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Sleep, Executive Functioning, and Emotion Regulation in Adolescent Athletes

by

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To the Graduate Faculty,

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Thesis Abstract –Idaho State University (2018)

Onset of psychological disorders typically occurs during adolescence, making this a vulnerable developmental period and highlighting the need to examine emotion regulation and factors that can hinder it among adolescents, such as poor sleep and impairments in executive functioning. Some research demonstrates a link between poor sleep and executive functioning impairments, suggesting sleep difficulties may indirectly predict poor emotion regulation through associations with executive functioning. The present study sought to contribute to understanding of executive functioning processes in relation to sleep and emotion regulation using an objective measure of sleep and a global scale of emotion regulation difficulties in adolescent athletes. Sixty-four athletes aged 11-15 completed baseline assessments of sleep, executive functioning, and emotion regulation across two appointments. Despite observations of significant relationships between poor sleep, costs to executive functioning, and emotion regulation difficulties in prior literature, these findings were not replicated in the current investigation. Lack of findings are postulated to be due to a number of factors, including low statistical power, unique assessment of emotion regulation, and nature of the current sample, among whom few concerns of sleep or emotion regulation difficulties were observed. As the sample solely included healthy young athletes, findings may provide some limited support for participation in extracurricular activities as a protective factor against impairments in processes that predict emotion dysregulation and subsequent development of psychopathology. Future research is recommended to examine these processes among youth who are at risk for or experience symptoms of psychopathology.

Key words: adolescence, emotion regulation, executive functioning, sleep

Chapter One: Introduction and Literature Review

Adolescence is associated with a host of developmental changes. Although existing research has indicated significant alterations in sleep (Carskadon, 2011), executive functioning (Blakemore & Choudhury, 2006), and emotional functioning (Steinberg, 2005) during adolescence, little is known about interrelationships among these variables. Understanding how sleep and executive functioning relate to emotion regulation may deepen understanding of adolescents who might be at particular risk for emotion dysregulation and subsequent psychopathology, including youth diagnosed with sleep disorders and/or who experience difficulties with executive functioning (e.g., children/adolescents diagnosed with Attention-Deficit/Hyperactivity Disorder or traumatic brain injury [TBI]). Furthermore, prior research has suggested sleep is of particular importance for physical, cognitive, and emotional functioning among adolescent athletes (Taylor, Chrismas, Dascombe, Chamari, & Fowler, 2016). As an initial step in understanding how sleep, executive functioning, and emotion regulation may present and be related among young athletes at baseline functioning, the purpose of the present study is to investigate how sleep problems and executive functioning may relate to emotion regulation among healthy adolescent athletes.

Given that emotional regulation is the primary dependent variable in the present investigation, and in order to provide rationale for examining this variable in an adolescent population, a description of emotion regulation and its relationship to psychopathology will be presented first. Discussion of the current state of the literature regarding interrelationships between sleep, emotional regulation, and executive functioning with adolescents will follow. In order to present the clearest picture, the following review will focus specifically on research conducted in adolescents, though gaps in adolescent literature will be addressed by describing studies conducted with adults.

Emotion Regulation

Emotion regulation has received considerable attention as an underlying mechanism contributing to the development of depression, anxiety, substance use, and eating disorders (Aldao, Nolen-Hoeksema, & Schweizer, 2010). Defined broadly, emotion regulation refers to the ability to self-soothe, shift attention, and control and maintain goal-related behavior while experiencing intense emotions (Linehan, 2015). Importantly, emotion regulation can encompass changes in emotional arousal, valence, or approach-avoidance and does not necessarily require a discrete change in emotion (Koole, 2009).

Conceptualizations of emotion regulation difficulties. Emotion regulation has been proposed to take place across four stages, which include identification, selection, implementation, and monitoring (Sheppes, Suri, & Gross, 2015). Identification reflects the recognition of emotion and valuation of the emotional state. Examples in which this first stage of emotion regulation can be misguided include panic attacks and experiential avoidance of emotional states, where the former reflects overrepresentation of an emotional state and the latter reflects devaluation of an emotional state (Sheppes, Suri, & Gross). The second and third stages, selection and implementation, capture the representation and use of strategies to regulate the present emotional state. Clinically relevant examples of difficulties in the selection and implementation stages include valuation and use of maladaptive strategies to manage negative emotional states, such as non-suicidal self-injury, substance use, binge eating, and worry (Sheppes, Suri, & Gross). Finally, the monitoring stage encompasses stopping or switching emotion regulation efforts to resolve a discrepancy between the initial and desired emotional state. A notable example of maladaptive monitoring includes rumination, an ineffective emotion regulation strategy which may lead to depressive symptoms and prolonged worry if not replaced by a more effective regulation strategy (e.g., Sheppes, Suri, & Gross).

Consistent with stages of emotional regulation theorized above, dysregulation of emotion has been conceptualized as difficulties identifying and maintaining awareness of emotions, difficulties engaging in goal-directed behaviors and inhibiting impulsive behaviors when upset, and believing negative emotions cannot be altered (Gratz & Roemer, 2004). In congruence with this definition, using exploratory and confirmatory factor analysis, Mennin, Holaway, Fresco, Moore, and Heimberg (2007) identified three components of emotional dysregulation. These factors included fear and negative beliefs about emotions, difficulty describing and identifying emotions, and maladaptive management of emotions, otherwise reflected by difficulty increasing or decreasing emotional experiences in congruence with contextual demands. For example, Mennin and colleagues observed that individuals with Generalized Anxiety Disorder (GAD) experienced heightened intensity of emotions to a significantly greater degree than individuals with depression or social anxiety, which may subsequently lead to greater difficulties managing emotional responses. This argument followed from observation that when a fourth factor of heightened emotionality, or intense experience of negative affect, was included in the model, significant independent relationships between the four regulation factors and self-reported GAD, Major Depressive Disorder (MDD), and Social Anxiety Disorder were identified. Whereas GAD symptoms were predicted by heightened intensity and maladaptive management of emotion, MDD and Social Anxiety Disorder symptoms were predicted by difficulty identifying and describing emotion as well as negative beliefs about emotions. Such findings support the importance of awareness and recognition of emotion, acceptance of emotional experience, and adaptive use of emotion regulation strategies for promoting psychological health.

Emotion regulation strategies and psychopathology. Use of emotion regulation strategies and its relation to psychological disorders represents an aspect of emotion dysregulation that has received considerable attention in the literature. As approaches to modulate emotional experiences, emotion regulation strategies could arguably encompass an endless number of techniques an individual can use to influence or manage his or her emotional state. Gross (2008) conceptualizes five "families" of emotion regulation strategies, each reflecting a different point at which emotion can be affected along a continuum of internal (i.e., individual) to external (situational) levels. Specifically, Gross argues that emotional responses occur when individuals are not only present within but also make attributes about meanings of events. With this in mind, the five "parent categories" of emotion regulation strategies include emotion regulation through external means (e.g., choosing which situations to participate in) as well as internal means (e.g., redirecting attention away from emotionally-arousing features once already part of a situation). Along this continuum of emotion regulation strategies, perhaps most research to date has examined reinterpretation, or cognitive reappraisal, of situations in order to modulate emotional responses as well as suppression, or the attempt to "hide" how one is truly feeling.

In contrast to maladaptive strategies, such as suppression and rumination, problem-solving and reappraisal have been supported as adaptive means to influence emotional responding and have been negatively related to anxiety and depression (Aldao et al., 2010). Indeed, self-reported tendency to use reappraisal, which refers to reinterpretation of emotionally-arousing events, has been associated with fewer symptoms of depression among adults and adolescents, and fewer symptoms of anxiety among adults (Garnefski et al., 2002). Further, compared to non-diagnosed individuals, children and adolescents who met criteria for generalized anxiety, social anxiety, or separation anxiety disorder reported infrequent use of reappraisal in everyday life, despite equivalent abilities to generate reappraisals to negative images (Carthy, Horesh, Apter, Edge, & Gross, 2010). In their investigation, Carthy and colleagues further observed a negative relationship between the severity of depressive and anxiety symptoms and everyday use of reappraisal among anxiety-disordered adolescents.

Investigations of the relationships between emotion regulation strategies and psychopathology have yielded generally consistent findings that strategies such as avoidance, rumination, and suppression are less effective at regulating emotional states. Specifically, a recent meta-analysis of 114 studies investigating emotion regulation strategies and psychological disorders reported that avoidance, rumination, and suppression were independently and positively related to reports of anxiety and depression (Aldao, Nolen-Hoeksema, & Schweizer, 2010). Another group of researchers found that rumination following stressful or threatening events was related to anxiety and depressive symptoms among both adults and adolescents (Garnefski, Legerstee, Kraaij, van den Dommer, & Teerds, 2002). Importantly, rumination reflects an inflexible, “sustained focus on emotionally-eliciting stimuli (Gross, 2008, p. 503),” a point that bridges how basic processes, such as difficulties shifting attention, may represent a vulnerability to rumination and subsequent anxiety and depression. This argument will be returned to later in the chapter.

Extended aspects of emotion regulation difficulties and psychopathology. The above research confirms a significant association between maladaptive use of emotion regulation strategies and psychopathology among adults and youth. Per conceptualization of emotion regulation, however, maladaptive use of emotion regulation strategies represents only a facet of emotion dysregulation. Again, emotion dysregulation includes difficulties identifying emotions, poor acceptance and awareness of emotions, and beliefs that one cannot change negative emotional states (Gratz & Roemer, 2004). While these aspects of emotion dysregulation have been largely ignored in comparison to investigation of emotion regulation strategies, the few studies that do exist show consistent findings to those of the strategy literature (e.g., Kashdan, Zvolensky, & McLeish, 2008; Suveg, Sood, Comer, & Kendall, 2009).

Indeed, anxious arousal and worry are more frequently observed among individuals who are unaccepting of their emotions and among individuals who believe they cannot alter negative emotions (Kashdan, Zvolensky, & McLeish, 2008). Additionally, relative to non-diagnosed individuals, children and adolescents with anxiety disorders endorse more difficulties coping with negative emotions and more frequently report beliefs that they cannot make themselves feel better in situations that evoke negative emotional experiences (Suveg et al., 2008; Suveg & Zeman, 2004). Even among youth without anxiety disorders, anxiety symptoms are related to poor awareness of and difficulties labelling emotions (Suveg, Sood, Comer, & Kendall, 2009).

The above findings regarding relationships between emotion regulation difficulties and psychopathology are particularly notable given the increase in onset of many mental health issues, such as anxiety and mood disorders, that occurs in adolescence (Henry, Castellini, Moses, & Scott, 2016; Kessler et al., 2007). While examination of psychopathology is beyond the goals of the current study, the above findings suggest that emotional dysregulation (e.g., difficulties using strategies to modulate emotions, poor awareness of emotions, non-acceptance of emotions) in adolescence may present a vulnerability to development of anxiety and depression among adolescents. Factors that may affect emotional regulation in adolescents, such as sleep and executive functioning, are therefore important to understand. Thus, the present review now turns to a discussion of sleep and its relationship to emotion regulation among adolescents. While a number of studies have examined sleep and psychopathology (e.g., Brown et al., 2018; Forbes et al. 2008; Talbot et al., 2010), scant research exists on sleep and emotion regulation specifically. The literature discussed below highlights available findings regarding sleep and psychopathology, and, therefore, examines emotion dysregulation indirectly. Given the significant changes that occur in sleep during adolescence, however, the discussion first begins with highlights of sleep alterations through this period of development.

Sleep in Adolescence

Specific alterations in adolescent sleep include the ability to tolerate longer periods of wakefulness before feelings of sleepiness (Jenni, Achermann, & Carskadon, 2005), a shift to later bed and wake times, and a decrease in the threshold of arousal from sleep (Dahl & Lewin, 2002). Sleep pressure, reflected in shorter time to fall asleep after long periods of wakefulness, also builds more slowly during adolescent versus pre-pubertal development, contributing to the shift in later bed times and ability to tolerate longer periods of wakefulness during this developmental period (Carskadon & Tarokh, 2013). Aside from changes in homeostatic sleep pressure, a circadian delay has also been observed as adolescent development progresses; this circadian shift is attributed to intrinsic, biological regulation, as it has been observed in other mammalian species as well (Carskadon, 2011). Importantly, early-morning demands during adolescence, such as school start-times, are not adjusted to accommodate the shift to later bedtimes, thereby potentially cutting adolescents' sleep short. Additional psychosocial factors associated with delay in falling asleep among adolescents include adolescent-set bedtimes and evening use of electronics (e.g., watching TV, cell phone use, computer use; Carskadon, 2011).

Sleep Difficulties and Psychopathology

While adolescents typically get by with less sleep, need for sleep may actually increase during this period of development (Kuula et al., 2015). It is, therefore, not surprising that restricted sleep and sleep duration have been among the most common sleep variables examined in relation to mental health among adolescents. Shorter sleep duration in adolescence has been associated with higher reports of concentration difficulties and worry (Kaneita et al., 2007) as well as increased anxiety, anger, and depressive symptoms (Barnes & Meldrum, 2015; Baum et al., 2014; Talbot et al., 2010). Further, reduced sleep duration observed on weekdays specifically has been associated with increased reports of depressive symptoms (Pasch, Laska, Lytle, & Moe, 2010), highlighting an increased vulnerability to affective disturbance during weekdays when sleep may be more restricted than weekends.

Additional sleep variables that have been evaluated in relation to adolescent psychopathology include number of night awakenings and delay of sleep onset upon going to bed. Among these investigations, findings have been consistent with those of studies examining sleep duration and sleep problems. Specifically, higher numbers of night awakenings have been observed among youth with anxiety disorders (Forbes et al., 2008). Youth with anxiety disorders have also demonstrated longer sleep onset latencies compared to depressed youth and controls (Forbes et al., 2008) though longer sleep onset latency has been associated with adolescent depression in other research (Dahl et al., 1996). Such findings suggest sleep difficulties may serve an important role in comorbidity between depression and anxiety (e.g., Brown et al., 2018).

Subjective reports of sleep problems, which have included composite ratings of sleep quality, trouble sleeping, and sleeping less or more than other people, represent other variables that have received attention in relation to adolescent mental health. Similar to sleep restriction, general ratings of sleep problems have been associated with poor mental health status (Kaneita et al., 2009) and internalizing problems, such as depression and anxiety (Wong, Brower, & Zucker, 2009). Further, sleep problems among children and adolescents have been observed in conjunction with symptoms of generalized anxiety disorder (GAD), social phobia, separation anxiety, obsessive-compulsive disorder (OCD), and panic disorder (Alfano, Zakem, Costa, Taylor, & Weems, 2009).

Importantly, longitudinal findings suggest sleep problems can have a lasting impact on adolescents' emotional functioning. For example, trouble sleeping in early adolescence has been associated with thoughts of suicide and self-harm, a notable maladaptive emotion regulation strategy (e.g., Sheppes, Suri, & Gross, 2015), in mid to late adolescence (Wong, Brower, & Zucker, 2011). Examination of parent-report has further indicated that the relationship between anxiety, depression, and sleep problems may correlate more strongly in adolescence compared to childhood (Gregory & O'Connor, 2002), warranting additional consideration of various aspects of sleep in relation to adolescent emotional regulation. Discussion of cognitive factors in relation to emotion regulation is therefore reviewed below.

Executive Functioning and Emotion Regulation

Conceptualization of executive functioning. Executive functioning broadly refers to a set of cognitive abilities, typically associated with the frontal lobes, that fundamentally support the ability to self-regulate and, therefore, underlie engagement in goal-directed behavior (Hofmann, Schmeichel, & Baddeley, 2012; Schmeichel & Tang, 2015). Examinations of specific cognitive processes that underlie executive functioning among adults have pointed to three primary abilities: working memory, inhibition, and task-switching (e.g., Miyake et al., 2000).

Specifically, working memory refers to the ability to process and hold information in mind whilst drawing upon that information to accomplish goal-relevant tasks (Brocki & Bohlin, 2004). As the name implies, working memory is not a passive cognitive process, but rather it reflects an active process of continual integration and memory for new information, a so-called *updating* process (Miyake et al., 2000). Furthermore, working memory is a limited-capacity system, such that throughout any given situation, only some information gets "in" to working memory and has opportunity for subsequent retrieval, whereas information that is not attended to and processed further becomes unavailable for later recall (e.g., Baddeley & Hitch, 1974, Kane, Bleckley, Conway, & Engle, 2001). In regards to self-regulation, working memory has been argued to fundamentally support mental representation of goals, direction of attention towards relevant and away from irrelevant information, and maintenance of goal-related information (Hofmann, Schmeichel, & Baddeley, 2012).

A second factor of executive functioning, task-switching (or shifting) refers to the ability to flexibly switch between mental sets or "rules" to allow for appropriate adaptation to new situations (Gul & Kahn, 2014; Hofmann, Schmeichel, & Baddeley, 2012). Task-switching has generally received little attention in relation to self-regulation, though Hofmann and colleagues point to the need for flexible adaptation in successfully accomplishing goals. Specifically, they argue that shifting underlies the ability to disengage from task-incongruent means and orient to alternatives. Similarly, Johnson (2009) suggests shifting is fundamental to flexibility in attention, thus closely integrating this skill with working memory and inhibition.

Inhibition represents a third factor of executive functioning and refers to the ability to withhold a prepotent or inappropriate response (e.g., Schmeichel & Tang, 2015). Implications of the importance of inhibition for self-regulation are clear given its fundamental representation of the ability to abandon responses that are inconsistent with goals in favor of goal-relevant responses. Importantly, inhibition has been argued to underlie the success of task-switching and working memory abilities, as both processes require resisting interference from irrelevant or distracting information (Brocki & Bohlin, 2004; Lee, Bull, & Ho, 2013). As such, Brocki and Bohlin highlight that developmental changes in executive functioning are theorized to occur largely because of improvements in inhibition with age.

Developmental changes in executive functioning. While working memory, inhibition, and task-switching have been reliably delineated as facets of executive functioning in adults, recent findings suggest this three-factor model less consistently captures executive functioning abilities in childhood and adolescence (Lee, Bull, & Ho, 2013). Indeed, in a study examining the structure of executive functioning in late childhood through early and mid-adolescence, Lee and colleagues observed that inhibition and switching may not begin to differentiate until 11 years of age. Such findings, thus, caution application of Miyake and colleagues' (2000) three-factor structure of executive functioning to children aged 10 and younger.

Studies that have examined how each executive function improves with age further note that developmental trajectories are not equivalent across executive functioning abilities. Specifically, the ability to quickly inhibit responding has been noted to improve between the ages of approximately 7 to 12 alongside decreased tendency to make impulsive errors (Brocki & Bohlin, 2004; Williams, Ponesse, Schachar, Logan, & Tannock, 1999**)**. In contrast, working memory and switching exhibit relatively linear improvement from childhood to late adolescence (Brocki & Bohlin, Lee, Bull, & Ho, 2013), consistent with views that these abilities may draw upon, yet are relatively more complex in relation to inhibition (e.g., Brocki & Bohlin).

Such developmental improvements in executive functioning abilities have clear implications for maturation of self-regulation through continued improvement in representation and maintenance of goals, attentional shifting, and inhibition throughout childhood and adolescence. Of specific interest to the current study is how executive functions relate to the ability to regulate emotions, as discussed below. Given linkages between emotion regulation and psychopathology as reviewed prior, understanding how executive functioning relates to emotion regulation has implications for understanding whether poor executive functioning represents vulnerabilities to development of psychopathology.

Working memory and emotion regulation in adolescence. Arguably most of the examinations of executive functioning in relation to emotion regulation have been specific to working memory and use of emotion regulation strategies, such as reappraisal, the ability to reframe a situation, and suppression, the attempt to conceal emotional expression (Gross, 2008). For instance, Lantrip and colleagues (2016) examined relationships between self-reported executive functioning abilities, assessed using the Behavior Rating Inventory of Executive Function (BRIEF; Guy, Isquith, & Gioia, 2004), and self-reported tendency to use reappraisal and suppression among adolescents aged 12-18. Findings indicated no significant relationship between working memory and reappraisal use, though difficulties with working memory (i.e., maintaining information in mind) and shifting (i.e., adapting to new tasks) were related to more frequent use of suppression relative to individuals with fewer difficulties in these areas. Lantrip and colleagues argued that such findings may reflect a tendency for individuals with poorly developed working memory and shifting skills to try conceal emotional responses rather than attempt to change emotion through re-thinking a situation.

Reappraisal has also been examined in relation to developmental improvements in working memory. Specifically, in a study examining participants aged 10 to 22, McRae and colleagues (2012) reported linear improvements in reappraisal ability with age, which was reflected in larger decreases in self-reported negative affect during reappraisal of negative images. Importantly, reappraisal ability was observed in conjunction with activation of the left ventrolateral prefrontal cortex, a region argued to support verbally-based working memory (Thomason et al., 2009; Wager & Smith, 2003). These findings are consistent with the idea that reappraisal is a verbal strategy (Gyurak, Goodkind, Kramer, Miller, & Levenson, 2012; McRae, Jacobs, Ray, John, & Gross, 2012) and, thus, implicate overlap between neural substrates of working memory using verbal processes and reappraisal ability.

Working memory and emotion regulation in adults. Support for a connection between working memory and reappraisal is also evident in adult samples. For example, working memory has been associated with the magnitude of reductions in negative affect when utilizing reappraisal (McRae, Jacobs, Ray, John, & Gross, 2012). Further, some studies have reported reappraisal-related decreases in negative affect, anger, anxiety, and disgust only among individuals with high working memory ability, whereas individuals with low working memory do not appear to benefit from utilization of reappraisal (Pe, Raes, & Kuppens, 2013; Schmeichel, Volokhov, & Demaree, 2008).

Considered together, the above findings across both adult and adolescent samples support hypotheses that working memory is fundamental to reappraisal ability. Moreover, these findings seem intuitive, as reappraisal necessarily requires individuals to integrate and maintain new or alternative interpretations in order to shift an emotional response (McRae, Jacobs, Ray, John, & Gross, 2012). Observations that working memory ability moderates the effectiveness of reappraisal use, especially for high-arousal states, such as anger and anxiety, further imply reliance on working memory resources to cognitively reframe in the midst of emotionally-arousing states.

Based on prior research, emotional and threat-related information arguably taxes working memory due to demand placed on attentional resources, which are biased to emotional content and/or threat rather than to task-relevant information (Blanchette & Richards, 2010). Individuals with low working memory may, therefore, be disadvantaged in the ability to successfully utilize reappraisal given greater limitations placed on needed cognitive resources during high-arousal situations (Pe, Raes, & Kuppens, 2013; Schmeichel, Volokhov, & Demaree, 2008). Consistent with Lantrip and colleagues' (2016) observations, this argument may explain, at least partially, the tendency for adolescents with less-developed working memory and shifting abilities to manage emotional states through reliance on suppression more frequently than reappraisal. While less effective in evoking emotional change than reappraisal, attempts to conceal emotional responses may appear more accessible than reappraisal due to high cognitive demands of updating and maintaining alternative interpretations in working memory.

Some inconsistency in findings of a relationship between working memory and emotion regulation exist, however. For example, Andreotti and colleagues (2013) did not observe a significant relationship between self-reported or performance-based working memory and tendency to use reappraisal in daily life. However, the researchers argued that lack of findings could be attributed to restricted variability in working memory performance, limiting the ability to observe meaningful variations between working memory and reappraisal use. In another study, Gyurak, Goodkind, Kramer, Miller, and Levenson (2012) failed to observe a relationship between working memory and ability to suppress or exaggerate emotional responses in line with task instructions. In contrast to the above research, however, Gyurak and colleagues utilized simple recall tasks to measure working memory ability rather than tasks that demand both processing and maintenance of information. Lack of findings in their study was, therefore, attributed to inability to capture complexity of working memory abilities that are fundamental to management of emotional states.

Consistent with arguments that working memory is fundamental to attentional deployment, working memory has also been associated with the ability to direct attention away from threatening stimuli (Hofmann, Schmiechel, & Baddeley, 2012; Vanderlind et al., 2014). This is notable, as deficits in attention regulation may be linked to internalizing disorders in adolescence (Zeman, Cassano, Perry-Parrish, & Stegall, 2006). Such relationship has been hypothesized to be due to persistent, limited ability to disengage attention away from threat and negative emotions (Blanchette & Richards, 2010).

Inhibition and emotion regulation. Consistent with arguments that working memory relates to emotion regulation through management of attention, some evidence indicates a connection between inhibitory control and emotion regulation. For example, Hilt, Leitzke, and Pollak (2014) assessed set-shifting and inhibition among children and adolescents aged 9 to 16 before they completed the Children's Response Style Questionnaire (Abela, Brozina, & Haigh, 2002) and Children's Depression Inventory (Kovacs, 1992) to measure rumination and depressive symptoms, respectively. Rumination was of primary interest in their study given its representation of a maladaptive emotion regulation strategy in which attention is persistently directed towards negative information, leading to difficulties adjusting emotional responding in congruence with changing context (Aldao, Nolen-Hoeksema, & Schweizer, 2010).

Hilt, Leitzke, and Pollack's (2014) findings did not indicate a significant relationship between errors made or stages completed during the set-shifting task and rumination, though a significant positive relationship emerged between rumination and the number of errors made during the inhibition task. Specifically, children high in rumination were more likely to erroneously respond to negative information during presentation of positive words, confirming a tendency to prolong attentional bias to negative information despite the discontinued presence of negative information. This finding provides additional evidence that difficulty inhibiting negative content is related to use of a less effective emotion regulation strategy, even among older children and adolescents.

Task-switching and emotion regulation. Lastly, very little research has examined task-switching, or shifting in relation to emotion regulation among adolescents, despite indication that the two are related in adult samples. Specifically, greater difficulties disengaging attention away from emotional stimuli has been observed in conjunction with more frequent use of suppression and less frequent use of reappraisal (Gul & Ahmad, 2014; Gul & Kahn, 2014). Furthermore, McRae, Jacobs, Ray, John, and Gross (2012) observed a significant relationship between reappraisal ability and accurate responding during a set-shifting task, implicating that the ability to alternate between mental sets supports generation of alternative interpretations of events.

Thus far, the present review has highlighted relationships between poor sleep and risk for psychopathology, a proxy for emotion regulation difficulties in the current research, and between executive functioning and aspects emotion regulation. Such aspects primarily include executive functioning in relation to reappraisal, though, as reviewed above, emotion regulation strategies represent only a portion of emotion regulation as it has been conceptualized. In addition to strategy use, emotion regulation is also reflected in acceptance and awareness of emotions, identification of emotions, and beliefs that one has access to strategies that can alter his/her emotional state (Gratz & Roemer, 2004). Indeed, these aspects deserve further attention, as poor emotional awareness, poor identification and acceptance of emotions, and negative beliefs about the ability to alter emotional states has been shown to predict increased risk of psychopathology (Kashdan, Zvolensky, & McLeish, 2008; Suveg, Sood, Comer, & Kendall, 2009; Suveg & Zeman, 2004). Therefore, understanding whether and how external constraints, such as sleep, and self-regulatory processes, such as executive functioning, may serve a role in creating or mitigating vulnerability to these additional aspects of emotion regulation is an area in need of further exploration.

As independent relationships between sleep and psychopathology, and between executive functioning and emotion regulation are evident, further review now turns to literature examining how sleep and executive functioning may themselves be related. The findings reviewed, in turn, set the stage for understanding how impairments in sleep and executive functioning may represent vulnerabilities to a spectrum of emotion regulation difficulties.

Sleep Difficulties and Executive Functioning

Subjective sleep difficulties and executive functioning. Similar to relationships observed between sleep problems and psychopathology among children and adolescents, problems with sleep have also been associated with costs to executive functioning abilities. For example, Friedman and colleagues (2009) examined nine tasks as indices of broad executive functioning in conjunction with the following parent-reported items: bed wetting, overtiredness, nightmares, sleep talking/walking, longer sleep duration than other children, shorter sleep duration than other children, and trouble sleeping. Children whose sleep difficulties decreased across ages 4 to 16 exhibited better executive functioning abilities (i.e., working memory, shifting, and inhibition) than children whose sleep difficulties did not change significantly. Findings also showed sleep problems at age 13 predicted poorer inhibition and switching abilities at age 17, which suggested that sleep problems early in adolescent development could poorly impact executive functioning in late adolescence.

Other studies examining youth and parent subjective reports of sleep disturbances have yielded similar results. For example, daytime sleepiness, difficulty initiating and maintaining sleep, and waking at night have been associated with impairments in planning, working memory, and self-monitoring among children aged 6 to 16 (Caruso et al., 2014). Further, sleepiness has been significantly associated with poorer performance on inhibition and switching tasks among adolescents, even after confounding factors, such as poor socioeconomic status, were controlled for (Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009). Finally, a more recent longitudinal study reported that maternal ratings of overtiredness at ages 3-8 predicted poor response inhibition in adolescents aged 16 and 17 (Wong, Brower, Nigg, & Zucker, 2010). Considered together, the above findings support a connection between subjective sleep difficulties and poorer executive functioning outcomes, a relationship that appears to span across early and late adolescent development.

Waketime after sleep onset, sleep duration, and executive functioning. One of the most commonly used objective measures of sleep is actigraphy, which assesses sleep quality through recording movements via a watch worn on the wrist (Baddam, Canapari, van Noordt, & Crowley, 2018). Actigraphy records a number of variables, including waketime after sleep onset (WASO), sleep duration, number of nighttime awakenings, onset to fall asleep, and sleep efficiency (i.e., the percentage of nighttime asleep). At present, only WASO and sleep duration have been investigated in relation to executive functioning. Specifically, Kuula and colleagues

(2015) observed a positive association between WASO, the difference between time of assumed sleep and time of actual sleep, and perseverative errors on the Wisconsin Card Sorting Task in girls aged 11 to 13 (Kuula et al., 2015). This finding suggested the possibility that objective sleep disturbance could negatively impact cognitive flexibility.

Findings regarding sleep duration appear less conclusive, however. Among 11 to 14-year-olds, Hahn and colleagues (2012) reported no significant relations between self-reported sleep duration and performance on shifting, working memory, and inhibition tasks. These results were similar to findings of Anderson and colleagues (2009), who examined both self-reported and actigraphy-based sleep duration in relation to self-report and performance-based measures of executive functioning among 13 to 16-year-olds. In their study, Anderson and colleagues observed a significant relationship between sleepiness and self-reported executive functioning abilities, though no association was observed between actigraphy measures and performance across planning, working memory, and inhibition tasks.

In contrast, in a separate investigation (Holley et al., 2014) with children and young adolescents, reduced sleep time as measured by actigraphy was observed in conjunction with lower executive functioning performance, which was aggregated across attention, working memory, planning, inhibition, speed of processing information, and verbal fluency. As both Anderson and colleagues (2009), and Holley and colleagues utilized actigraphy and performance-based measures of executive functioning, distinct findings between the two studies do not appear to be a function of incongruent methodology. Further, average sleep duration was relatively similar across both investigations.

A key difference between the studies was age of the samples, such that the average age in Holley and colleagues' (2014) investigation was 9, and participants in Anderson and colleagues'

(2009) study averaged 13 years of age. Discrepancy in findings could, therefore, indicate that objectively-measured sleep duration is associated with executive functioning performance among children, but not adolescents. Thus, further research is needed to replicate these findings before any conclusions can be confidently made.

Executive functioning as it relates to sleep extension and restriction. In efforts to extend understanding about how sleep and executive functioning may be related, additional studies using actigraphy have examined executive functioning performance as a result of extended versus restricted sleep. Among children aged 9 to 12, Sadeh, Gruber, and Raviv (2003) noted no significant impact of sleep restriction on executive functioning, though improved working memory performance was observed in children who extended their sleep time. Similarly, a separate investigation (Robertson, 2015) reported no significant differences in perseverations or measures of inhibitory control between children who restricted and extended their sleep, though sleep extension was associated with higher working memory and sustained attention.

Considered altogether, the above findings imply that subjective ratings of sleep difficulties, both self and parent-reported, consistently relate to poorer performance across working memory, task-switching, and inhibition tasks relative to individuals who report fewer sleep difficulties (e.g., sleepiness, trouble sleeping). In contrast, thus far, findings are inconclusive regarding relationships between short sleep duration and executive functioning performance across both subjective (Hahn et al., 2012) and objective (Anderson et al., 2009; Holley et al., 2014) assessments of sleep. While it may be that executive functioning abilities are more sensitive to short sleep duration among younger samples (i.e., 9 versus 13-year-olds), there is currently not enough research available to support this conclusion. Furthermore, while one investigation of sleep and executive functioning (Holley et al., 2014) assessed sleep efficiency in addition to sleep duration, sleep efficiency was not analyzed in relation to executive functioning performance. Also, only one study to date has assessed WASO as it relates to task-switching (Kuula et al., 2013). While some findings point to impairments in shifting ability in conjunction with time spent awake at night, replication and extension of this finding is needed to warrant firm conclusions.

Overview of the Present Study

The above findings provide evidence that subjective reports of sleep disturbances are reliably related to poorer executive functioning, while objective measures of reduced sleep duration and time awake after falling asleep inconsistently predict executive functioning difficulties. The impact of sleep difficulties on executive functions is important to explore further, however, given prior indication that executive functions may support reappraisal, management of attention to threatening stimuli, and inhibition of distracting and/or negative stimuli to facilitate effective emotion regulation (e.g., Hilt, Leitzke, and Pollack, 2014, McRae et al., 2012; McRae, Jacobs, Ray, John, & Gross, 2012). Effective emotion regulation has, in turn, been associated with fewer symptoms of depression and anxiety among adolescents, drawing the need for additional research focused on factors that predict, and may underlie, emotion regulation difficulties. Given the heightened risk for psychopathology in adolescence (Henry, Castellini, Moses, & Scott, 2016; Kessler et al., 2007), these relationships are especially important to investigate in an adolescent population.

Thus far, few studies have considered sleep problems, executive functioning, and emotion regulation in relation to each other, which is surprising given early discussion of the overlap between neural areas, such as the prefrontal cortex, in regulating sleep, attention, and emotion (Dahl, 1996). The present research, therefore, investigates how sleep, working memory, inhibition, and task-switching predict to emotion regulation. Such efforts stem from prior research (e.g., Hofmann, Schmeichel, & Baddeley, 2012; McRae, Jacobs, Ray, John, & Gross, 2012), that has indicated that these abilities may be foundational to the ability to regulate emotions.

Research that has examined these relationships in adults presents compelling evidence for an overlap between sleep problems, executive functioning, and emotion dysregulation. For example, Cox, Ebesutani, and Olatunji (2016) reported a negative impact of sleep disturbance on broad executive functioning which, in turn, predicted reports of maladaptive repetitive thought. Importantly, these relationships remained after controlling for general distress. Such findings are notable given the researchers' arguments that maladaptive, repetitive thought plays a role in worry and rumination, processes that are further implicated in anxiety and depression. Indeed, in an investigation of sleep quality, executive function, and depression, self-reported poor sleep quality significantly hindered the ability to disengage attention from negative stimuli, which then predicted increases in depressive symptoms in young adults (Vanderlind et al., 2014).

In efforts to extend understanding of these factors in relation to actigraphy-based measures of sleep, the current study will examine sleep duration, sleep efficiency, WASO, and sleep onset latency, (detailed below) as indices of sleep difficulties. These variables are examined in efforts to extend findings of prior examinations that utilized actigraphy (e.g., Holley et al., 2014) and to adequately assess a range of sleep difficulties that may be associated with executive functioning and emotion regulation. Specifically, while sleep duration has been examined with relative frequency in relation to executive functioning (Anderson et al., 2009; Holley et al.) and psychopathology (Barnes & Meldrum, 2015; Baum et al., 2014; Talbot et al., 2010), only two studies have assessed sleep efficiency (Holley et al., 2014) and WASO (Kuula et al., 2015) in the context of executive functioning performance. Furthermore, onset latency as measured by actigraphy has not been evaluated in relation to executive functioning, despite findings that onset latency predicts anxiety and depression in youth (Dahl et al., 1996; Forbes et al., 2008).

Similarly, given that current literature has been vastly limited to examining how executive functions are associated with emotion regulation strategies (i.e., reappraisal), the present study will explore executive functioning in relation to emotion regulation more broadly, including acceptance and awareness of emotions, ability to carry out goals when upset, and attitudes about the ability to alter negative emotional states. These efforts are in line with prior indication that non-acceptance of emotions, beliefs one cannot alter negative emotions, and poor emotional awareness are related to anxiety symptoms in youth, such as physiological arousal and worry (e.g., Kashdan, Zvolensky, & McLeish, 2008; Suveg, Sood, Comer, & Kendall, 2009).

In order to target these areas of emotion regulation, assessment of emotion regulation in the current study will utilize the Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004), which assesses awareness and identification of emotions, clarity of emotional experiences, impulse control and ability to maintain goal-related behavior when upset, and access to adaptive emotion-management strategies (Gratz & Roemer). To date, the DERS is the only measure that provides a comprehensive assessment of these areas, in contrast to alternative self-report scales (e.g., Emotion Regulation Questionnaire; Gross & John, 2003) that are limited to assessing the use of emotion regulation strategies.

As stated early on, alongside limited research into interrelatedness among the present factors in youth, no study to date has examined whether sleep and executive functioning predict emotion regulation among young athletes. Baseline assessment of these factors may be especially important to understand in young athletes in order to inform follow-up assessments and aid future research efforts in understanding how these processes may be impacted by injury (e.g., traumatic-brain injury [TBI]; Schatz, Moser, Solomon, Ott, & Karpf, 2012). Furthermore, given findings that suggest athletes are at reduced risk for sleep and emotion regulation difficulties (e.g., Brand et al., 2010; Eime, Young, Harvey, Charity, & Payne, 2013), it is possible that these processes are not as strongly related among adolescent athletes relative to general community samples. However, the strength of interrelationships among these factors in athletic youth is currently unclear. In order to present an initial step to investigating interrelationships among the aforementioned factors and assess baseline functioning, the present research examines how sleep and executive functioning may relate to emotion regulation among healthy adolescent athletes.

Chapter Two: Methods

Sample Characteristics

The final sample included 64 adolescent athletes aged 11 to 15 at time of initial participation who were participating in a short-term longitudinal study designed to assess the impact of sport-related concussion on young athletes' sleep, neurocognitive functioning, and emotional functioning. Recruitment for the broader study occurred via flyers given to coaches and trainers of athletic teams as well as ads posted through Facebook. Consistent with prior stated goals of assessing healthy athletes, only baseline data from athletes without prior concussion history were included in the current study. Per guidelines of the larger study, athletes were excluded from the present study if they were taking any medication that could affect sleep (e.g., antidepressant or stimulant medication) and/or were diagnosed with a medical condition that affected sleep.

Demographic characteristics are provided in Table 1. The average age of athletes was 12.5 (*SD* = 1.3) years old, and most athletes (92.2%) identified as Caucasian. There was a relatively equal number of females (45.3%) and males (54.7%). Due to watch malfunction, actigraphy data were missing for one participant, whose data were excluded from analyses. Ospan data were missing for two participants, one of whom was unable to complete the session due to time constraints and another of whom was unable to successfully complete a full practice trial within the time limit. The same participant failed to respond between Stop-Signal Task stimulus presentations, and thus stop-signal reaction time (SSRT) data were considered missing. Lastly, one athlete's Wisconsin Card Sorting Task (WCST) performance was coded as missing due to endorsed color-blindness. Analyses were, therefore, conducted using Mplus statistical software, which utilizes Full-Information Maximum Likelihood (FIML) to estimate parameters and their standard errors in the presence of missing data.

Table 1

Demographic Characteristics

	N = 64
Age, mean (*SD*)	12.5 ± 1.3
Ethnicity	
Caucasian	59 (92.2 %)
Asian-American	2 (3.1 %)
Multi-ethnic	2 (3.1%)
Native-American	1 (1.6 %)
Female	29 (45.3%)

Parameter estimates for analysis were derived by several multiple regression models. Cohen's table (Cohen, 1988) was used to estimate statistical power in each multiple regression model. For each model in the current study, two predictors (i.e., sleep variable, executive functioning ability) were examined in relation to total Difficulties in Emotion Regulation Scale (DERS) scores. Prior to conducting mediation analyses, correlations between demographic characteristics and variables of interest were analyzed. Age was significantly related to total sleep time (TST; [r = -0.46, p < .001]) and, thus, was controlled for in models assessing TST and DERS scores as mediated by executive functioning. Based on past research using actigraphy that shows small to medium effect sizes (f^2 = .15), power to detect significant effects of the predictor variables in each mediation model using 60 participants is approximately .50.

Measures

Actigraphy. Sleep variables were assessed using Philips Respironics Actigraph Pro wrist watches. Movements of the wrist were detected by software within the watch and summed as activity counts per 1-minute period. In addition, a light sensor featured on the watch provided data regarding pattern of light throughout the day and rest period. Actigraphy variables included sleep efficiency, total sleep time, onset latency, and WASO, averaged across the actigraphy-wearing period for each athlete. Sleep efficiency was calculated as a percentage by determining the ratio of total sleep time to the total rest period (Soffer-Dudek, Dahl, & Rosenblat-Stein, 2011). TST was calculated by excluding periods of wakefulness from the total rest period, which is itself reflected in the period of sleep onset time to morning awakening time (Sadeh, Gruber, & Raviv, 2002; Sadeh, Gruber, & Raviv, 2003). WASO, on the other hand, was reflected by the difference between assumed sleep period and actual sleep time (Kuula et al., 2015). In turn, onset latency was reflected by the delay between the start of the rest interval and the first epoch of sleep, or consecutive activity counts of "0" (Philips Respironics, 2009).

Among 10-14 year olds, TST as measured by single-night actigraphy has demonstrated high correlations ($r = .88$) with polysomnography (PSG), which is considered a gold standard in sleep assessment (Johnson et al., 2007; Quante et al., 2018). A strength of PSG is the rigorous methodology (e.g., EEG; heart rate monitors) it utilizes to provide measures of brain activity, breathing, heart rate, and muscle movement during sleep, though such measurements are typically conducted in hospitals and, therefore, its ecological validity is questioned (e.g., Holley et al., 2014). In contrast, actigraphy represents a less-invasive and less costly alternative to the assessment of sleep, making it an increasingly popular tool in research investigations of sleep.

Daily sleep log. Daily sleep logs that specified bed and wake times and sleep quality (i.e., how well did you sleep; how long did it take you to fall asleep after lights out; how tired were you in the morning) were completed for each night of actigraphy. Prior research has reported consistency (i.e., no significant differences) of TST, bed times, and wake times between sleep diary reports and actigraphy among 13 to 19-year-olds (Wolfson et al., 2003). Consistent with methodology reported in Chow and colleagues (2016), rest interval start and end times were set by consistency between sleep diary bed and wake times alongside reduction in light to zero, reduction in activity to zero counts, and event markers. When reported bed and wake times were inconsistent with actigraphy indicators, rest interval start and end times were set according to match between drop in light and activity, drop in light and the event marker, or drop in activity and the event marker. In the current sample, diary-reported sleep duration, calculated by finding the difference between sleep and wake times, correlated well with actigraphy ($r = 0.74$, $p = .000$) and indicated reasonable consistency between sleep diary and actigraphy data (Chow et al., 2016).

Working Memory. Working memory was assessed using a modified version of the Operation Span Task (Ospan; Turley-Ames & Whitfield, 2003; Turner & Engle, 1989), a dual-span task that requires participants to solve simple mathematical equations before viewing to-be-remembered (TBR) words. Equations were presented one number/symbol at a time, and participants were required to solve the math problem and view the TBR word within a 7-second limit. Participants were instructed to rehearse the TBR words when they appeared on the computer screen and to write down as many words in the current set as they could remember after each trial. Trials increased from sizes of 3 to 6 math/word sets, with 3 trials per set, for a total of 15 trials.

One point was awarded for each correctly remembered word for which a correct math response was provided. This scoring method guards against awarding credit for items in which either the processing or the storage component are emphasized at the expense of the other (Turley-Ames & Whitfield, 2003). The Ospan has demonstrated good reliability (Cronbach's α range from .70 to .90) and correlates with tasks that rely on working memory, such as reading comprehension, following directions, and contextually-based vocabulary learning (e.g., Conway et al., 2005; Turley-Ames & Whitfield, 2003) in adult samples. Higher Ospan scores reflect better working memory ability.

Inhibition. Response inhibition was assessed using the Stop-Signal Task (SST; Logan, 1994). Participants were instructed to press, as quickly as possible, corresponding keys when a square or circle is presented on a computer screen. On 25% of trials, an auditory stimulus was presented in which participants were told to withhold their response. The auditory stimulus was presented during a smaller proportion of trials than the regular, “go” trials, thus allowing a response tendency to build that required inhibition when the signal was heard. Stop-signal reaction time (SSRT) was evaluated as the measure of response inhibition.

SSRT was calculated by finding the difference between mean “go” reaction time, or reaction time during non-inhibit trials, and stop-signal delay, which reflected the delay in presentation of the initial stimulus to presentation of the stop-signal (Logan, 1994; Logan, Schachar, & Tannock, 1997). Specifically, the delay between the stimulus and stop-signal was increased or reduced by 50 ms. until 50% accuracy was achieved in withholding responses upon hearing the stop-signal. The delay at which 50 % accuracy was achieved was an index of a “tie” between two independent processes, the “go” process and inhibit process (Logan, Schachar, & Tannock). In accordance with Logan and colleagues’ methods, this delay was subtracted from the average reaction time to non-inhibit stimuli to index the length of the inhibitory process. Longer SSRTs reflected greater difficulty inhibiting a response when the auditory signal was presented, while shorter SSRTs reflected better inhibition ability.

Task-Switching. Task-switching was assessed using the Wisconsin Card Sorting Test – Computer Version 4 (WCST-CV4; Grant & Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtiss, 1993). The WCST required participants to sort response cards onto one of four stimulus decks based on number, color, or form. The sorting rule was not communicated to the examinee, and the rule changed without warning throughout the task. The participant received feedback after each trial as to whether his/her response was correct or incorrect. Scores on the WCST were converted to standard scores based on age norms, with a mean of 100 and standard deviation of 15 (Heaton, Chelune, Talley, Kay, & Curtiss, 1993).

Task-switching was measured using the perseverative errors standard score, which reflects maintenance of a prior sorting principle that is incongruent with the correct sorting principle. Greater perseverative errors standard scores indicate fewer perseverative errors, compared to same-aged peers, and reflect greater cognitive flexibility. Scores on the WCST have demonstrated moderate reliability (average Cronbach's $\alpha = .57$; Heaton, Chelune, Talley, Kay, & Curtiss, 1993.

Emotion Regulation. Emotion regulation difficulties were assessed using the Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004). The DERS is a 36-item, self-report measure that assesses an individual's difficulties in emotion regulation within the following domains: acceptance and awareness of emotions, maintenance of goal-directed behavior in the presence of negative emotions, and the ability to modulate emotions using situationally appropriate strategies. Given the theoretical and empirical work discussed above, outlining the importance of awareness and identification of emotion, acceptance of emotional experiences, and appropriate use of regulation strategies, the DERS was determined to be an appropriate measure for the current study as it considers difficulties in each of these domains. A higher score on the DERS reflects greater difficulties regulating emotions. Scores can be calculated for each of six subscales: Non-acceptance, Goals, Impulse, Emotional Awareness, Clarity, and Strategies, and a total score can be obtained by summing the responses to the 36 items.

The DERS correlates positively with measures of emotional avoidance and negatively with measures of emotional expression and negative mood regulation in adults (Gratz & Roemer, 2004), and it demonstrated adequate reliability in the present study (Cronbach's $\alpha = .86$). Research using the DERS in adolescents has confirmed the six-factor structure in both community-based and inpatient samples (Neumann, Lier, Gratz, & Koot, 2010; Perez, Venta, Garnaat & Sharp, 2012). Validity of the DERS in adolescents is supported by a recent study that reported significantly higher DERS scores, and, thus, greater emotion regulation difficulties, among inpatients in an adolescent mental health unit compared to adolescents from the general community (Henry, Castellini, Moses, & Scott, 2016).

Procedure

During the first session, athletes and their parents were asked to provide informed assent and consent (see Appendix A and B). Upon assent and consent, athletes were then instructed on how to appropriately wear the actigraph watch and complete the sleep diary (Appendix C). Athletes were instructed to wear the watch on their non-dominant wrist during the day and prior to getting into bed to assess sleep quality throughout the night. Athletes were also instructed to press a button on the watch (i.e., event marker) when getting into bed with intent to fall asleep and upon waking in the morning. Watches were worn for an average of 8.1 nights ($SD = 2.5$**),** as prior research has reported reliable estimates of average total sleep period after 7 nights of actigraphy among 11-16 year olds (Acebo et al., 1999).

Immediately following the watch-wearing period, athletes were scheduled for the second session to complete the Stop-Signal Task (SST), Wisconsin Card Sort Task (WCST), and

Operation span task (OSPAN) on the computer. Order of the SST and WCST was counterbalanced with the OSPAN administered last to avoid possible transfer of strategy to inhibition and task-switching assessments. Athletes then completed the DERS (Appendix D) in addition to a demographics questionnaire (Appendix E). Athletes and their parents were then compensated $35 for completion of both sessions. The procedure is outlined below in Figure 1.

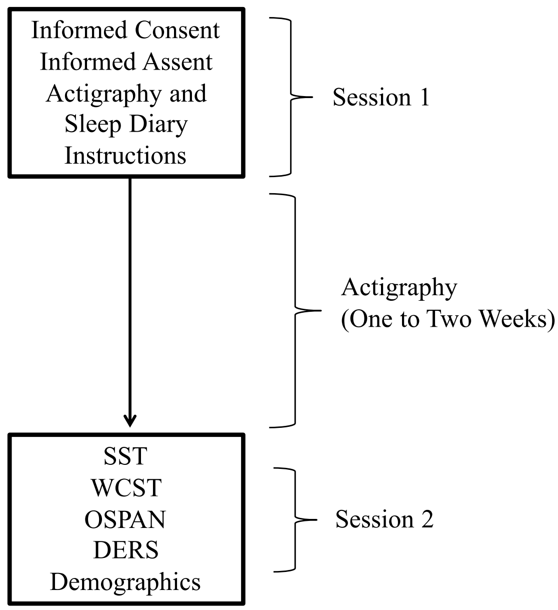

Figure 1. Outline of study procedures. Note that the SST and WCST were counterbalanced.

Hypotheses

Hypothesis 1. It was predicted that sleep difficulties would predict emotion regulation difficulties.

Hypothesis 1a. H_1: Specifically, longer WASO would be associated with higher scores on the DERS (Gratz & Roemer, 2004), which represents a composite of difficulties with emotional awareness, clarity of emotional experience, acceptance of emotion, impulse control, access to emotion regulation strategies, and inability to carry out goals during an emotional experience. H_0: WASO would not be significantly associated with DERS scores.

Hypothesis 1b. H_1: Lower sleep efficiency, or the proportion of total sleep time to the total time in bed, would also be associated with higher DERS scores, or greater emotion regulation difficulties. H_0: Sleep efficiency would not be significantly associated with DERS scores.

Hypothesis 1c. H_1: Additionally, onset latency was hypothesized to predict higher DERS scores. H_0: Onset latency would not be significantly related to DERS scores.

Hypothesis 1d. H_1: In contrast, TST would be negatively associated with DERS scores. H_0: TST would not be associated with DERS scores.

Hypothesis 2. It was predicted that sleep difficulties would be negatively related to executive functioning performance. Specifically, longer WASO (*Hypothesis 2a;* H_1), lower sleep efficiency (*Hypothesis 2b;* H_1), and longer onset delay (*Hypothesis 2c;* H_1), would each be associated with lower Ospan scores, lower perseverative errors standard scores, and longer SSRT. In contrast, it was predicted that longer TST would be associated with higher Ospan scores, higher perseverative errors standard scores, and shorter SSRT's (*Hypothesis 2d;* H_1). H_0: Neither WASO, sleep efficiency, nor onset delay would be significantly associated with Ospan scores, perseverative errors, nor SSRT.

Hypothesis 3. Greater working memory performance was hypothesized to predict fewer reports of emotion regulation difficulties. H_1: Specifically, higher scores on the Operation Span (Ospan; Turley-Ames & Whitfield, 2003) would be associated with lower DERS scores. H_0: Ospan scores would not be significantly associated with DERS scores.

Hypothesis 4. Given the hypothesized relationships between sleep problems and working memory, and between working memory and emotion regulation (e.g., Schmeichel, Volokhov, &

Demaree, 2008), working memory was expected to partially mediate the relationship between sleep disruptions and emotion regulation difficulties.

Hypothesis 4a. H_1: Specifically, the magnitude of the relationship between WASO and DERS scores would be reduced when Ospan scores were included in the regression model (Figure 2). H_0: The magnitude of the relationship between WASO and DERS scores would remain the same when Ospan scores were included in the regression model.

Hypothesis 4b. H_1: Additionally, the magnitude of the relationship between sleep efficiency and DERS scores would decrease when Ospan scores were included in the regression model (Figure 3). H_0: The magnitude of the relationship between sleep efficiency and DERS scores would remain the same when Ospan scores were included in the regression model.

Hypothesis 4c. H_1: The magnitude of the relationship between onset latency and DERS scores was also expected to be reduced when Ospan scores were included in the regression model (Figure 4). H_0: The magnitude of the relationship between onset latency and DERS scores would remain the same when Ospan scores were included in the regression model.

Hypothesis 4d. H_1: Further, the magnitude of the relationship between TST and DERS scores was expected to be reduced when Ospan scores were included in the regression model (Figure 5). H_0: The magnitude of the relationship between TST and DERS scores would remain the same when Ospan scores were included in the regression model.

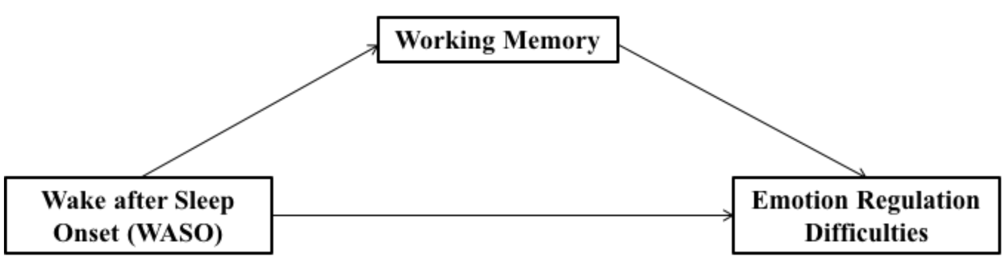

Figure 2. Proposed mediation model using WASO as the independent variable and working memory as the mediator.

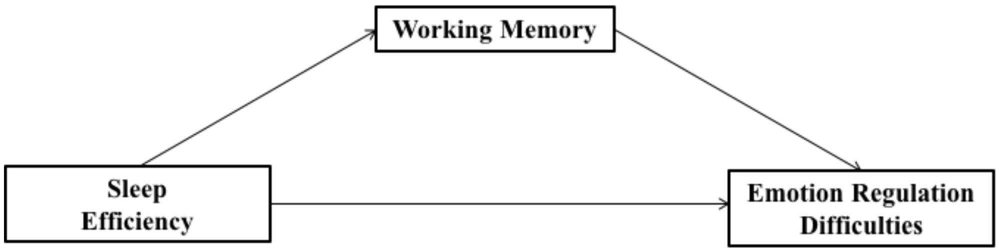

Figure 3. Proposed mediation model using sleep efficiency as the independent variable and working memory as the mediator.

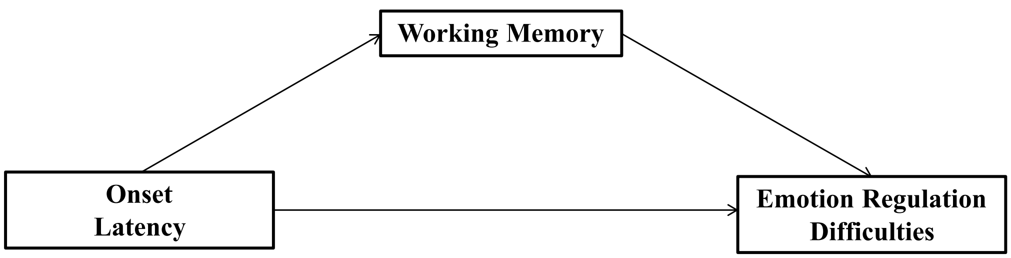

Figure 4. Proposed mediation model using onset latency as the independent variable and inhibition as the mediator.

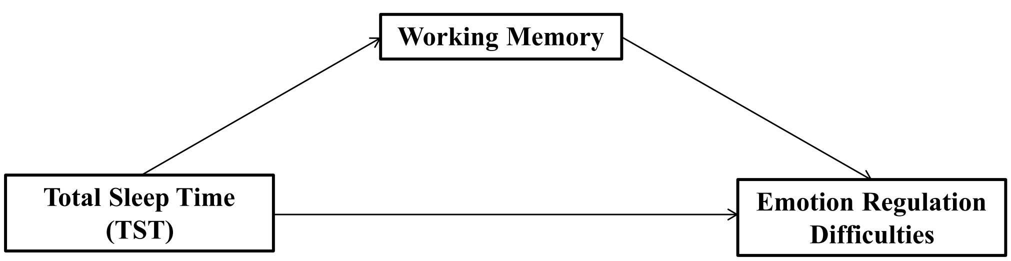

Figure 5. Proposed mediation model using TST as the independent variable and working memory as the mediator.

Hypothesis 5. H_1: It was hypothesized that greater inhibitory control would be associated with fewer reports of emotion regulation difficulties. Therefore, shorter Stop-Signal reaction times (SSRT), assessed using the Stop-Signal Task (Logan, 1994), would predict lower scores on the DERS. H_0: SSRT would not be significantly associated with DERS scores.

Hypothesis 6. Inhibitory control would partially account for the relationship between sleep disturbances and emotion regulation difficulties. This hypothesis was in line with findings that poor sleep is related to poorer inhibition (Wong, Brower, Nigg, & Zucker, 2010) and that inhibition is associated with emotion regulation (e.g., Tabibnia et al., 2011).

Hypothesis 6a. H_1: Specifically, the magnitude of the relationship between WASO and DERS scores would be reduced when SSRT was entered into the regression model (Figure 6). H_0: The magnitude of the relationship between WASO and DERS scores would remain the same when SSRT was entered into the regression model.

Hypothesis 6b. H_1: Further, the relationship between sleep efficiency and DERS scores would be weakened when SSRT was entered into the regression model (Figure 7). H_0: The magnitude of the relationship between sleep efficiency and DERS scores would remain the same when SSRT was entered into the regression model.

Hypothesis 6c. H_1: Additionally, the relationship between onset latency and DERS scores was expected to decrease when SSRT was entered into the regression model (Figure 8). H_0: The magnitude of the relationship between onset latency and DERS scores would remain the same when SSRT was entered into the regression model.

Hypothesis 6d. H_1: The magnitude of the relationship between TST and DERS scores was expected to be reduced when SSRT was included in the regression model (Figure 9). H_0: The magnitude of the relationship between TST and DERS scores would remain the same when SSRT was entered into the regression model.

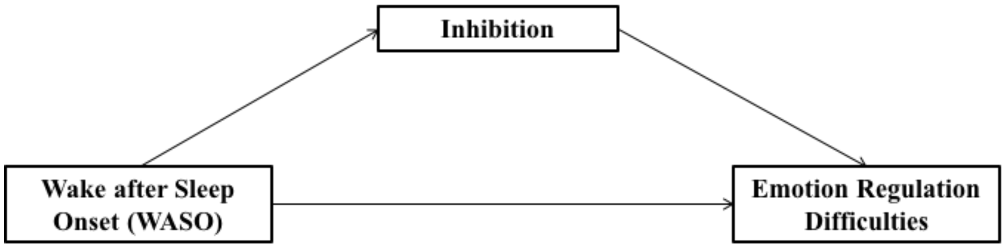

Figure 6. Proposed mediation model using WASO as the independent variable and inhibition as the mediator.

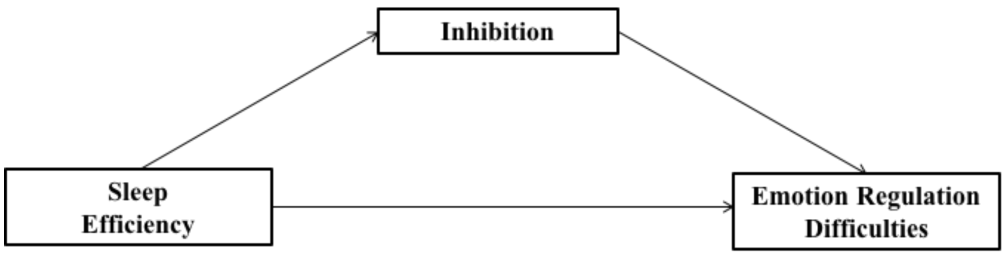

Figure 7. Proposed mediation model using sleep efficiency as the independent variable and inhibition as the mediator.

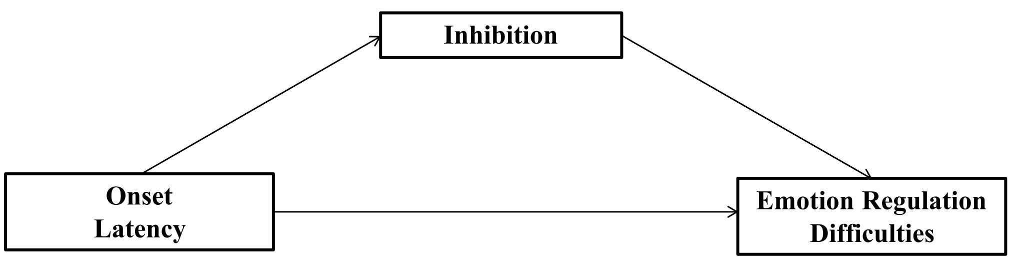

Figure 8. Proposed mediation model using onset latency as the independent variable and inhibition as the mediator.

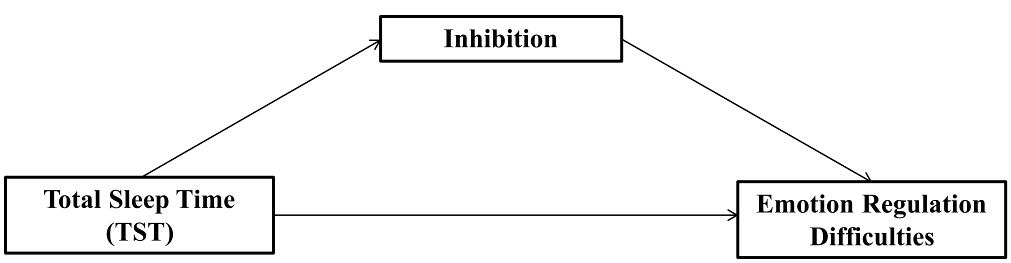

Figure 9. Proposed mediation model using TST as the independent variable and inhibition as the mediator.

Hypothesis 7. H_1: Task-switching ability was expected to predict fewer emotion regulation difficulties. Specifically, fewer perseverative errors on the Wisconsin Card Sorting Task (WCST; Grant & Berg, 1948) would be associated with lower DERS scores. H_0: Perseverative errors would not be significantly associated with DERS scores.

Hypothesis 8. Task-switching would partially account for the relationship between sleep disturbances and emotion regulation difficulties. This hypothesis is supported by findings relating poor sleep to costs in task-switching ability (Kuula et al., 2015), which is subsequently related to emotion regulation (Gul & Ahmad, 2014; Gul & Kahn, 2014).

Hypothesis 8a. H_1: When perseverative errors were included in the regression model, the magnitude of the relationship between WASO and DERS scores was expected to decrease (Figure 10). H_0: The magnitude of the relationship between WASO and DERS scores would remain the same when perseverative errors were included in the regression model.

Hypothesis 8b. H_1: Similarly, the relationship between sleep efficiency and DERS scores was hypothesized to weaken when perseverative errors were included in the regression model (Figure 11). H_0: The magnitude of the relationship between sleep efficiency and DERS scores would remain the same when perseverative errors were included in the regression model.

Hypothesis 8c. H_1: The magnitude of the relationship between onset latency and emotion regulation was also expected to decrease when perseverative errors were included in the regression model (Figure 12). H_0: The magnitude of the relationship between onset latency and DERS scores would remain the same when perseverative errors were included in the regression model.

Hypothesis 8d. H_1: Further, the magnitude of the relationship between TST and DERS scores was expected to decrease when perseverative errors were included in the regression model

(Figure 13). H_0: The magnitude of the relationship between TST and DERS scores would remain the same when perseverative errors were included in the regression model.

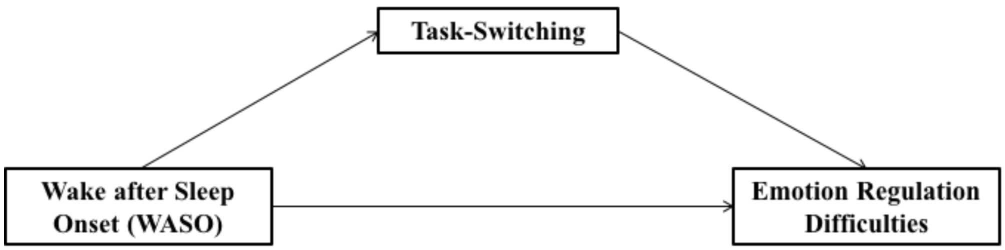

Figure 10. Proposed mediation model using WASO as the independent variable and task-switching as the mediator.

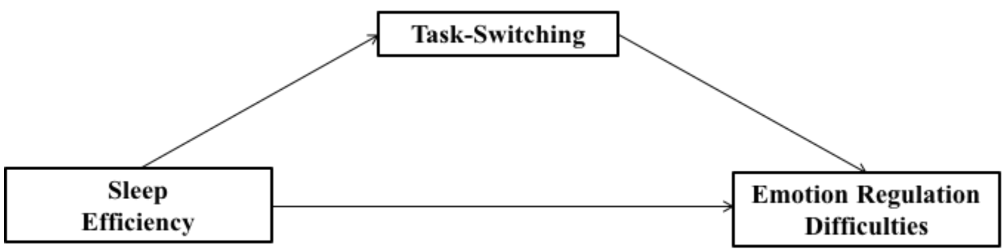

Figure 11. Proposed mediation model using sleep efficiency as the independent variable and task-switching as the mediator.

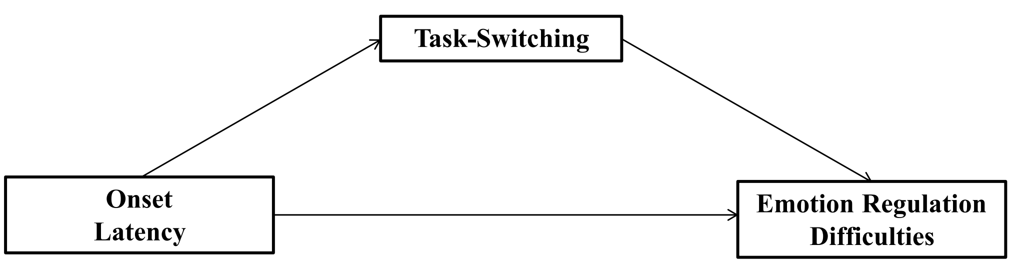

Figure 12. Proposed mediation model using onset latency as the independent variable and inhibition as the mediator.

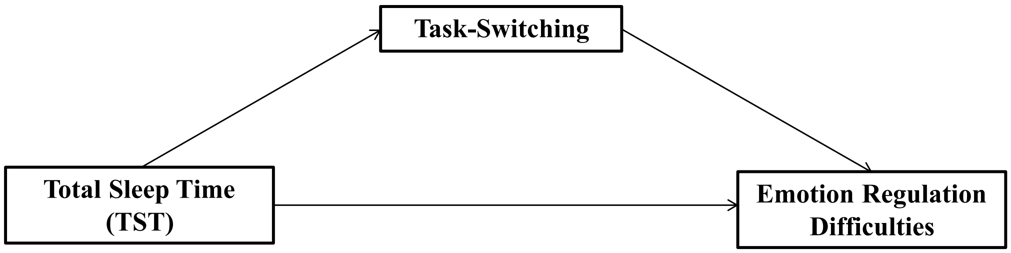

Figure 13. Association between TST and emotion regulation difficulties as mediated by task-switching.

Plan of Analyses

Bivariate correlations between sleep, executive functioning, and emotion regulation variables were computed to assess bivariate relationships between sleep, executive functioning, and emotion regulation variables. Twelve mediation models were then tested to assess whether, and to what degree, working memory, inhibition, and task switching abilities mediated the relationship between WASO, sleep efficiency, TST, and onset latency and difficulties in emotion regulation. Mediators were assessed separately due to the likelihood of multicollinearity between working memory, inhibition, and task-switching. Indirect effects were evaluated via bootstrapping, a method in which standardized indirect effects were calculated for each of 10,000 bootstrapped samples (Graham, Hofer, Donaldson, MacKinnon, & Schafer, 1997). In contrast to the Sobel method, this approach accounts for the asymmetric distribution of the product of two normally distributed variables, *ab*, and, therefore, provides more accurate Type 1 error and higher power when testing the significance of the indirect effect (MacKinnon, Fritz, Williams, & Lockwood, 2007; MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002). Confidence intervals that do not include zero are indicative of significant mediation. Given the number of participants in the current study, multiple regression was determined to be more appropriate analyses method than conducting a simple SEM model, for which a sample size of at least 200 is recommended (Tomarken & Walker, 2005).

Predictor variables for the current study included WASO, sleep efficiency, TST, and onset latency. Mediators included working memory (i.e., Ospan scores), inhibition, (i.e., SSRT), and task-switching (i.e., WCST perseverative errors) abilities. The outcome variable was the total score on the DERS. Consistent with recommendations in the original study proposal, the use of averaged versus last-day actigraphy data was determined by conducting a paired t-test. Given no significant difference between averaged and last-day actigraphy data ($t(62) = 0.91$, $p = 0.37$), and to maintain consistency with prior literature (e.g., Baddam, Canapari, van Noordt, & Crowley, 2018; Kuula et al., 2015), sleep variable averages for each athlete were used in current analyses.

Chapter Three: Results

Variable Normality

Skewness and kurtosis statistics, P-P plots and detrended plots, and histograms with normal curve overlay were examined for each variable to assess normality prior to analysis (Table 2). Average onset latency showed significant negative skewness, and sleep efficiency, SSRT, and WCST perseverative errors showed significant negative skewness and kurtosis. Those that were not normally distributed were log transformed to allow for more normally distributed variables. Square root transformations improved the distribution for average onset latency ($S_{statistic}$ = 1.09; $K_{statistic}$ = -1.07), average sleep efficiency ($S_{statistic}$ = 0.64; $K_{statistic}$ = 0.37), and perseverative errors ($S_{statistic}$ = -1.73; $K_{statistic}$ = 3.89). Log transformation improved the distribution for SSRT ($S_{statistic}$ = -0.51; $K_{statistic}$ = 1.14). While perseverative errors maintained significant kurtosis upon square root transformation, visual inspection of the histogram, P-P plots, and detrended plots indicated improved distribution to a greater degree than log transformation. Square root transformation of perseverative errors was, therefore, maintained in present analyses.

Table 2

Descriptive Statistics of Sleep, Executive Functioning, and Emotion Regulation Variables

Variable	Mean (*SD*)	Skewness (*se*)	$Z_{skewness}$	Kurtosis (*se*)	$Z_{kurtosis}$	% Missing
Average TST (minutes)	445.19 (*36.13*)	-0.04 (*.30*)	-0.12	0.08 (*.56*)	0.14	1.6 %
Average WASO	55.64 (*13.93*)	0.19 (*.30*)	0.62	-0.51 (*.56*)	-0.86	1.6 %
Average Sleep Efficiency	83.28 (*3.86*)	-1.03 (*.30*)	-3.41*	1.67 (*.56*)	2.81*	1.6 %
Average Onset Latency	18.99 (*10.59*)	0.85 (*.30*)	2.81*	0.25 (*.56*)	0.42	1.6 %
Sleep Diary Ratings						
Sleep quality	3.97 (*.59*)	-0.64 (*.30*)	-2.13*	0.15 (*.60*)	0.25	0.03%
Onset latency	1.94 (*.76*)	0.27 (*.30*)	0.90	0.54 (*.60*)	0.90	0.03%
Daytime tiredness	2.32 (*.51*)	-0.24 (*.30*)	-0.80	-0.62 (*.60*)	-1.03	0.03%
Ospan Total	32.87 (*12.10*)	-0.39 (*.30*)	-1.27	-0.84 (*.60*)	-1.39	3.1 %
Perseverative Errors	113.71 (*15.23*)	-0.91 (*.30*)	-2.99*	2.06 (*.60*)	3.46*	1.6 %
Average SSRT	373.28 (*99.68*)	1.12 (*.30*)	3.70*	4.21 (*.60*)	7.07*	1.6 %
DERS Total	72.27 (*16.19*)	0.40 (*.30*)	1.34	-0.11 (*.60*)	-0.19	0 %
Non-acceptance	11.93 (4.81)	0.81 (*.30*)	2.70*	0.00 (*.59*)	0.00	0 %
Awareness	15.13 (4.69)	0.27 (*.30*)	0.90	-0.59 (*.59*)	-1.00	0 %
Strategies	13.75 (4.50)	1.26 (*.30*)	4.20*	1.45 (*.59*)	2.46*	0 %
Clarity	9.20 (3.24)	0.87 (*.30*)	2.90*	0.54 (*.59*)	0.92	0 %
Goals	11.53 (4.70)	0.58 (*.30*)	1.93	-0.42 (*.59*)	-0.71	0 %
Impulse Control	10.65 (4.04)	1.00 (*.30*)	3.33*	0.68 (*.59*)	1.15	0 %

TST = total sleep time, Onset latency = delay between rest and onset of sleep at bedtime, Sleep efficiency = ratio (reflected as percentage) of total sleep time to the total rest period, WASO = difference between assumed sleep period and actual sleep time
Sleep quality ratings were made on a 5-point scale, where 1 = *very bad* and 5 = *very good*; Onset latency ratings were made on a 4-point scale, where 1 = *0-5 minutes* and 4 = *31+ min.*; Daytime tiredness ratings were made on a 4-point scale, where 1 = *very alert* and 4 = *very tired*
* Correlation is significant at the 0.05 level (2-tailed)

Bivariate Correlations

Bivariate correlations between sleep, executive functioning, and emotion regulation variables were computed to assess relationships as predicted by hypotheses 1, 2, 3, 5, and 7. Correlations are presented in Table 3. Hypothesis 1, which broadly predicted relationships between sleep variables and emotion regulation difficulties, was not supported, as no significant relationships between actigraphy variables and DERS scores were observed. Furthermore, neither WASO, sleep efficiency, onset latency, nor TST were related to executive functioning measures, inconsistent with predictions of hypothesis 2. Hypothesized relationships between executive functioning and emotion regulation, as assessed by Ospan, SSRT, and WCST performance and DERS scores were also not supported.

Among actigraphy variables, sleep efficiency was significantly related to TST ($r = -.40$; $p < .01$), onset latency ($r = .60$, $p < .01$), and WASO ($r = .71$, $p < .01$). When accounting for negative skewness of sleep efficiency and onset latency, the correlations indicated that greater sleep efficiency was associated with longer sleep duration, shorter onset latency, and less WASO. Among executive functioning measures, Ospan total scores were significantly associated with WCST performance, such that, after accounting for negative skewness of perseverative errors standard scores, better working memory performance was associated with fewer perseverative errors on the WCST ($r = -.26$; $p < .05$).

In contrast to hypothesis 1, neither WASO, sleep efficiency, onset latency, nor TST were significantly related to emotion regulation difficulties, as measured by the DERS. Additionally, inconsistent with hypothesis 2, sleep variables were not significantly related to working memory, inhibitory control, or task-switching. Furthermore, contrary to hypotheses 3, 5, and 7, working memory, inhibitory control, and task-switching performance were not significantly correlated with the DERS. Despite lack of significant relationships among the primary variables, examinations of mediation models were maintained, consistent with analyses specified in the original study proposal.

Table 3

Correlation Matrix of Sleep, Executive Functioning, and Emotion Regulation Variables

	TST	Onset Latency	Sleep Efficiency	WASO	Ospan Total	SSRT	Perseverative Errors Standard Score	DERS
TST	1	-0.14	-.40**	0.04	0.03	0.11	0.19	0.03
Onset Latency		1	.60**	0.17	-0.19	0.01	-0.07	-0.03
Sleep Efficiency			1	.71**	-0.10	-0.10	-0.13	0.05
WASO				1	0.02	-0.03	-0.08	0.01
Ospan Total					1	0.08	-.26*	-0.09
SSRT						1	-0.20	0.08
Perseverative Errors Standard Score							1	-0.01
DERS								1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Sleep Difficulties, Working Memory, and Emotion Regulation

Mediation of WASO and emotion regulation by working memory. Working memory was hypothesized to partially account for a relationship between sleep disruption and DERS scores. When examining working memory as a mediator between WASO and DERS scores, the standardized regression coefficient between WASO and working memory was not significant (b = 0.01 (0.15), p = .95; Figure 14). The standardized regression coefficient between working memory and DERS scores after controlling for WASO was not significant (b = -0.10 (0.12), p = .44). In contrast to predictions, working memory did not significantly mediate a relationship between WASO and DERS scores (ab = -0.00 (0.03), p = .97, 95% CI [-0.05, 0.05]).

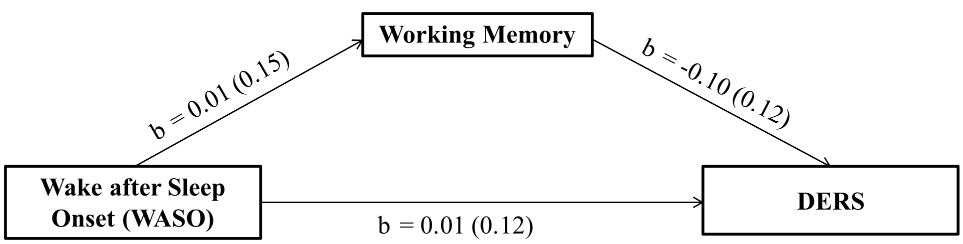

Figure 14. Association between WASO and emotion regulation difficulties as mediated by working memory.

Mediation of sleep efficiency and emotion regulation by working memory. The relationship between sleep efficiency and DERS scores with working memory included as the mediator are displayed in Figure 15. The standardized regression coefficient between sleep efficiency and working memory was not significant (b = -0.10 (0.12), p = .43). The standardized regression coefficient between working memory and DERS scores when controlling for sleep efficiency was not significant (b = -0.10 (0.13), p = .45). In contrast to predictions, working memory did not significantly mediate a relationship between sleep efficiency and DERS scores (ab = 0.01 (0.02), p = .68, 95% CI [-0.04, 0.05]).

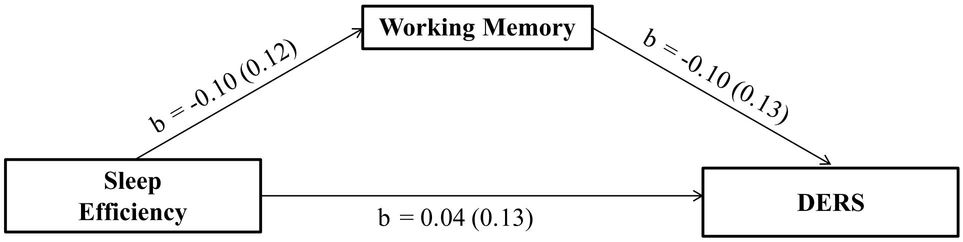

Figure 15. Association between sleep efficiency and emotion regulation difficulties as mediated by working memory.

TST and emotion regulation as mediated by working memory. Figure 16 displays the association between TST and DERS scores with working memory entered as a mediator. The standardized regression coefficient between TST and working memory was not significant (b = 0.03 (0.10), p = .81). Similarly, the standardized regression coefficient between working memory and DERS scores when controlling for TST and age was not significant (b = -0.07 (0.14), p = .59). In contrast to predictions, working memory did not significantly mediate a relationship between TST and DERS scores (ab = -0.00 (0.02), p = .91, 95% CI [-0.03, 0.03]).

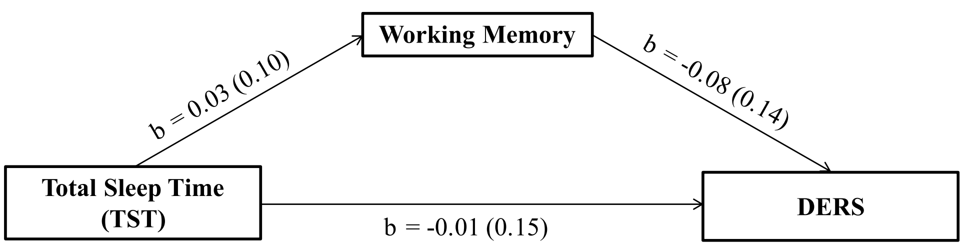

Figure 16. Association between TST and emotion regulation difficulties as mediated by working memory.

Onset latency and emotion regulation as mediated by working memory. The relationship between onset latency and DERS scores using working memory as a mediator is presented in Figure 17. The standardized regression coefficient between onset latency and working memory was not significant (b =-0.19 (0.12), p = .11). Similarly, the standardized regression coefficient between working memory and DERS scores was not significant after controlling for onset latency (b = -0.11 (0.13), p = .39). In contrast to predictions, working memory did not significantly mediate a relationship between onset latency and DERS scores (a*b* = 0.02 (0.03), *p* = .51, 95% CI [-0.04, 0.08]).

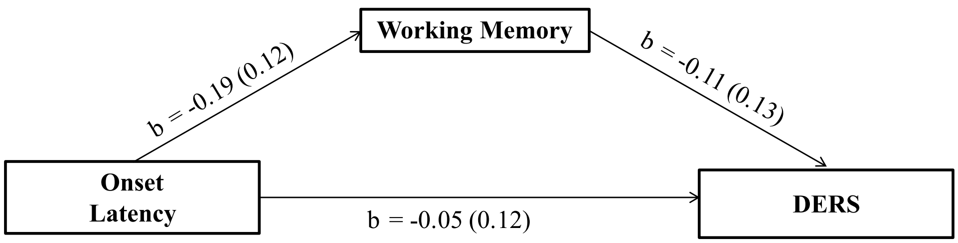

Figure 17. Association between onset latency and emotion regulation difficulties as mediated by working memory.

Sleep Difficulties, Inhibition, and Emotion Regulation

Mediation of WASO and emotion regulation by inhibition. Results for mediation models with inhibition were similar to those assessing working memory. Inhibition was hypothesized to partially mediate a relationship between sleep and DERS scores. Regression coefficients for the relationship between WASO and DERS scores when inhibition was entered as a mediator are presented in Figure 18. The relationship between WASO and inhibition was not significant (*b* = -0.02 (0.11), *p* = .84). Similarly, the relationship between inhibition and DERS scores was not significant after controlling for WASO (*b* = 0.08 (0.11), *p* = .48). Contrary to hypotheses, inhibition did not significantly mediate a relationship between WASO and DERS scores (a*b* = -0.00 (0.02), *p* = .91, 95% CI [-0.03, 0.03]).

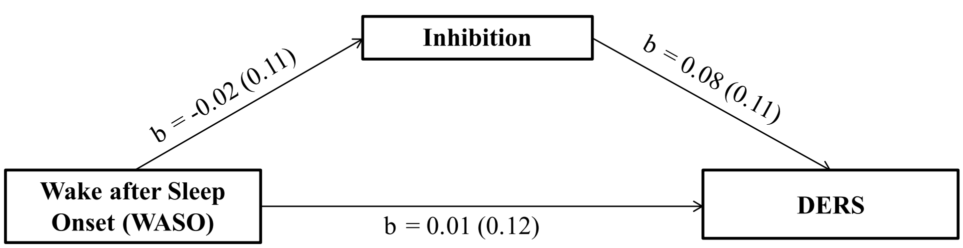

Figure 18. Association between WASO and emotion regulation difficulties as mediated by inhibition.

Sleep efficiency and emotion regulation as mediated by inhibition. The relationship between sleep efficiency and DERS scores using inhibition as a mediator is presented in Figure 19. The relationship between sleep efficiency and inhibition was non-significant (*b* = -0.10 (0.12), *p* = .41). Similarly, the standardized regression coefficient between inhibition and DERS scores after controlling for sleep efficiency was not significant (*b* = -0.08 (0.11), *p* = .46). Inhibition did not significantly mediate a relationship between sleep efficiency and DERS scores (a*b* = -0.01 (0.02), *p* = .70, 95% CI [-0.05, 0.03]).

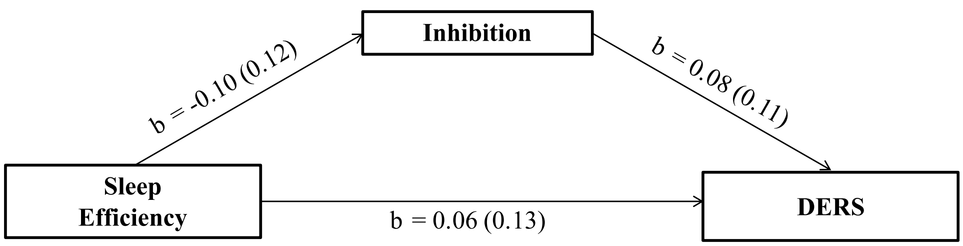

Figure 19. Association between sleep efficiency and emotion regulation difficulties as mediated by inhibition.

TST and emotion regulation as mediated by inhibition. Figure 20 displays the association between TST and DERS scores when inhibition is entered as a mediator. The standardized regression coefficient between TST and inhibition was not significant (*b* = 0.11 (0.13), *p* = .41). Further, the standardized regression coefficient between inhibition and DERS scores when controlling for TST and age was not significant (*b* = 0.09 (0.11), *p* = .41). In contrast to predictions, inhibition did not significantly mediate a relationship between TST and DERS scores (a*b* = 0.01 (0.02), *p* = .65, 95% CI [-0.03, 0.05]).

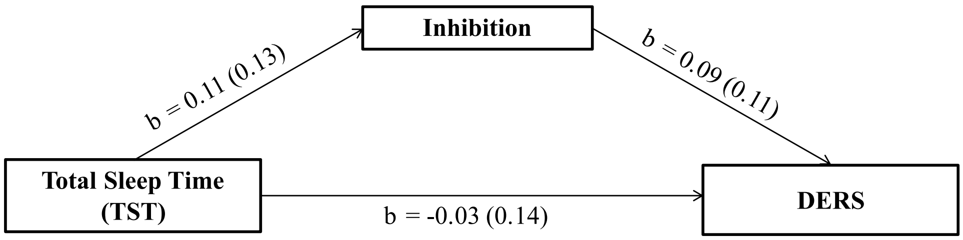

Figure 20. Association between TST and emotion regulation difficulties as mediated by inhibition.

Onset latency and emotion regulation as mediated by inhibition. Figure 21 shows the relationship between onset latency and DERS scores with inhibition included as a mediator. Onset latency and inhibition showed a non-significant relationship (b =0.01 (0.15), p = .96). The relationship between inhibition and DERS scores was not significant (b = 0.08 (0.11), p = .47). Inhibition did not significantly mediate a relationship between onset latency and DERS scores (ab = 0.00 (0.02), p = .98, 95% CI [-0.04, 0.04]).

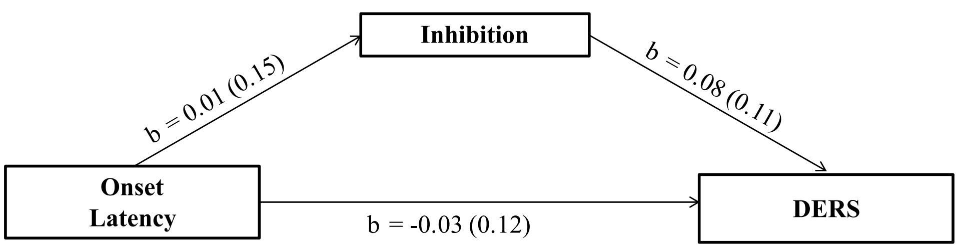

Figure 21. Association between onset latency and emotion regulation difficulties as mediated by inhibition.

Sleep Difficulties, Task-Switching, and Emotion Regulation

WASO and emotion regulation as mediated by task-switching. The proposed relationship between sleep and DERS scores was hypothesized to be partially mediated by task-switching ability. The relationship between WASO and DERS scores including task-switching as a mediator is presented in Figure 22. The standardized regression coefficient between WASO and task-switching was not significant (b = -0.08 (0.16), p = .65). Similarly, the relationship between task-switching and DERS scores was not significant when controlling for WASO (b = -

0.02 (0.13), *p* = .91). Task-switching did not significantly mediate a relationship between WASO and DERS scores (a*b* = 0.00 (0.02), *p* = .96, 95% CI [-0.05, 0.05]).

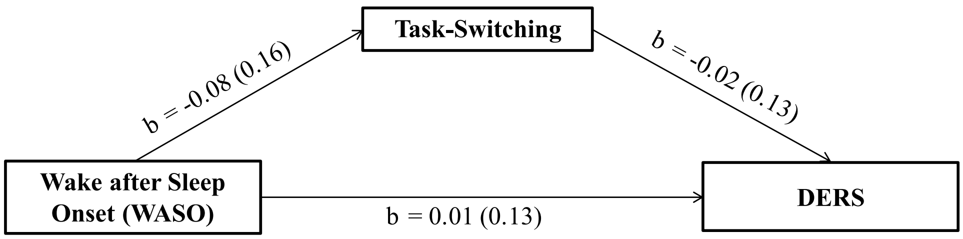

Figure 22. Association between WASO and emotion regulation difficulties as mediated by task-switching.

Mediation of sleep efficiency and emotion regulation by task-switching. The relationship between sleep efficiency and DERS scores with task-switching entered as a mediator is presented in Figure 23. The standardized regression coefficient between sleep efficiency and task-switching was not significant (*b* = -0.13 (0.17), *p* = .45), nor was the relationship between task-switching and DERS scores after controlling for sleep efficiency (*b* = -0.01 (0.13), *p* = .93). In contrast to predictions, task-switching did not significantly mediate a relationship between sleep efficiency and DERS scores (a*b* = 0.00 (0.03), *p* = .96, 95% CI [-0.05, 0.06]).

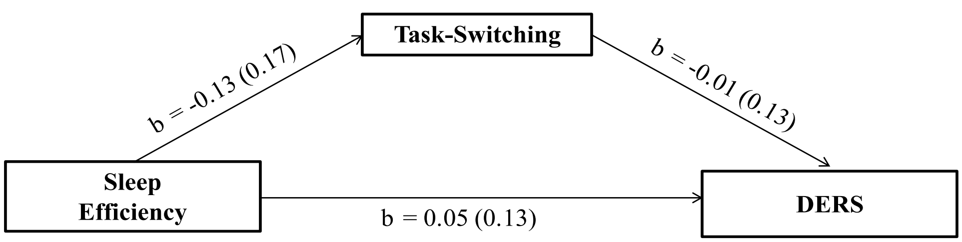

Figure 23. Association between sleep efficiency and emotion regulation difficulties as mediated by task-switching.

Mediation of TST and emotion regulation by task-switching. Figure 24 displays the association between TST and DERS scores when including task-switching as a mediator. The standardized regression coefficient between TST and task-switching was not significant (*b* = 0.19 (0.15), *p* = .22). When controlling for TST and age, the relationship between task-switching and DERS scores was also not significant (*b* = -0.03 (0.13), *p* = .81). In contrast to predictions, task-switching did not significantly mediate a relationship between TST and DERS scores (a*b* = -0.01 (0.03), *p* = .85, 95% CI [-0.03, 0.03]).

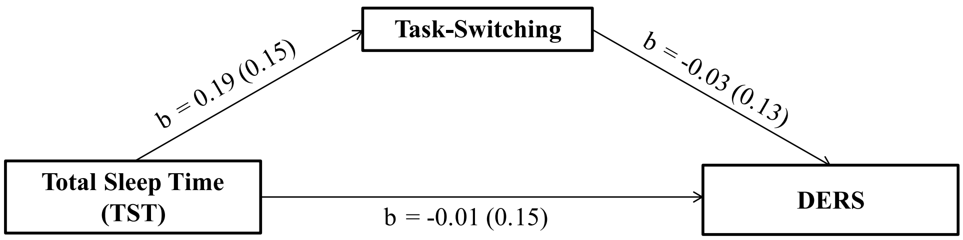

Figure 24. Association between TST and emotion regulation difficulties as mediated by task-switching.

Onset latency and emotion regulation as mediated by task-switching. Figure 25 displays the relationship between onset latency and DERS scores when task-switching is entered as a mediator. Neither the relationship between onset latency and task-switching (*b* = -0.07 (0.13), *p* = .61), nor the relationship between task-switching and DERS scores when controlling for onset latency (*b* = -0.02 (0.13), *p* = .90) were significant. Task-switching did not significantly mediate a relationship between onset latency and DERS scores (a*b* = 0.00 (0.02), *p* = .95, 95% CI [-0.04, 0.04]).

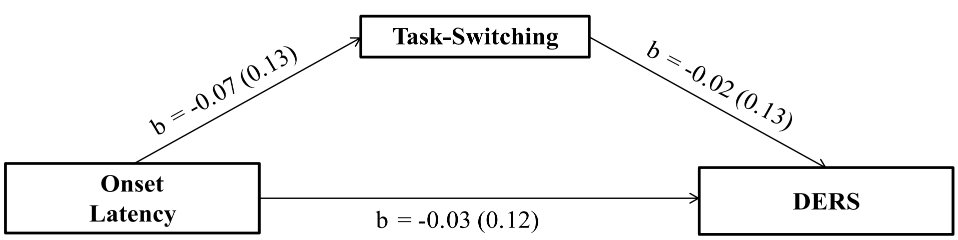

Figure 25. Association between onset latency and emotion regulation difficulties as mediated by task-switching.

Sleep and Emotion Regulation Difficulties by Working Memory Group

Consistent with committee recommendations during study proposal, differences in sleep and DERS scores by working memory performance were explored through conducting a tertiary split of Ospan scores. Based on the split, groups were categorized by high (39-54 points), medium (29-38 points), and low (0-28 points) working memory performance. One-way ANOVAs were conducted to examine whether groups differed on TST, onset latency, WASO, sleep efficiency, and/or DERS scores. No significant differences in TST ($F(2, 60) = 0.59$, $p = .56$), onset latency ($F(2, 60) = 0.31$, $p = .73$), WASO ($F(2, 60) = 0.50$, $p = .61$), sleep efficiency ($F(2, 60) = 0.02$, $p = .98$), or DERS scores ($F(2, 59) = 0.91$, $p = .41$) were observed between working memory performance groups. This finding indicated that, in the current sample of athletes, comparatively high versus low working memory performance did not represent a vulnerability nor protective factor, respectively, in regards to sleep nor emotion regulation difficulties.

Chapter Four: Discussion

The present study sought to understand whether sleep and executive functioning were associated with emotion regulation difficulties, which broadly predict anxiety and depressive symptoms (e.g., Aldao, Nolen-Hoeksema, & Schweizer, 2010; Suveg, Sood, Comer, & Kendall, 2009). Interrelationships among these factors are especially important to understand in adolescents, given that onset of mood and anxiety disorders typically occurs during this developmental period (Kessler et al., 2007). Furthermore, to my knowledge, no research to date has examined these factors among healthy young athletes. The present study was the first to examine how sleep and executive functioning may interact in predicating emotion regulation difficulties among healthy adolescent athletes. In doing so, efforts were also taken to expand understanding beyond a narrowed aspect of emotion regulation (i.e., reappraisal) to emotion regulation difficulties across a number of areas (e.g., acceptance and awareness of emotions, ability to control impulses when upset). Furthermore, the present study sought to extend the literature using actigraphy-based assessments of sleep in relation to executive functioning and emotion regulation, which is limited to date in adolescent samples. While efforts to address limited literature through use of the DERS as an index of emotion regulation and through use of actigraphy to assess sleep represent unique strengths of the present study, use of these measures may also explain lack of significant findings and help inform the nature of relationships among sleep, executive functioning, and emotion regulation. Implications of these relationships, given findings of the current study, are reviewed in turn.

Emotion Regulation and Executive Functioning

Contrary to predictions specified in hypotheses 3, 5, and 7, that working memory, inhibition, and task-switching performance would be negatively associated with emotion regulation difficulties, significant relationships among these variables were not observed in the current sample of healthy 11 to 15-year-old athletes. These findings may suggest that executive functioning and emotion regulation are unrelated in young athletes, or that the magnitude of relationships between working memory, inhibition, task-switching, and emotion regulation is smaller among athletes in comparison to general community samples (e.g., Gul & Ahmad, 2014; Hilt, Leitzke, & Pollak, 2014; Lantrip et al., 2016). In either case, it is also important to consider how the nature of the tasks used in the present study may have contributed to null findings.

As noted above, the DERS evaluated self-reported difficulties in a number of areas of emotion regulation, including awareness of emotions and attributes about one's ability to alter negative emotional states (Gratz & Roemer, 2004). In contrast, to date, measures of emotion regulation in studies assessing its relation to executive functioning have included self-reported or performance-based measures of the abilities to reappraise (e.g., Lantrip et al., 2016; McRae, Jacobs, Ray, John, & Gross, 2012) or shift attention away from emotional stimuli (e.g., Gul & Ahmad, 2014). Furthermore, emotion regulation and executive functioning in prior work have been assessed across similar timelines, such as general ratings of emotion regulation strategies and executive functioning skills as evaluated in Lantrip and colleagues' (2016) work. Null findings regarding relationships between executive functioning and emotion regulation in the current study may, therefore, have been partially due to inconsistent timelines across each measure. Specifically, the DERS evaluated generalized emotion regulation difficulties, while executive functioning was performance-based, and thus dependent on situational factors (e.g., participant-experimenter interaction) on a specified testing day.

Lack of significant relationships between executive functioning and emotion regulation, as assessed in the present study, may also indicate that executive functioning may relate to specific facets of emotion regulation (e.g., reappraisal) rather than emotion regulation more broadly. In assessing this further, exploratory analyses indicated a significant negative relationship between working memory and the emotional awareness subscale of the DERS (r = -0.30, $p < .05$), such that higher working memory performance was associated with fewer difficulties with emotional awareness (e.g., caring about feelings when upset, attending to how one feels, believing one's feelings are important). This finding suggests that, similar to findings regarding reappraisal, working memory may support the ability to attend to one's emotional experience during upsetting situations. Given that this finding was a post-hoc analysis, however, specific relationships between facets of emotion regulation, working memory, and psychopathology should be investigated further in future research.

Sleep and Executive Functioning

According to hypothesis 2, sleep measures were expected to be positively related to executive functioning, such that longer TST, greater sleep efficiency, and lower onset latency and WASO predicted better working memory, inhibition, and task-switching performance. In contrast to predictions, this hypothesis was not supported. In understanding why sleep and executive functioning were not significantly related in the current study, level of sleep difficulties reported in the current sample may provide some insight. Specifically, executive functioning may be negatively impacted only when sleep difficulties are more pronounced than observed in the current study. For instance, Radazzo, Muehlbach, Schweitzer, and Walsh (1998) reported poorer abstract reasoning, assessed by total scores on the WCST, and poorer verbal creativity among children who slept 5 hours compared to children who slept 11 hours. In the current sample, athletes slept 445.19 minutes (> 7 hours) on average, and only one athlete averaged less than 6 hours of sleep. Furthermore, longitudinal findings suggest that sleep-related impairments in executive functioning may present as a cumulative impact, whereby chronic sleep difficulties in early childhood predict poor executive functioning performance in early and late adolescence (e.g., Friedman et al., 2009; Wong, Brower, Nigg, & Zucker, 2010). These findings provide some indication that, when present in childhood, pronounced sleep difficulties tend to persist, which may have downstream impacts on the development of executive functioning. Furthermore, marked and chronic sleep difficulties may coincide with a greater subjective sense of sleepiness or fatigue, which has been associated with executive functioning performance in prior investigations (e.g., Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009).

Along similar lines, sleep-related impairments in executive functioning may be more robustly related to subjective ratings of sleep difficulties rather than objective assessments, such as actigraphy and PSG. Specifically, subjective reports of sleep difficulty capture perceived sleep quality and feelings of tiredness, which have been reliably associated with poorer executive functioning performance (e.g., Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009; Caruso et al., 2014). Moreover, perceptions of sleep quality likely draw upon multiple facets of sleep (i.e., onset latency and sleep duration; Zhang & Zhao, 2007) and, thus, present a more comprehensive picture of sleep difficulties than actigraphy measures in isolation. Such reasoning may partially explain why actigraphy-based assessments of sleep have yielded more inconsistent relationships between working memory, inhibition, and task-switching among youth (e.g., Anderson et al., 2009).

In the current study, athletes' reported, on average, that their sleep quality was "good" ($M = 3.97$, $SD = 0.59$). Furthermore, average onset latency ratings ($M = 1.94$, $SD = 0.76$) indicated that adolescent athletes fell asleep in less than 6 minutes upon going to bed and felt alert in the morning (daytime tiredness rating, *M* = 2.32, *SD* = 0.51). However, post-hoc analyses in the current study indicated the significance and magnitude of relationships between sleep diary ratings, executive functioning, and emotion regulation did not differ from those of actigraphy measures. Such finding may, however, be confounded by inconsistency in the structure of measures across the primary variables of interest (discussed further below). Further research, therefore, may be needed to assess how subjective and objective sleep measures relate to executive functioning and emotion regulation.

Sleep and Emotion Regulation

Lastly, the nature of the current sample offers guidance in understanding null findings between sleep variables and emotion regulation in the present study, which contrasted with hypothesized relationships (i.e., hypotheses 1a-1d). Importantly, none of the athletes in the present investigation reported history of TBI, medical disorders, or recent use of psychotropic medication (e.g., ADHD or antidepressants). It is perhaps unsurprising, then, that average levels of sleep and emotion regulation difficulties among the current sample appeared notably low compared to prior samples. For example, the mean DERS score in the current sample was 75.17 (*SD* = 16.19), indicating relatively infrequent levels of emotion regulation difficulties (note that a DERS score of 36 is equivalent to “never” having difficulties in the 6 areas of emotion regulation assessed). Most emotion regulation difficulties were reported in the domain of awareness (*M* = 15.13, *SD* = 4.69), while fewest difficulties were reported for clarity of emotions when upset (*M* = 9.20, *SD* = 3.24). In contrast, Henry, Castellini, Moses, and Scott (2016) reported mean DERS scores of 92 among adolescents without clinical diagnoses and average scores of 128.6 among adolescents with clinical diagnoses (e.g., major depression, anxiety disorders).

Findings of the current study, therefore, likely reflected a sample with comparatively few concerns of emotion regulation difficulties. Furthermore, as stated above, athletes slept an average of at least 7 hours. Among non-clinical youth, observable sleep-related emotion regulation difficulties have been reported when sleep was restricted to 6 ½ hours on average, or less (Baum et al., 2014). Therefore, sleep and emotion regulation difficulties observed in the present sample likely represented a restricted range. More specifically, the range of sleep and emotion regulation difficulties observed in the current study appeared narrowed, which limited the ability to evaluate the ways in which sleep and emotion regulation may vary together along a broader continuum of difficulties.

Importantly, involvement in extracurricular activities (e.g., athletic teams) is associated with reduced risk of developing mental health disorders among adolescents (National Research Council and Institute of Research Medicine, 2009). A more recent review of participation in sports and its relation to social-emotional health echoed mental health benefits, including increased self-confidence, emotion regulation, connectedness with others, and resilience in conjunction with participation in athletics among children and adolescents (Eime, Young, Harvey, Charity, & Payne, 2013). Additionally, adolescents who are regularly active may exhibit fewer sleep difficulties compared to less active counterparts, which is partially attributed to increased daily structure throughout the week (Brand et al., 2010). Considered in conjunction with relatively low DERS scores in the present sample, lack of interrelatedness among sleep and emotion regulation suggest that the presence of additional factors, including environmental and interpersonal aspects of participation in athletics, may protect against impairments in emotion regulation. Further support for this suggestion is offered by numerous studies (e.g., Eime, Young, Harvey, Charity, & Payne, 2013) documenting the positive impact of sports participation on management of negative emotions (Hansen, Larson, & Dworkin, 2003) and confidence in the ability to cope with negative emotions (Valois, Umstattd, Zullig, & Paxton, 2008) among adolescent athletes.

Consistent with this argument, reliable relationships between sleep and emotion regulation difficulties may occur along a broader continuum that includes youth who have been diagnosed with a psychological disorder. For example, Cousins and colleagues (2011) assessed differences in sleep between a control group and youth diagnosed with either major depression or anxiety. Cousins and colleagues observed that reduced positive affect during the day was related to reduced sleep duration, though this relationship was present only among anxious youth. Additionally, anxious adolescents both display and report more pronounced sleep difficulties, such as delayed onset to fall asleep and frequent nighttime awakenings, compared to depressed youth and non-clinical controls (Baddam, Canapari, van Noordt, & Crowley, 2018). With these findings in mind, a natural next step for future research would be to examine if presence of a clinical disorder moderates interrelationships among impairments in sleep, executive functioning, and emotion regulation, and specifically whether interrelationships among these factors are indeed stronger in clinical vs. non-clinical populations.

Limitations

Directions for future research should also be considered within the context of the current study's limitations. As the present investigation included only 64 athletes, power to detect significant relationships among variables of interest was low (i.e., .50) in comparison to the conventional standard of .80. A larger sample size of at least 100 would, therefore, be needed to more accurately evaluate interrelationships among the present variables (Faul, Erdfelder, Buchner, & Lang, 2009). Inclusion of a larger sample would also allow for discernment of whether lack of significant relationships in the current study are due to low power, or if relationships between sleep, executive functioning, and emotion regulation are of less magnitude among healthy young athletes. Such possibility appears likely, given small effect sizes (i.e., range of beta values from 0.00 to 0.19) observed in the current sample. Should this be the case, additional research may clarify potential reasons for this trend, such as few concerns of sleep and mental health difficulties among adolescent athletes (e.g., Brand et al., 2010; Eime, Young, Harvey, Charity, & Payne, 2013).

An additional limitation of the present investigation concerns the version of the operation span task used, which has been used as a measure of working memory primarily with adult and college populations. Inclusion of additional measures of working memory that have been normed among adolescents (e.g., BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000; Wechsler Intelligence Scale for Children-Fifth Edition [WISC-V] Digit Span and Number-Letter Sequencing; Wechsler, 2014) would aid in addressing this limitation and facilitate understanding of how working memory may be differentially impacted by sleep and/or relate to specific aspects of emotion regulation among developing adolescents.

Relatedly, it is important to note that not all of the present executive functioning measures were significantly correlated, as would be expected given theoretical understanding of executive functions as a set of goal-directed abilities (e.g., Hofmann, Schmeichel, & Baddeley, 2012). Such limitation is likely due to low power, and therefore limited ability to detect relationships among executive functioning measures. Thus, while criterion measures (i.e., Stop-Signal Task) were available to assess validity of the current operation span task for use in an adolescent population, this could not be evaluated in the present study due to limitations of low power.

Further, as briefly mentioned earlier, given that performance-based measures of emotion regulation were not included in the current investigation, the extent to which self-reported emotion regulation difficulties broadly relate to emotion regulation performance (e.g., reappraisal), sleep, and executive functioning performance remains unclear. Given the nature of the DERS as a self-report measure, the degree to which limitations of self-report, such as response bias (e.g., Van de Mortel, 2008) or inaccurate reporting, affected the present findings is also unclear. Future exploration of these relationships will likely help elucidate whether certain facets of emotion regulation (e.g., beliefs about versus demonstrated ability to alter negative mood states) are uniquely related to sleep difficulties and executive functioning.

Lastly, identifying relationships between these factors in the current study may have been complicated by the fact that measures of sleep, executive functioning, and emotion regulation were each rated or assessed across different timelines. For instance, while actigraphy was averaged across one to two weeks, emotion regulation difficulties were rated across a general, non-specified timeline. As such, in order to better examine interrelationships among these processes, further evaluation using methodology that is congruent in structure (e.g., all performance-based) and timeline may be warranted.

Conclusions and Future Directions

In closing, while null findings were observed across all primary analyses, the present findings offer guidance in understanding reduced vulnerability to emotion regulation difficulties and subsequent psychopathology among young adolescent athletes. Specifically, lack of significant relationships among the present variables could suggest that interrelatedness among these factors is of less magnitude among adolescent athletes compared to general or clinical samples. One possibility is that this trend is due to the presence of protective factors in an adolescent's daily functioning (e.g., involvement in extracurricular activities) that may buffer against impairments in emotion regulation (Hansen, Larson, & Dworkin, 2003; Valois, Umstattd, Zullig, & Paxton, 2008) and mental health difficulties (e.g., Eime, Young, Harvey, Charity, & Payne, 2013; National Research Council and Institute of Research Medicine, 2009).

In contrast, sleep, executive functioning, and emotion regulation may be more strongly interrelated among clinical populations, such as adolescents diagnosed with anxiety disorders, who exhibit more pronounced sleep disturbances (e.g., frequent nighttime awakenings; Forbes et al., 2008) and emotion regulation difficulties (e.g., Mennin, Holaway, Fresco, Moore, & Heimberg, 2007; Suveg, Sood, Comer, & Kendall, 2009) than non-clinical youth. Considering noted limitations, further research is needed to examine a broader range of sleep, executive functioning, and emotion regulation measures among more diverse samples to elucidate how specific facets of each may or may not be interrelated. Understanding the nature and directionality of these relationships using experimental designs and examining how the magnitude of these relationships may differ between athletic and non-athletic youth represent additional areas of future research in service of identifying vulnerabilities to mental illness among youth. Examining these factors in clinical populations, among whom fewer protective factors likely exist and for whom cyclical patterns likely perpetuate symptom severity, represents a next step forward in understanding risk for psychopathology among adolescents.

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Appendix A

Idaho State University
Informed Consent Form

CONSENT TO PARTICIPATE IN RESEARCH – Parent /Adult Guardian Form
Concussion, Sleep Habits and Neurocognitive processes in Young Athletes

We are asking you to allow your child to participate in a research study conducted by Dr. Maria Wong, Dr. Caroline Faure, Dr. Tina Miyake, and Dr. Kandi Turley-Ames from the Departments of Psychology and Education at Idaho State University. Your child has been asked to participate in this research because they are an athlete in __________________ (Names of Sports League) in Idaho. Your decision to enroll your child in this study and their participation in this research project is voluntary. Please read the information below and ask questions about anything you do not understand.

1. **PURPOSE OF THE STUDY**
This study is being conducted to examine the sleep habits and neurocognitive processes (e.g., the ability to plan, solve problems, and pay attention) of young athletes with or without a concussion in the last three months.

2. **PROCEDURES**
If you volunteer to enroll your child in this study, we would ask you and your child to visit us at the Idaho State University Department of Psychology located in Garrison Building 63 at 1400 E. Terry St., Pocatello, ID 83209.

The study will take place across two sessions. During the first session, you and your child will complete the informed consent form and several questionnaires on concussion and sleep. Your child will also complete questionnaires about their feelings, behaviors, and physical development. We will also ask your child to complete a few activities to assess cognitive abilities on the computer.

At the end of the session, your child will be given an actigraph watch and a sleep and activity log. They will be asked to wear that actigraph watch every night for seven nights, starting half an hour before they go to bed and finishing half an hour after they get up. They will also keep a daily record of when they go to bed, when they get up, and how alert or tired they feel during the day. You may need to assist your child in wearing the watch or remembering to keep the daily sleep diary.

During the follow-up session, we will invite you and your child to return to the Department of Psychology to complete questionnaires and activities to assess their cognitive abilities once again. We will also ask your child to wear the actigraph watch and keep a record of their bed and wake times for an additional seven nights.

If your child suffers from a concussion during the period of the study, we will invite you and your child to complete the questionnaires, cognitive activites, and actigraph for an additional session within a month of their concussion. We will also ask you, your child, and your child's coach to complete a questionnaire about their experience of concussion symptoms at this time.

Ten adolescents in the study will be invited to participate in an fMRI scan at the University of Utah Center for Advanced Imaging Research located in Salt Lake City, Utah. Your child will spend approximately 1 hour in the scanner. An MRI machine is a tube-like structure surrounded by a large circular magnet. Before entering the MRI room, the entire procedure will be explained to you and your child. To enter the scanner, your child is instructed to lie down on a bed outside of the scanner. When on the bed of the scanner, your child will be offered pillows to go under their feet or knees as well as a blanket if the room is cold to increase comfort. Once your child is ready and comfortable, a research assistant will slowly move the bed into the magnet. While the space is small, several efforts are made to ease any concerns participants may have. While your child is in the scanner, a research assistant will communicate with them the entire time. Additionally, while in the MRI scanner, participants will hear several noises produced by the actual machine. These noises are normal and research assistants will prepare your child for these noises so that they do not come as a surprise once in the scanner. Importantly, your child will have a squeeze-ball in hand during the entire scan. At any point in which your child is uncomfortable and does not wish to continue, the child may squeeze the ball and that will stop the scan. The child will immediately be removed from the scanner. Families who participate in this part of the study will be required to drive to the imaging center in Salt Lake City and will be compensated additionally for participation and travel.

Four adolescents will be invited to sleep in a research lab for one night. The athletes will be accompanied by one of their parents. During this time we will measure your child's brain activity and other activities while you are sleeping. We will do this by using small sensors that stick to your child's head and body with glue. Your child will be able to remove this glue when you shower.

3. **POTENTIAL RISKS AND DISCOMFORTS**

Questionnaires

Your child may feel uncomfortable or embarrassed answering some of the questions we ask them. They will be informed that their responses will be kept confidential, and that they do not have to answer a question they are uncomfortable with.

Actigraph Watch

It may take time for your child to get used to wearing the actigraph watch each night. In our experience, most individuals get used to it very quickly and we haven't had any complaints in the past.

fMRI

Your child may feel uncomfortable while engaged in the MRI scanner. The scanner does make loud noises and the space can feel small to some. However, the uncomfortable feeling will only be temporary and should subside quickly after completion of the scan. In the rare instance that your child expresses discomfort or stress, s/he will be reminded of the ability to discontinue the study at any time without penalty. Additionally, while in the scanner, your child will have a squeeze-ball at all times that s/he may use if they experience any anxiety. If s/he squeezes the ball, the scanning will immediately stop. This is in line with safety protocols at UCAIR.

Undisclosed bits of ferrous metal in the body may cause injury or discomfort. If your child reports any discomfort, the research assistant will immediately stop the scan. In addition to metal, the small space in the MRI machine would likely make someone with claustrophobia feel uncomfortable. Research assistants will make every effort to address this concern before your child is even scheduled for the MRI session. If however, your child expresses distress while in the scanner, the research assistant will stop the scan or your child can stop the scan by squeezing a squeeze-all that will be provided for the duration of the scan.

EEG

While sleeping in the sleep lab, there is a small chance that your child may develop an allergic reaction or slight skin irritation from the adhesive used to paste the sensors to your child's body. To minimize this risk, your child will be monitored for any allergic reaction to the adhesive and receive topical ointment for any skin irritation that occurs.

The research procedures may involve risks that are currently unforeseeable.

4. **ANTICIPATED BENEFITS TO SUBJECTS**

There are no direct benefits for you and your child. You and your child may know more about your child's sleep habits and cognitive processes.

You and your child have the right to refuse participation in this research study.

5. **ANTICIPATED BENEFITS TO SOCIETY**

The research your child participates in will add to our understanding of the effects of concussion in young athletes, a topic that has not been well researched. This knowledge may be helpful in improving and creating treatment and prevention efforts.

6. **PAYMENT FOR PARTICIPATION**

You and your child will be given $35 in cash per session for participating in this study. You will also be entered into a drawing for a tablet computer at the conclusion of the study. Families who participate in fMRI scanning at the University of Utah Center for Advanced Imaging Research or in the sleep lab EEG data collection will be compensated an additional $80 in cash for each task.

7. **FINANCIAL OBLIGATIONS**

Not applicable

8. **PRIVACY AND CONFIDENTIALITY**

The only people who will know that your child is a research subject are members of the research team. No information about them, or provided by them during the research, will be disclosed to others without your written permission, except (a) if necessary to protect our rights or welfare (for example, if you are injured), or (b) if required by law.

When the results of the research are published or discussed in conferences, no information will be included that would reveal their identity.

9. **PARTICIPATION AND WITHDRAWAL**

Your decision to enroll your child in this research is VOLUNTARY. If you choose not to enroll your child, it will not affect your relationship with Idaho State University, or your right to receive services at Idaho State University to which you are otherwise entitled. If you decide to enroll your child, you are free to withdraw your consent and discontinue participation at any time without prejudice to your future at Idaho State University. Your child will be asked to provide their assent and may also discontinue participation at any time.

10. **IDENTIFICATION OF INVESTIGATORS**

In the event of a research related injury or if you experience an adverse reaction, please immediately contact one of the investigators listed below. If you have any questions about the research, please feel free to contact

Maria M. Wong, Ph.D.	(208) 282-2752	wongmari@isu.edu
Caroline Faure, Ph.D.	(208) 282-4085	faurcaro@isu.edu
Tina Miyake, Ph.D.	(208)-282-2462	miyatin2@isu.edu
Kandi Turley-Ames, Ph.D.	(208) 282-3890	turlkand@isu.edu

11. **RIGHTS OF RESEARCH SUBJECTS**

You may withdraw your consent for your child to participate in this study at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your child's participation in this research study. If you have any questions regarding your rights as a research subject, you may contact the Human Subjects Committee office at 282- 3811 or by writing to the Human Subjects Committee at Idaho State University, Campus Box 8056.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

I have read (or someone has read to me) the information provided above. I have been given an opportunity to ask questions, and all of my questions have been answered to my satisfaction. I have been given a copy of the informed consent form.

BY SIGNING THIS FORM, I WILLINGLY AGREE TO ALLOW MY CHILD TO PARTICIPATE IN THE RESEARCH IT DESCRIBES.

____

Child Name

____

Parent Name

____

Signature of Parent

Appendix B

Youth Assent Form (Ages 13-17) Child Assent Form (Ages 7-12)

Study of Sleep Habits in Young Athletes

1. I am working with Dr. Maria Wong, Dr. Caroline Faure, Dr. Tina Miyake, and Dr. Kandi Turley-Ames.

2. We are asking you to take part in a research study because we are trying to learn more about sleep habits in young athletes. We also want to know if getting a concussion during a game changes a teenager's sleep habits.

3. If you agree to be in this study, we'll start today by having you answer some questions for us .We will also ask you to do a few activities on the computer. After that, we'll give you a special watch called an actigraph that we'll ask you to wear for the next seven nights, starting half an hour before you go to bed and ending half an hour after you wake up. We'll also give you a sleep diary, and ask you to keep track of when you go to bed, when you get up and how tired or alert you feel during the day.

Later in the study, we will ask you to come back another time to answer questions, do activities on the computer, and wear the actigraph watch again. If you happen to get a concussion during one of your gams, we will ask you to come answer questions, do activities on the computer, and wear the actigraph watch one more time.

We will be asking a few of the young athletes in our study to take part in an MRI scan in Salt Lake City. If you are one of those athletes, this means you would travel to Salt Lake City with your parent and spend about 1 hour in an MRI scanner. Before going into the machine, a research assistant will show you the scanning machine, explain the entire scanning process to you, and tell you what it will be like to actually be in a scanner including descriptions of the movements and noises. The MRI scanner is a machine that shows us what your brain is doing while you do some tasks. The MRI machine is a big tube surrounded by a large magnet. To enter the scanner, you will be asked to lie down on a bed. Once the research assistant has made sure that you are ready and comfortable, he or she will slowly move the bed into the magnet. The space in the scanner is small, but research assistants will help you feel as comfortable as possible while you are in the scanner. You will be given pillows to go under your feet or knees and a blanket to keep you warm if the room feels cold. While you are in the scanner, a research assistant will talk to you the entire time. You will hear the machine make some noises when it scans, and research assistants will tell you about these noises so that you do not feel surprised by them while you are in the scanner. You will also have a squeeze-ball in your hand during the entire scan. At any point in which you are uncomfortable and do not wish to continue, you may squeeze the ball and that will stop the scan and you will be removed from the scanner.

We will also be asking a few athletes to sleep in a research lab. The athletes will be with one of their parents in the sleep lab for one night. During this time we will measure your brain activity and other activity while you are sleeping. We will do this by using small sensors that stick to your head and body with glue. You will be able to remove this glue when you shower.

4. The risks for participating in this study are really small. We might ask you some questions that you are embarrassed to answer, but you don't have to answer and your teacher, coach, parents, and friends will not see your answers. The actigraph can take some time to get used to wearing, but in the past most people we've asked to wear them get used to it quickly.

5. You may feel uncomfortable when you are in the MRI scanner. However, this will only last a little while and should go away quickly after the scans are over. If you feel really uncomfortable, you will be reminded that you can stop participating in the study at any time without penalty. You will also have a squeeze-ball at all times when you are in the scanner so that you can squeeze it and stop the scan if you feel really uncomfortable.

6. In the sleep lab, you may feel uncomfortable with the sensors on the skin. Please tell us if they do. We will give you a lotion to remove the sensors.

7. For participating in each session of this study, you and your parent will receive $35 for each part that you complete. If you are one of the athletes we ask to have an MRI scan or sleep in the research lab, you and your parent will receive $80 for each task. You'll also be entered into a drawing to win a tablet computer after the study is over.

8. Your participation in this study will help us to learn more about the sleep habits in adolescent athletes, and about the immediate effects of concussions on athletes. From that information, we might be able to come up with new and better ways to help athletes who get a concussion.

9. We have already received permission from your parent(s) for you to participate in this research. Even though your parent(s) have given permission, you still can decide for yourself if you want to participate.

10. If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you and no one will be upset if you don't want to participate or even if you change your mind later and want to stop.

11. You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can ask me later.

12. Signing your name at the bottom means that you agree to be in the study. You and your parents will be given a copy of this form after you have signed it.

____
Name of Subject

____ ______________
Signature of Subject Date

____ ______________
Signature of Witness (if appropriate) Date

Appendix C

ID Number ________ **Daily Sleep Diary** Date of Day 1 ________________

Complete the diary each evening and morning

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Time out of bed		__:__	__:__	__:__	__:__	__:__	__:__	__:__
How tired were you in the morning?		① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired
Nap?	__:__ to __:__	__:__ to __:__	__:__ to __:__	__:__ to __:__	__:__ to __:__	__:__ to __:__	__:__ to __:__	__:__ to __:__
	Night 1	**Night 2**	**Night 3**	**Night 4**	**Night 5**	**Night 6**	**Night 7**	
Lights out time	__:__	__:__	__:__	__:__	__:__	__:__	__:__	
# of times awake at night?								
How long were you awake?								
How well did you sleep?	① Very Bad ② Bad ③ OK ④ Good ⑤ Very Good	① Very Bad ② Bad ③ OK ④ Good ⑤ Very Good	① Very Bad ② Bad ③ OK ④ Good ⑤ Very Good	① Very Bad ② Bad ③ OK ④ Good ⑤ Very Good	① Very Bad ② Bad ③ OK ④ Good ⑤ Very Good	① Very Bad ② Bad ③ OK ④ Good ⑤ Very Good	① Very Bad ② Bad ③ OK ④ Good ⑤ Very Good	
How long did it take you to fall asleep after lights out?	① 0 – 5 min. ② 6 – 20 min. ③ 21 – 30 min. ④ 31 min. +	① 0 – 5 min. ② 6 – 20 min. ③ 21 – 30 min. ④ 31 min. +	① 0 – 5 min. ② 6 – 20 min. ③ 21 – 30 min. ④ 31 min. +	① 0 – 5 min. ② 6 – 20 min. ③ 21 – 30 min. ④ 31 min. +	① 0 – 5 min. ② 6 – 20 min. ③ 21 – 30 min. ④ 31 min. +	① 0 – 5 min. ② 6 – 20 min. ③ 21 – 30 min. ④ 31 min. +	① 0 – 5 min. ② 6 – 20 min. ③ 21 – 30 min. ④ 31 min. +	
How tired were you at night?	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	① Very Alert ② Alert ③ Tired ④ Very Tired	

Appendix D

DERS

1 Almost Never (0-10 %)	2 Sometimes (11-35 %)	3 About half the time (36-65 %)	4 Most of the time (66-90 %)	5 Almost always (91-100 %)

Please indicate how often the following 36 statements apply to you by writing the appropriate number from the scale above (1 – 5) in the box next to each item.

1. I am clear about my feelings	
2. I pay attention to how I feel	
3. I experience my emotions as overwhelming and out of control	
4. I have no idea how I am feeling	
5. I have difficulty making sense out of my feelings	
6. I am attentive to my feelings	
7. I know exactly how I am feeling	
8. I care about what I am feeling	
9. I am confused about how I feel	
10. When I'm upset, I acknowledge my emotions	
11. When I'm upset, I become angry with myself for feeling that way	
12. When I'm upset, I become embarrassed for feeling that way	
13. When I'm upset, I have difficulty getting work done	
14. When I'm upset, I become out of control	
15. When I'm upset, I believe that I will remain that way for a long time	
16. When I'm upset, I believe that I will end up feeling very depressed	
17. When I'm upset, I believe that my feelings are valid and important	
18. When I'm upset, I have difficulty focusing on other things	

19. When I'm upset, I feel out of control	
20. When I'm upset, I can still get things done	
21. When I'm upset, I feel ashamed at myself for feeling that way	
22. When I'm upset, I know that I can find a way to eventually feel better	
23. When I'm upset, I feel like I am weak	
24. When I'm upset, I feel like I can remain in control of my behaviors	
25. When I'm upset, I feel guilty for feeling that way	
26. When I'm upset, I have difficulty concentrating	
27. When I'm upset, I have difficulty controlling my behaviors	
28. When I'm upset, I believe there is nothing I can do to make myself feel better	
29. When I'm upset, I become irritated at myself for feeling that way	
30. When I'm upset, I start to feel very bad about myself	
31. When I'm upset, I believe that wallowing in it is all I can do	
32. When I'm upset, I lose control over my behavior	
33. When I'm upset, I have difficulty thinking about anything else	
34. When I'm upset, I take time to figure out what I'm really feeling	
35. When I'm upset, it takes me a long time to feel better	
36. When I'm upset, my emotions feel overwhelming	

1 **Almost Never** **(0-10 %)**	**2** **Sometimes** **(11-35 %)**	**3** **About half the time** **(36-65 %)**	**4** **Most of the time** **(66-90 %)**	**5** **Almost always** **(91-100 %)**

Appendix E

Demographic Questionnaire

Today's Date: ________________

Sex: _______ Male _______ Female

Age: _______ Grade: ____________ Date of Birth: ______________

What is your height? _______ feet _______ inches

What is your weight? _______ pounds

What best describes your racial/ethnic background? Circle one response that best applies to you:

a. African- American

b. Hispanic

c. Native-American

d. White

e. Asian & Asian-American

f. Others, please specify : _______________________

What is your father's job? ___________________________

Does your father work outside the home?

_____ Yes

_____ No

Indicate your father's highest level of education below –

____________ no formal education

____________ elementary school

____________ high school

____________ associate degree

____________ college degree (Bachelor)

____________ postgraduate degree (e.g., Master, Ph.D.)

What is your mother's job? ____________________________

Does your mother work outside the home?

_____ Yes

_____ No

Indicate your mother's highest level of education below –

____________ no formal education

____________ elementary school

____________ high school

____________ associate degree

____________ college degree (Bachelor)

____________ postgraduate degree (e.g., Master, Ph.D.)

Are your grades in school mostly?

_______ A's	_______ C's
_______ A's and B's	_______ C's and D's
_______ B's	_______ D's
_______ B's and C's	_______ D's and F's

When compared to your classmate's how well do you do in the following subjects?

Math

_______ Failing _______ Below Average _______ Average ________ Above Average

What was your grade in math last semester? _______

Science

_______ Failing _______ Below Average _______ Average ________ Above Average

What was your grade in science last semester? _______

Reading, English, or Language Arts

_______ Failing _______ Below Average _______ Average ________ Above Average

What was your grade in reading/english/language arts last semester? _______

History or Social Studies

_______ Failing _______ Below Average _______ Average ________ Above Average

What was your grade in history or social studies last semester? _______

What is the highest grade you expect to complete?

_______ May not finish high school

_______ Will finish high school

_______ Will get a college degree

_______ Will get a degree beyond college

Compared to other people your age, would you say that your health is:

_______ Poor

_______ Fair

_______ Good

_______ Excellent

Do you have attention deficit hyperactivity disorder (ADHD) or a learning disability?

_______ Yes

_______ No

Do you take Ritalin or some other medication to help with concentration or a learning problem?

_______ Yes

_______ No

Are you color blind?

_______ Yes

_______ No