multi-method design) to adequately address convergent and divergent construct validity. The majority of students in this sample were from introductory psychology or communication classes; therefore a more diverse sample would enhance the external validity of this study. An additional limitation of the present study is that ADHD symptomatology was the variable of interest; consequently the results do not extend to college students with an ADHD diagnosis. Based on the present study, it is plausible that college students with ADHD experience poor sleep quality and self-reported EF deficits, however it was not specifically addressed. Similar to previous studies on ADHD symptomatology, all the surveys were self-reported, thus objective measures of sleep quality such as actigraphy and laboratory EF tasks should be used in future studies. Furthermore, no pilot testing was conducted. Pilot testing would have found the unusually high correlation (r = 0.848) among self-reported ADHD symptomatology and self-reported EF. As a result, this would have allowed an opportunity to modify the parameters of the study to increase the chance of observing a moderation effect.

Although speculative, variables such as IQ, stimulant medication use, and napping may confound EF performance in college students. IQ may confound EF in college students, since IQ was found to share covariance with EF and/or remove significant relationships between ADHD discriminability and EF in children (Scheres et al., 2004; Sergeant, Geurts, & Oosterlaan, 2003; Riccio, Homack, Pizzitola-Jaratt, and Wolfe, 2006; Roodenrys, 2006). In addition to IQ, stimulant medication use may also confound the results of the present study. For example, studies suggest that a significant proportion (up to 43%) of college students misuse stimulant medication (McCabe, Knight, Teter, & Wechsler, 2005; Advokat, Guidry, & Martino, 2008). As a result, these college students manifested sleep problems (60%) and reduced academic self-efficacy (41%) (Rabiner et al., 2009). In contrast to the deleterious effects of medication misuse, napping may improve sleep quality and EF performance. In healthy adults, daytime naps as short as ten minutes were shown to improve alertness and performance in the work environment (Ficca, Axelsson, Mollicone, Muto, & Vitiello, 2010). However, napping's effect on higher cognitive functions such as EF remains an open question in the literature. As a result, college students may manifest better sleep quality than reported, since the PSQI does not include napping in any of the seven subscales. Given this evidence, IQ, stimulant medication use, and napping should be controlled for in future studies.

In conclusion, the present study found support for the hypothesis that higher levels of self-reported ADHD symptomatology and poorer sleep quality would be predictive of poorer EF performance. Results revealed that higher levels of self-reported poor sleep quality were predictive of poorer EF performance after controlling for mental health condition, but not after controlling for both mental health condition and ADHD symptomatology. In addition, it was revealed that inattention was the strongest predictor of EF after controlling for mental health condition, sleep quality, hyperactivity, and impulsivity. Lastly, the findings of the present study revealed that sleep quality did not moderate the association between self-reported ADHD symptoms and self-reported EF.

Collectively, the results of the present study suggest that sleep quality is related to ADHD symptomatology and EF among healthy college students. Given that 77.3% of students in the present study reported poor sleep quality and that sleep hygiene education may improve sleep quality and ADHD symptomatology (Hiscock et al., 2015), future research is warranted to help develop programs that emphasize the importance of sleep quality in college students.

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