ABSTRACT

Associations Between Sleep and Memory
in a Clinical Sample of Obese Children and Adolescents

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Today more than one third of U. S. children and adolescents are classified as overweight or obese. While interventions have produced short term improvements in weight status, treatment effects are infrequently maintained. Standard interventions may not be well-suited for the cognitive profile associated with obesity, which is characterized by impaired executive functioning. The literature on memory consolidation during sleep suggests that sleep problems associated with obesity may contribute to this cognitive profile in ways that have yet to be elucidated. The present study examined the associations between sleep and multiple indices of memory in a clinical sample of 45 obese children and adolescents. Sleep was assessed from both child and parent perspectives. Memory was evaluated using the Wide Range Assessment of Memory and Learning, Second Edition (WRAML2). Multiple linear regression analyses revealed that sleep duration and sleep quality explained the most variation in visual memory abilities. The results underscore the importance of early intervention in childhood obesity and illuminate the importance of targeting sleep as a component of weight loss interventions.

Associations Between Sleep and Memory
in a Clinical Sample of Obese Children and Adolescents

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

Introduction

Childhood Obesity

The number of obese children in the United States (U.S.) has tripled over the past thirty years (Ogden, Carroll, Curtin, Lamb, & Flegal, 2010). Today the Centers for Disease Control and Prevention report that more than one third of U.S. children and adolescents are classified as overweight or obese (CDC, 2013). There are a number of adverse medical conditions associated with childhood obesity including high cholesterol and triglycerides, hypertension (Freedman, Dietz, Srinivasan, & Berenson, 1999), insulin resistance (Shaibi & Goran, 2008), type 2 diabetes (Pinhas-Hamiel & Zeitler, 1996), metabolic syndrome, polycystic ovarian syndrome, and nonalcoholic fatty liver disease (Cruz et al., 2005). Obese children are also more likely to experience psychosocial difficulties such as social stigma, anxiety, depression, suicidal thoughts, and body dissatisfaction (French, Story, & Perry, 1995; Ge, Elder, Regnerus, & Cox, 2001; Lobstein, Baur, & Uauy, 2004; Spruijt-Metz, 2011; Valente, Fujimoto, Chou, & Spruijt-Metz, 2009). Excess weight in childhood is not a transient phenomenon, but tends to persist. Children who were overweight at age 5 are four times more likely than normal-weight 5 year-olds to be obese as fourteen year-olds (Cunningham, Kramer, & Narayan, 2014). Similarly, a longitudinal study of a nationally representative U.S. sample found that 85.3% of obese adolescents continued to fall in this weight class as young adults (Gordon-Larsen, Adair, Nelson, & Popkin, 2004). Consequently, the U.S. Surgeon

General has identified obesity as a serious public health concern and emphasized the need for greater research to enhance obesity prevention and intervention (United States Department of Health & Human Services, 2001).

Interventions for Childhood Obesity

In light of children's intellectual immaturity and level of dependence on their parents with regard to activity scheduling and dietary decisions, behavioral, family-based lifestyle interventions are the mainstay for treating overweight and obese children and adolescents (Barlow & Dietz, 1998; Han, Lawlor & Kimm, 2010). These interventions incorporate self-monitoring (Lansky & Vance, 1983), nutrition education and/or diet planning (Epstein, Wing, Koeske, & Valoski, 1984), implementation of an exercise program (Aragona, Cassady, & Drabman, 1975), and family therapy and/or parental involvement in the child's weight loss efforts (Flodmark, Ohlsson, Ryden, & Sveger, 1992). Meta-analyses examining the efficacy of these types of interventions confirm significant treatment effects immediately following interventions (Goldfield, Raynor, & Epstein, 2002; Jelalian & Saelens, 1999; Wilfley, Tibbs, Van Buren, Reach, & Walker, 2007). However, over time these treatment effects are not maintained and most children experience considerable weight relapse (Braet & VanWinckel, 2001; Epstein, Valoski, Wing, & McCurley, 1990, 1994; Flodmark, Ohlsson, Ryden, & Sveger, 1993; Israel, Guile, Baker, & Silverman, 1994; National Institutes of Health, 1993). For example, Epstein and colleagues found that fewer than half of children who had participated in a behaviorally based weight loss intervention maintained a 20% decrease in proportion overweight 10 years later, with 70% still classified as obese (Epstein, Roemmich, &

Raynor, 2001). Further research is needed to identify intervention strategies that may contribute to long-term improvements in child weight status.

Biological Correlates of Cognitive Differences in Obesity

One potential challenge in achieving effective long-term improvements in weight status is that obesity may be associated with cognitive impairments for which standard interventions are not well-suited. Several biological and molecular pathways have been hypothesized to affect cognition in obese individuals. Unger, Livingston, and Moss (1991) indicated that a low-degree inflammation of blood vessels in the brain associated with obesity may impact cognitive function (Unger, Livingston, & Moss, 1991). Increases in body weight affect insulin resistance, impairing cognitive function even in adult populations without diabetes (Gonzales et al., 2010). Changes in insulin levels and insulin receptor sensitivity result in altered glucose metabolism, which may affect key processes involved with learning and memory (Doyle, Cusin, Rohner-Jeanrenaud, & Jeanrenaud, 1995; Gonzales et al., 2010). Similarly, excess adiposity has been linked with increased resistance to leptin (a protein produced by the body's adipose tissue that inhibits appetite); higher leptin levels have been hypothesized to impede brain development (Dicou, Attoub, & Gressens, 2001).

In addition to biological mechanisms, lower intellectual function (as indicated by lower intelligence quotient score) may predispose individuals for subsequent obesity (Chandola, Deary, Blane, & Batty, 2006; Li, 1995; Yu, Han, Cao, & Guo, 2010). Intellectual deficits increase risk for problems with self-esteem, psychosocial functioning, and academic achievement—stressors that may increase risk for weight gain. Compared to their average weight counterparts, obese adolescent girls are more likely to report being held back in a grade in school, obese adolescent boys were more likely to expect to quit school, and obese children of both sexes were more likely to describe themselves as poor students (Falkner et al., 2001). Furthermore, higher IQ is associated with life experiences that may reduce the risk for developing obesity, including greater educational achievement in early adulthood and attainment of higher paying occupations in adulthood (Chandola et al., 2006). It is important to note that the association between intellectual function and obesity is likely bidirectional, with relatively low intelligence contributing to behaviors and lifestyle habits that increase weight gain, which in turn adversely affects neurocognition.

Cognitive Profile Associated with Obesity: Executive Functioning

To date, relatively few studies have investigated extensive neuropsychological profiles of obese children and adolescents. However, researchers utilizing brief cognitive batteries with obese youth consistently report deficits in the area of executive function (Smith, Hay, Campbell, & Troller, 2011). Executive function is the set of cognitive abilities necessary for planning, organizing and carrying out goal-directed behavior (Zelazo, Carter, Riznick, & Frye, 1997). Components of executive function include self-monitoring and self-regulating behaviors, strategizing, allocating attention across multiple stimuli, manipulating information held in conscious awareness, initiating and stopping actions, adjusting behavior based on predicted outcomes, as well as abstract thought (Chan, Shum, Toulopoulou, & Chen, 2008). As such, executive function is also involved in the cognitive control of eating, dieting and exercise behavior, and therefore has important implications for the maintenance of improvements in weight status. Specifically, researchers studying overweight and obese children have identified impairments in such executive abilities as cognitive flexibility, focused attention, sustained attention, response inhibition, and decision making (Cserje'si, Molnar, Luminet, & Leonard, 2007; Mond, Stich, Hay, Kraemer, & Baune, 2007; Verdejo-Garcia et al., 2010). Experimental evidence indicated overweight and obese adults make poorer decisions on a computerized gambling task, suggesting a link between overweight status and hypersensitivity to immediate rewards, and/or hyposensitivity to secondary punishment (Davis, Levitan, Muglia, Bewell, & Kennedy, 2006). Individuals with lower executive functioning abilities may be less able to interpret and respond appropriately to health-related information, as the ability to implement and maintain healthy eating and exercise habits depends upon intact cognitive function in the areas of impulse control, self-monitoring, and goal-directed behavior (Lezak, Howieson, & Loring, 2004). It appears both that the primary functional brain deficits associated with executive dysfunction lead to disinhibited eating and subsequent obesity, and that obesity and associated insulin resistance cause executive dysfunction (Maayan, Hoogendoorn, Sweat, & Convit, 2011; Smith, Hay, Campbell, & Trollor, 2011). There is preliminary evidence that increased physical activity may mitigate these effects, as it has been associated with improved executive functioning among overweight children ages 7-11 (Davis et al., 2011).

Memory

Memory may also be critical to the long-term success of weight loss interventions. Memory is the process by which information is encoded, stored, and retrieved. Intact *explicit memory*, or memory for consciously, intentionally recalled experiences and information, enhances an individual's ability to benefit from cognitive-behavioral interventions (Wild & Gur, 2008). Factor analytic studies indicate that memory is comprised of several independent components (e.g., Schneider & Bjorklund, 1998). To date, the majority of studies assessing memory in obese populations have been conducted with adults. Overall, obese adults demonstrate significant weaknesses in short-term explicit memory for verbal information, as well as short- and long-term explicit memory for nonverbal information (Boeka & Lokken, 2008; Cournot et al., 2006; Dore, Elias, Robbins, Budge, & Elias, 2008; Gunstad, Paul, Cohen, Tate, & Gordon, 2006; Gunstad et al., 2007; Sabia, Kivimaki, Shipley, Marmot, & Singh-Manoux, 2009). Obese adults exhibit weakness in such short-term memory tasks as digit span recall (Boeka & Lokken, 2008; Gunstad et al., 2007) and recall of the contextually related elements of a story (Dore et al., 2008). Performance is also impaired on an explicit verbal memory task requiring subjects to remember a list of words (Boeka & Lokken, 2008; Cournot et al., 2006; Gunstad et al., 2006; Sabia et al., 2009). Moreover, some, but not all studies of the effects of weight loss on cognitive function have reported that weight loss significantly improves verbal memory performance in obese adults with the magnitude of the effect significantly associated with baseline BMI (Gunstad et al., 2011; Smith et al., 2010; Witte, Fobker, Gellner, Knecht, & Floel, 2009).

Deficits in nonverbal explicit memory have also been reported among obese adults (Boeka & Lokken, 2008; Gunstad et al., 2007; Wolf et al., 2007). *Nonverbal* memory tasks test retention and retrieval of visual or spatial information. Memory for the visuospatial location of objects relative to one another depends upon intact functioning of a dorsal stream of brain regions, including the parietal cortex (Ungerleider & Mishkin, 1982). Obese adults have significant impairment in tasks requiring them to draw figures they have just seen, including the Rey Complex Figure Task (RCFT) (Boeka & Lokken, 2008; Rey, 1941), Benton Visual Retention Test (Benton-Sivan, 1992; Gunstad, Lhotsky, Wendell, Ferrucci, & Zonderman, 2010;), and other line drawings (Wolf et al., 2007). Researchers observed impairments in both the short-term and long-term memory components of these tasks (i.e., figure reproduction that immediately followed presentation of the figure, as well as after delays of three minutes and thirty minutes following presentation of the figure, respectively; Boeka & Lokken, 2008; Wolf et al., 2007). In a visual memory span task that was less dependent on executive functioning, Gunstad and colleagues (2007) identified significant impairment in this task among obese adults relative to normal-weight peers. Studies reporting associations between obesity and impaired nonverbal memory are consistent with animal models demonstrating that obese mice maintained on a high fat diet demonstrate impaired memory for hippocampus-dependent spatial memory (Heyward et al., 2012). Thus, obesity is associated with impairments in short-term and long-term nonverbal memory abilities in adults.

To date, studies of the memory abilities of obese children and adolescents have been relatively limited. Of nine cross-sectional studies investigating cognitive abilities of obese children, only three examined memory specifically (Cserje'si et al., 2007; Gunstad et al., 2008; Lokken, Boeka, Austin, Gunstad, & Harmon, 2009). Further, two of these examined memory using a single subtest of digit recall, and reported inconsistent findings (Cserje'si et al., 2007; Lokken et al., 2009): while Cserje'si and colleagues (2007) found no differences in digit span between 12 obese boys and 12 normal weight peers (Cserje'si et al., 2007), Lokken and colleagues (2009) identified a significant deficit in digit recall in their clinical sample of 25 extremely obese adolescents. The use of a single subtest to measure memory constitutes a major limitation of the current studies assessing memory in obese children and adolescents (Schneider & Bjorklund, 1998). Gunstad and colleagues (2008) used a more comprehensive memory battery including assessment of verbal memory, working memory, and long-term memory in 478 children and adolescents without significant medical history, and observed no significant differences in memory abilities across BMI quartiles.

Sleep and Memory

Recent research has demonstrated the importance of sleep in intentional memory processes (Stickgold & Walker, 2005). In particular, sleep assists in the consolidation of learned material, which consists of stabilization, transformation, or enhancement of the encoded memory trace in order to protect the information from decay or retroactive interference with other content (Born, Rasch, & Gais, 2006). Sleep can also enhance memories, integrate them with existing memories, and modify memories in ways that facilitate creative insights (Stickgold & Walker, 2013). Sleep after learning improves performance on word recognition and word pair association tasks in adults (in the absence of circadian rhythm confounds or differences in fatigue at the time of testing) and also enhances nondeclarative (procedural) learning (see Stickgold, 2005 for a review). However, sleep in childhood is distinctly different from sleep in adulthood; children spend a relatively greater percentage of sleep time in slow wave sleep than adults (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). Slow wave sleep has been implicated in the consolidation of hippocampus-dependent declarative memories (Buzsaki, 1998; Gais & Born, 2004; Wilhelm, Prehn-Kristensen, & Born, 2012; Wilhelm et al., 2013). Specifically, the slowly oscillating change in field potential dominating slow wave sleep has been hypothesized to play a role in the transfer of memories from the short-term store (in the hippocampus) to long-term store (in the neocortex) (Born, Rasch, & Gais, 2006). The relatively greater percentage of time children spend in slow wave sleep, relative to adults, may account for youths' stronger ability to store and retrieve declarative memories (Wilhelm et al., 2013).

Studies of sleep restriction among normal weight youth have revealed somewhat inconsistent findings, with some reporting adverse effects on memory (Carskadon, Harvey, & Dement, 1981; Sadeh, Gruber, & Raviv, 2002), and others finding no effect (Carskadon, Harvey, & Dement, 1981; Randazzo, Muehlbach, Schweitzer, & Walsh, 1998; Vriend et al., 2012). An experimental manipulation that delayed bedtime by one hour for four nights identified adverse effects on short-term memory, working memory, and aspects of attention (Vriend et al., 2013). One possible explanation for equivocal findings is that developmental factors may mediate the effects of sleep restriction on memory: adolescents appear to compensate for sleep debt by flexibly increasing the depth of their sleep, for example (Voderholzer et al., 2011).

Short Sleep Duration and Obesity

The rise in prevalence and severity of childhood obesity has corresponded with findings that children and adolescents today are sleeping for shorter durations than ever before (Iglowstein, Jenni, Molinari, & Largo, 2003). A recent study indicated that 8-12 year-old children slept for an average of 8.85 hours per night, one hour less than the recommended number of hours (Vriend et al., 2012). Several studies have reported that obesity increases risk for shorter nightly sleep duration, even after controlling for potential confounding variables (Beebe et al., 2007; Chaput, Brunet, & Tremblay, 2006; Gangwisch et al., 2010; Gupta, Mueller, Chan, & Meininger, 2002; Knutson, 2005; Sekine et al., 2002). A recent meta-analysis of studies reporting associations between obesity and short sleep duration found that children who slept for fewer than 8 hours per night were 58% more likely to be obese than their peers (Chen, Beydoun, & Wang, 2008). There is a stronger association between short sleep duration and obesity in children compared to adults, which suggests children may be more vulnerable to the weight gain-related effects of reduced sleep (Danielsen, Pallesen, Stormark, Nordhus, & Bjorvatn, 2010; Nielsen, Danielsen, & Sorenson, 2010). Studies also suggest that the relationship between short sleep duration and weight may be more powerful for boys than for girls (Chaput et al., 2006; Mamun et al., 2007; Sekine et al., 2002). While the persistence of sleep habits over time precludes inference of a causative relationship between short sleep duration and overweight status (Hasler et al., 2004), a recent cross-over design study reported that teens who were restricted to 6.5 hours in bed per night chose diets that were higher in glycemic index and glycemic load, and tended to consume more calories and carbohydrates (Beebe et al., 2013). Inadequate sleep—like obesity—is also more common among individuals of lower SES (Gellis et al., 2005; Grandner et al., 2010; Patel, Grandner, Xie, Branas, & Gooneratne, 2010) and racial minority populations (Hale & Do, 2007; Mezick et al., 2008; Patel et al., 2010).

Behavioral factors driving the association between short sleep duration and weight gain remain to be elucidated. While Gupta proposed that inadequate sleep might result in weight gain over time by increasing children's level of daytime fatigue and reducing their daytime energy expenditure (Gupta et al., 2001), others found a significant relationship between short sleep duration and BMI even after controlling for television viewing time (a proxy for sedentary time) (Agras, Hammer, McNicholas, & Kraemer, 2004; Chaput et al., 2006; Locard et al., 1992; Reilly et al., 2005; Sekine et al., 2002). Not only do individuals who are awake longer have more eating opportunities, but they are more likely to choose energy-rich foods due to hormonal changes associated with shorter sleep (Knutson & Van Cauter, 2008; Landgren et al., 2011).

Biological Mechanisms for Relationship Between Short Sleep Duration and Obesity

Biological mechanisms linking short sleep duration to increased BMI are not currently well-understood. While some researchers have found that short sleep duration is associated with higher levels of ghrelin—a hormone that stimulates feeding behavior, and lower levels of leptin—a hormone that reduces feeding behavior (Chaput, Després, Bouchard, & Tremblay, 2007; Spiegel, Leproult, Tasali, Penev, & Van Cauter, 2003), others have not replicated this association (Bunt et al., 2003; Folsom et al., 1999). There is some evidence that short sleep duration reduces parasympathetic nervous system activity, disrupting hormonal signaling pathways regulating growth hormone (Van Cauter, 1992) and cortisol (Leproult, Copinschi, Buxton, & Van Cauter, 1997). Some, but not all researchers found that sleep deprivation causes cortisol levels to remain high in the evening instead of dropping, which can reduce insulin sensitivity the following morning (Van Cauter, Polonsky, & Sheen, 1997). Increased sympathetic activity may reduce insulin secretion from beta pancreatic cells (Spiegel, Tasali, Penev, & van Cauter, 2004; Spiegel, Leproult, & Van Cauter, 1999). Sleep deprivation induces shorter, more frequent pulses of growth hormone, which may cause transient insulin resistance in muscle cells (Spiegel, Knutson, Leproult, Tasali, & Van Cauter, 2005). As insulin has the effect of inhibiting appetite and feeding behavior, lower sensitivity, lower levels, and resistance to insulin have been associated with increased caloric consumption (Reaven, 1988). In addition, reduced sleep may decrease brain glucose utilization, promoting reduced glucose tolerance (Thomas et al., 2000). Shorter sleep duration may produce dietary cravings (Spiegel et al., 2004) and has been associated with decreased physiologic sensitivity to satiety cues (Knutson & Van Cauter, 2008). Moreover, by adversely affecting attention, impulse control, and problem solving, shorter sleep duration increases the likelihood of making poor dietary choices (Durmer & Dinges, 2005).

Sleep Disordered Breathing

About 30% of school-age children experience sleep problems (Liu, Liu, Owens, & Kaplan, 2005), ranging from medical conditions including obstructive sleep apnea, restless leg syndrome, and parasomnias to behavioral sleep problems such as inadequate sleep hygiene, behavioral insomnia, nightmares and nighttime fears, delayed sleep phase syndrome, and psychophysiological insomnia (Moore, 2012). One serious medical condition, obstructive sleep apnea syndrome (OSAS), is four times more common in obese children than among healthy-weight peers (Redline et al., 1999). OSAS is the most common form of sleep apnea, and is characterized by collapse of the airway between the epiglottis and the soft palate during sleep (American Academy of Sleep Medicine, 2001). Obstruction of this airway causes partial (hypopnea) and/or complete (apnea) cessation of breathing. According to Lavie and Lavie (2009), oxygen levels in the brain are reduced as blood oxygen saturation declines (hypoxia is defined by 90% and lower levels of oxyhemoglobin desaturation), producing oxidative stress and inflammation (Lavie & Lavie, 2009). The diaphragm and chest muscles work to open the obstructed airway, and breathing typically resumes with a loud gasp, snort, or body jerk that can interfere with normal sleep architecture. Obstructive sleep apnea is diagnosed in both adults and children when polysomnography indicates five or more apneic, hypopneic, or respiratory effort-related arousal (RERA) events per hour. Diagnostic criteria are the same for children as for adults, though Rosen and colleagues argued that adult criteria may not be sufficiently sensitive to detect clinically significant sleep problems in children (Rosen, D'Andrea, & Haddad, 1992). Up to 45% of obese children with OSAS have adenotonsillar hypertrophy (enlargement of the tonsils and/or adenoids due to an acute or chronic increase in immunologic activity; Gordon et al., 2006), yet OSAS persists in around half of these children even after adenotonsillectomy (Mitchell & Kelly, 2004). This finding suggests that other anatomic or functional factors also contribute to the condition, such as alterations in neuromotor tone and tissue properties increasing airway collapsibility, and/or reduced functional residual capacity due to abdominal visceral fat weighting the chest wall (Arens & Muzumdar, 2009). Not only does obesity increase risk for obstructive sleep apnea in both children and adults, it may also exacerbate the condition by increasing time spent in nocturnal hypoxia, independent of apnea severity (Gabbay, Gabbay, & Lavie, 2012).

The hypoxia that results from OSAS has a number of neurocognitive implications. Children with OSAS commonly present with inattention, relatively poor academic performance, lower IQ, episodes of hyperactivity, daytime sleepiness, and developmental delay (Ali, Pitson, & Stradling, 1996). Parents of those youth with untreated OSAS report more daytime sleepiness and sleep duration problems than children who are compliant with continuous positive airway pressure (CPAP) treatment for their OSAS

(Simon & Duncan, 2012). These deficits have not been consistently found to correspond with OSAS severity as indicated by polysomnography (Archbold, Giordani, Ruzicka, & Chervin, 2004; Owens, Spirito, Marcotte, McGuinn, & Berkelhammer, 2000). Rhodes and colleagues (1995) found that five morbidly obese children and adolescents with obstructive sleep apnea scored significantly lower than nine morbidly obese children without the sleep disorder on all indices of the Wide Range Assessment of Memory and Learning (WRAML) and the Vocabulary subtest of the WISC-III (Rhodes et al., 1995). Hannon and colleagues found that obese adolescents with higher apnea-hypopnea index (number of obstructive apneas, plus hypopneas per hour of sleep) earned lower math calculation scores on the Wide Range Achievement Test (WRAT) (2012). Weight loss can result in reduced severity of sleep apnea in obese individuals (Strollo & Rogers, 1996). Improvements also result from nasal CPAP, tonsillectomy and/or adenoidectomy, and pharmacologic aids for chronic nasal congestion (Meltzer & Mindell, 2006). Importantly, successful treatment of sleep apnea can improve neuropsychological functioning (Ali et al., 1996). For example, one sample of eight children demonstrated significant improvements in verbal fluency, attention, and fine motor speed (finger tapping) eight weeks following adenotonsillectomy (Owens et al., 2000). Treatment for OSAS has also been associated with significant improvement in grades earned by elementary school-aged children (Gozal, 1998).

Primary snoring is a form of sleep disordered breathing (SDB) that results from collapse of the airway between the epiglottis and the soft palate (Horner et al., 1989). Obesity increases risk for primary snoring through its association with fat deposits in the neck and around the throat, which change the shape of the airway in such a way as to increase vibrations of airway tissues (Horner et al., 1989). Sleep disordered breathing is also more common among smokers and children of smokers, as well as in children of African and Asian descent (due to differences in craniofacial morphology; Morton et al., 2003; Redline et al., 1997, 1999). Primary snoring is more common than sleep apnea, occurring in 10-12% of young children, but decreases in prevalence as children age. While the American Academy of Pediatrics has suggested that this condition may be considered benign, many cognitive deficits and behavioral problems are linked to snoring in children. Parents of children (ages 5-7 years) who snore reported significantly more problems with attention, social skills, and anxiety/depression on the Conners and Child Behavior Checklist (CBCL) in their children (Blunden, Lushington, Lorenzen, Martin, & Kennedy, 2005; O'Brien et al., 2004; Achenbach & Rescorla, 2001). In an older sample of obese children and adolescents ages 6-17, those with primary snoring were more likely to experience depressive symptomology than non-snorers (Kralovic et al., 2012). While some researchers have identified significant differences in general intelligence among children with primary snoring (Blunden et al., 2005; Bourke et al., 2011; Kennedy et al., 2004; O'Brien et al., 2004), others have failed to detect such a difference (Emancipator et al., 2006; Kaemingk et al., 2003; Mulvaney et al., 2006). Similarly, while some researchers have not found significant differences in academic performance (Bourke et al., 2011), others have reported a link between sleep disordered breathing and poorer grades in school (Beebe et al., 2007; Gozal & Pope, 2001). Multiple studies noted significantly poorer memory abilities among children with sleep disordered breathing (Eszter, Pálma, Karolina, Gábor, & Dezso, 2013; Gottlieb et al., 2004; Kaemingk et al., 2003), but see Archbold and colleagues (2004) for an exception.

Other Sleep-Related Concerns, Cognitive and Memory Correlates

Behavioral sleep problems frequently seen in school-aged children include nightmares and nighttime fears, delayed sleep phase syndrome, and psychophysiological or primary insomnia. The most common sleep issues experienced by children and adolescents are behavioral in nature (Moore, 2012); however, up to 80% of sleep problems are neither reported to nor treated by primary healthcare providers (Blunden et al., 2003). Parents of overweight children report more parasomnias, abnormal movements and behaviors that occur during partial arousals from sleep, than parents of normal-weight children (Beebe et al., 2007). They are also more likely to report that their children are sleepy during the day, a finding that may suggest poorer nighttime sleep (Beebe et al., 2007). Daytime sleepiness has been linked to reduced physical activity in children, a behavior with clear implications for weight management (Steele, Richardson, Daratha, & Bindler, 2012). Behaviorally based sleep problems are nonhypoxic, yet are associated with attention problems and hyperactivity, implicating the involvement of other sleep-related processes (Blunden, Lushington, Lorenzen, Martin, & Kennedy, 2005). Behavioral sleep problems induce clinically significant changes on daytime behavior and cognition. They have also been implicated in memory function: Blunden et al. (2005) reported that behavioral sleep problems occurring in the absence of snoring were associated with increased problem behaviors and impaired nonverbal memory relative to controls (Blunden et al., 2005). Steenari and colleagues reported that children with longer sleep latency and lower sleep efficiency had significantly poorer auditory and visual working memory regardless of memory load (2003). Sleep deprivation in children has been associated with problematic behaviors (Aronen, Paavonen, Fjallberg, Soininen,

& Torronen, 2000), impaired attention (Fallone, Acebo, Seifer, & Carskadon 2005; Sadeh, Pergamin, & Bar-Haim, 2006), internalizing problems (Forbes et al., 2008; Gangwisch et al., 2010), hyperactivity (Touchette et al., 2009), and poorer academic functioning (Perkinson-Gloor, Lemola, & Grob, 2013; Dewald, Meijer, Oort, Kerkhof, & Bogels, 2010; Wolfson & Carskadon, 2003).

Sleep problems can result from poor sleep hygiene, in addition to the behavioral and environmental factors that precede and may affect sleep onset as well as sleep quality. One component of sleep hygiene involves avoiding use of technology such as cell phones, computer, television and video games before bed (National Sleep Foundation, 2004); these adversely impact sleep (Calamaro, Mason, & Ratcliffe, 2009; Dworak, Schierl, Bruns, & Strüder, 2007; Li et al., 2007). Amount of screen time is positively correlated with both daytime sleepiness (Steele, Richardson, Daratha, & Bindler, 2012) and negatively correlated with sleep duration (Johnson, Cohen, Kasen, First, & Brook, 2004). Consumption of caffeine also disrupts sleep (Pollak & Bright, 2003). Pollak and Bright (2003) found that greater consumption of caffeine was associated with shorter sleep duration, increased wake time after sleep onset, and increased napping during the day among seventh, eighth, and ninth graders (Pollak & Bright, 2003).

Purpose of the Present Study

In this study, the associations between sleep and multiple indices of memory are examined in a clinical sample of obese children and adolescents. While previous studies have investigated the relationship between sleep and memory (e.g., Blunden et al., 2005; Buckhalt, Sheikh, & Keller, 2007; Sadeh et al., 2002; Steenari et al., 2003), obesity and memory (Cserje'si et al., 2007; Gunstad et al., 2008; Lokken et al., 2009), and obesity and sleep (e.g., Beebe et al., 2007; Calhoun et al., 2011; Chaput et al., 2006; Gupta et al., 2002) in children and adolescents, no study to date has assessed the relative association between sleep and memory in a clinical sample of obese children and adolescents. Furthermore, existing studies that did report on the memory abilities of obese children generally tested only one component of memory using a brief battery (e.g., one subtest). A secondary purpose of the present study was to compare parent and child perspectives of the child's sleep duration and quality.

Hypotheses

In light of existing research highlighted herein, the following research questions and associated hypotheses guided the present study:

I. Primary research question: What are the associations between short term verbal memory, short term visual memory, and attention/concentration with sleep duration and quality in obese youth after controlling for demographic variables, intelligence, and physical activity levels?

1. Parent report of sleep duration will not be associated with the Verbal Memory Index (Astill, Van der Heijden, Van Ijzendoorn, & Van Someren, 2012; Carskadon, Harvey, & Dement, 1981; Sadeh et al., 2003).
2. Child self-report and parent report of sleep quality will be associated with the Verbal Memory Index (Hannon et al., 2012; Sadeh et al., 2002).
3. Parent report of sleep duration and child self-report and parent report of sleep quality will not be associated with the Visual Memory Index (Astill et al., 2012; Randazzo, Muelbach, Schweitzer, & Walsh, 1998; Sadeh et al., 2003).

4. Parent report of sleep duration and child self-report and parent report of sleep quality will be associated with the Attention/Concentration Index (Astill et al., 2012; Randazzo et al., 1998).

II. Secondary research question: How will parent report compare with child self-report of sleep quality?

1. Parent-child agreement will be strongest for items assessing sleep latency (Owens, Maxim, Nobile, McGuinn, & Msall, 2000).

CHAPTER TWO

Method

Participants

The study sample was comprised of 45 obese children and adolescents. In total, 43 obese participants were patients seeking evaluation for weight-related concerns at the Pediatric Endocrinology Clinic at Scott & White in Temple, Texas. Two additional subjects were recruited from the Baylor Psychology Clinic via posted study flyers. Obesity was operationally defined as BMI at or above the 95^{th} percentile for children of the same age and sex, in accordance with current standards set by the CDC (2012). Participants were considered eligible for the study if they were between the ages of 6 and 16 years; if they met BMI criteria for obesity; if they were accompanied by a primary caregiver, and if both patient and caregiver were fluent in English. Exclusion criteria included neurological disorder or injury, history of moderate or severe head injury, chromosomal or genetic disorder (i.e., Prader-Willi, Down Syndrome); developmental disability, intellectual disability; history of diagnosis of cortisol excess (i.e., Cushings); past or current severe psychiatric illness (i.e., schizophrenia, bipolar disorder); and history of use of a medication known to cause weight gain (i.e., anti-psychotic). Demographic characteristics of the sample are summarized in Table 1.

Table 1
Demographic Characteristics of Study Participants

Characteristic	N or Mean	% or SD	Range
Age (years)	13.11	2.55	6.8-16.9
BMI z-score	2.35	0.28	1.58-2.95
Sex			
Male	13	28.9%	
Female	32	71.1%	
Race			
Caucasian, non-Hispanic	10	22.2%	
Hispanic	12	26.7%	
African American	12	26.7%	
Other	11	24.4%	
Parent Education			
Some high school or less	4	8.9%	
High school diploma or GED	12	26.7%	
Vocational school or some college	20	44.4%	
College degree	7	15.6%	
Intelligence Scores			
WASI FSIQ-2	99.04	15.48	56-132
WASI Vocabulary	49.4	9.46	26-67
WASI Matrix Reasoning	51.71	12.86	20-104

(continued)

Characteristic	N or Mean	% or SD	Range
Memory Index Scores (WRAML2)			
Verbal Memory	98.29	12.23	69-123
Visual Memory	99.13	13.20	73-127
Attention/Concentration	88.91	11.16	70-120
General Memory	93.89	11.70	67-117
Total Sleep Problems			
CSHQ	20.99	8.22	6.6-37.7
SSR	38.74	7.03	26-60
Parent-reported sleep duration			
Weeknights	8.96	1.15	5.5-11
Weekend nights	10.11	1.49	7.5-13.5

Note. Because of rounding, percentages may not total 100.

Procedures

Forty-three of the 45 total subjects (95.5%) were recruited via recruitment flyer enclosed in new patient information mailings and posted in the waiting areas at the Pediatric Endocrinology Clinic. The study was also introduced by the patient's physician at the close of his/her scheduled appointment. Interested families subsequently met with a research assistant who informed them of the study's purpose and procedures. Patients and their caregivers were provided time to review the Baylor University and Scott & White Institutional Review Board-approved consent and assent forms, and the research assistant was available to answer their questions. Participants received a signed copy of the consent form. Participating parents were asked to complete paper-and-pencil versions of the Children's Sleep Habits Questionnaire (Owens, Maxim, Nobile, McGuinn, & Msall, 2000). Child Behavioral Checklist (CBCL), Child Nutrition/Physical Activity Questionnaire, Religiosity Questionnaire, and PedsQL Cognitive Functioning Scale. Parents were asked to select from the following options in responding to the question, "What race is your child?:" White/Caucasion, African American, Hispanic, Native American, and Other. Parents who selected "other" were asked to specify their child's race, and all of them indicated their child was either Asian American or biracial. Parents were asked to indicate the highest level of education attained by the child's mother or father by choosing from among the following options: some high school or less, high school diploma/GED, vocational school or some college, college degree, or professional/graduate degree. Parents were also queried, "during a normal week, how many hours a day does your child/adolescent typically watch television?" and were asked to select one of the following categories: less than one hour, between one and three hours, and greater than three hours. Finally, parents were asked, "how many sport teams and exercise programs has your child/adolescent participated in within the past year, not including physical education or gym class?", and space was provided for a numeric response.

Child and adolescent participants completed self-report versions of the Sleep Self-Report and PedsQL Emotional Functioning Scale in a private testing room. The patient also worked with the research assistant in the private testing room to complete two subtests from Wechsler Abbreviated Scale of Intelligence (WASI, Psychological Corporation, 1999) and 6 subtests from the Wide Range Assessment of Memory and

Learning, Second Edition (WRAML2, Sheslow & Adams, 2003). All data were de-identified. Parents consented that the child's medical chart could be reviewed by a Scott & White research assistant in order to obtain the following information relevant to the study: age, gender, race, medical/psychological condition(s) (including a physician diagnosis of sleep disordered breathing), medication usage, BMI, and blood pressure. The caregiver/patient dyad received a $30 gift card to Walmart upon completion of data collection procedures as a token of appreciation for their participation in the study.

Two additional participants were recruited through the Baylor Psychology Clinic. These participants underwent the same study procedures except that study eligibility criteria were confirmed via interview with the parent conducted by a trained research assistant, who also measured the child's height and weight. After the standard study procedures were implemented, the child and parent were reunited for an explanation of procedures related to the use of an actigraphy monitor. Parents and children were instructed that the child should wear the device on the nondominant wrist for three consecutive days, removing it only while bathing or swimming and replacing it thereafter. Parents and children were provided with a door hanger to use as a cue to replace the watch after bathing. Parents were instructed to return the actigraphy monitor after the recording period, at which point the dyad was provided with a $50 gift card to Walmart as a token of appreciation for their participation in the study. For all 43 participants, study materials were de-identified at the close of the testing session and these data were entered into a password-protected Excel database.

Measures

Body Mass Index

For 43 out of 45 subjects, information on each child's body mass index (BMI) was obtained from the medical record by a Scott & White clinic staff member to a de-identified Excel sheet. For the two participants recruited through the Baylor Psychology Clinic, BMI was computed by entering the patient's height, weight, age and sex into CDC pediatric growth charts. For all participants, BMI, BMI z-scores, and BMI percentiles were calculated using formulas based on CDC body mass index-for-age growth charts for children ages 2-20 years, with outer curves set at the fifth and ninety-fifth percentiles (Kuczmarski et al., 2000).

Parent Report of Child Sleep

The abbreviated version of the Children's Sleep Habits Questionnaire (CSHQ) was used to assess the school-aged child's/adolescent's sleep duration and behaviors indicative of sleep quality (Owens et al., 2000). The CSHQ-Abbreviated (CSHQ-A) is a 22-item parent-report questionnaire that encompasses eight domains: 1) bedtime resistance, 2) sleep onset delay, 3) sleep duration, 4) sleep anxiety, 5) night waking, 6) parasomnias, 7) sleep-disordered breathing, and 8) daytime sleepiness. The sum of scores on all items yields a Total Sleep Problems score. While the psychometrics of the abbreviated version of the CSHQ-A are less established, the full version of the CSHQ has demonstrated adequate internal consistency reliability in a sample of sleep clinic patients (total score, $\alpha = 0.78$) as well as in children without sleep disorders (total score, $\alpha = 0.68$). In this study, internal consistency reliability of the CSHQ-A total score was 0.672.

The CSHQ's test-retest reliability for the subscales for both community and clinical samples has been reported to range from 0.62 to 0.79 (Owens et al., 2000). The CSHQ has demonstrated validity by differentiating between clinical and community samples (Owens et al., 2000). The measure requires parents to report on sleep-related behaviors that occurred in the past week or during a typical week, if the past week was unusual (e.g., child was ill, parent was out of town, etc). Items of the CSHQ-A are rated on a five-point scale ranging from "always" if the sleep behavior occurred 7 times in the past week, "usually" if the behavior occurred 5-6 times in the past week, "sometimes" for 2 to 4 times that week, "rarely" for 1 time that week, and "never" for 0 times that week. Some items are reverse-scored such that higher scores uniformly indicated more disturbed sleep (Owens et al., 2000). In this study, missing data were imputed with the parent's mean item response, except in the case of missing bedtime and rise time values (these cases were excluded pairwise from analyses).

Previous researchers have validated parent proxy measures of child sleep by assessing their correlations with actigraphy recordings (e.g., Sadeh et al., 2000; Tikotzky & Sadeh, 2001; Werner, Molinari, Guyer, & Jenni, 2008; Wolfson et al., 2003). Actigraphy monitors are wristwatch-like devices that use a piezo-electric beam to detect movement. Movements are translated into digital counts accumulated across pre-set epoch intervals and stored in the device's internal memory. Actigraphy monitors can collect data continuously over an extended period; published studies have reported on recording periods ranging from one night (Rupp & Balkin, 2011) to three weeks in duration (Corkum, Panton, Ironside, MacPherson, & Williams, 2008). These devices record reliable and valid data on sleep and wake patterns (Acebo et al., 1999; Sadeh, Hauri, Kripke, & Lavie, 1995; Tryon, 2004). Actigraphs have demonstrated agreement with polysomnography-considered the gold standard for objectively measuring sleep indicators--across 1-minute epochs ranging between 85% and 95% for most community and clinical samples (Sadeh, et al., 1995; Sadeh, Hauri, Kripke & Lavie, 1995; Sadeh et al, 1991; Sadeh, Sharkey, & Carskadon,, 1994). Actigraphy devices carry an advantage over polysomnography in that that they are significantly less expensive to acquire and use, and they can be worn in the subject's natural sleeping environment (Elbaz, Yauy, Metlaine, Martoni, & Leger, 2012). While they cannot differentiate between partial and complete arousals, actigraphy monitors have also been shown to discriminate sleep disturbed children from controls (Morgenthaler et al., 2007). Comparing actigraphy to parent proxy reports of kindergartners' sleep, Tikotzky & Sadeh identified Pearson correlations of 0.87 (p <0.01) for both rise time and sleep duration (2001). These authors also identified a significant correlation (r = .42; p<0.01) between parent proxy report and actigraphic measures of night waking, though parents tended to underestimate the number of times their children awoke during the night (Tikotzky & Sadeh, 2001). Parents of younger children were more likely to be aware of the child's awakenings (Sadeh et al., 2000; Tikotzky & Sadeh, 2001). Questionnaires are generally thought to provide a better indication of certain sleep behaviors, however, including parasomnias, restless leg syndrome, and nighttime snoring (Beebe et al., 2006).

A preliminary investigation of the validity of the CSHQ-A was undertaken in a small subset of the sample by comparing the ratings of the informants with actigraphy recorded values. Two participants wore actigraphy monitors (MotionWatch 8, CamNtech, Inc.) for three nights each, in addition to participating in the standard study procedures. One subject was a 10 year-old African American girl with a BMI of 29.4 (99th percentile), and the other was a biracial 7year-old girl with a BMI of 28.0 (99th percentile). Actigraphy data were collected in the standard mode for sleep-wake scoring (one-minute epoch recordings, amplifier setting 18), and were extracted and analyzed using MotionWare analysis software. Prior to analysis, the recordings were visually inspected and epochs for which the actigraph had been removed were rejected. Values recorded by the actigraph indicated that neither of the two participants met criteria for "poor sleep," as defined by Sadeh, Raviv, and Gruber (2000). That is, both participants had sleep percentages greater than 90% (i.e., they spent less than 10% of the sleep period in wakefulness) and both participants awoke (wake bout greater than five minutes) fewer than three times per night, on average. Difference scores were calculated comparing parent reports of the child's usual bedtime, wake time, and sleep duration with the actigraphic recording corresponding values. Calculations were performed separately for nights preceding weekend days and for nights preceding school days. Overall, average parent error was approximately equivalent for sleep periods preceding weekend days (66.67 min.) and for those preceding weekdays (68.5 min.).   Mean parent error was smallest for bedtime/lights out (36.5 min.) and largest for sleep duration/assumed sleep (412 min.), with percent error for rise time falling in between the two (63.25 min.). Average values are presented below in Table 2.

Table 2

Average Parent Reports and Actigraphic Recordings of Sleep Duration and Related Behaviors

Sleep Behavior	Weekends		Weekdays	
	Subject 1	Subject 2	Subject 1	Subject 2
Bedtime/ Lights Out				
Parent-Reported Bedtime (pm)	11:00	10:30	9:30	8:30
Actigraphy-Recorded Lights Out (pm)	10:10	10:32	9:19	9:53
Parent Error (minutes)	50	2	11	83
Rise Time				
Parent-Reported Wake Time (am)	9:00	8:30	6:30	6:30
Actigraphy- Recorded Got Up (am)	9:42	7:23	8:23	7:01
Parent Error (minutes)	42	67	113	31
Sleep Duration/ Assumed Sleep				
Parent-Reported Sleep Duration (hours)	10	10	9	10
Actigraphy-Recorded Assumed Time in Bed (hours, minutes)	11,32	8,51	11,4	9,8
Parent Error (minutes)	92	69	124	52

Child Self-Report of Sleep

The Sleep Self-Report (SSR) is a 26-item questionnaire administered to youth in order to obtain a subjective report of typical sleep patterns (Owens et al., 2000). The SSR was designed to assess similar domains measured by the CSHQ. As with the CSHQ, items were rated on a three-point scale ranging from "usually" if the sleep behavior occurred 5 to 7 times per week, "sometimes" for 2 to 4 times per week, and "rarely" for 0–1 time per week. Some items were reverse-scored such that higher scores uniformly indicated more disturbed sleep. Three subjects omitted between one and three items and their mean response to the other items on the scale was imputed. The measure produces a total score, with higher scores indicating more sleep difficulties. This measure demonstrated validity by distinguishing between children with and without ADHD (Owens, Maxim, Nobile, McGuinn, & Msall, 2000). Previous research has established internal consistency of 0.75 for this measure (Owens et al., 2000); in the present study, internal consistency of the SSR total scale score was 0.782. Studies of non-clinical samples reported adequate internal consistency reliability (Cronbach's alpha = 0.79 and 0.80; Amschler & McKenzie, 2005 and Broeren, Muris, Bouwmeester, Van der Heijden, & Abee, 2011, respectively) and test-retest reliability of 0.95 (Amschler & McKenzie, 2005). Pearson correlations between sleep habits survey reports of adolescents and actigraphy measurements taken during subsequent school nights were 0.53 for sleep duration ($p<0.01$), 0.70 for bedtime ($p<0.01$), and 0.77 ($p<0.01$) for wake time (Wolfson et al., 2003).

School Performance

At the request of a committee member, the associations between sleep and school performance were assessed in the present study. Kruskal-Wallis H tests were used to determine whether there were differences in parental perceptions of their child's schoolwork based on the sleep variables. Parent ratings on CBCL item #61, "poor schoolwork," were made on a three-point Likert scale (*not true as far as you know, somewhat or sometimes true,* and *very true or often true*). Most parents (31) responded "not true" (indicating schoolwork is not poor) and only three parents responded "very true or often true." A Kruskal-Wallis H test was run to determine if there were differences in parent-reported schoolwork between the participants based on average sleep duration. Distributions of scores were not similar for all groups, as assessed by visual inspection of a boxplot. The distributions of parent-reported ratings of schoolwork were not statistically significantly different between groups, X^2 (2) = 0. 614, p = .736; mean average sleep durations were 9.21 hours for those children whose parents rated this item "not true," 8.84 hours for the "somewhat or sometimes true" group, and 9.59 for the "very true/often true" group. Parent ratings on this item of the CBCL were not significantly associated with total CSHQ-A score, X^2 (2) = 3.491, p = .175; mean scores on the CSHQ-A were 20 for those children whose parents responded "not true" to this item, 23 (indicating the poorest relative sleep quality, per parent report) for those children whose parents responded "somewhat or sometimes true," and 13 (indicating the highest relative sleep quality, per parent report) for those children whose parents responded "very true or often true". Differences in parent-reported quality of schoolwork did not differ significantly based on the child's report of his/her sleep (specifically, by total SSR score),

X^2 (2) = 4.265, p = .119; median scores on the SSR were 39 for those children whose parents responded "not true" to this item, 43.5 for those children whose parents responded "somewhat or sometimes true," and 35 for those children whose parents responded "very true or often true." These findings contrasted with the report of recent meta-analyses that concluded better-quality and longer sleep were related to better school performance (Astill et al., 2012; Dewald et al., 2010). However a number of studies have also failed to document relationships between naturally occurring shorter sleep duration and achievement in school (Sadeh, Gruber, & Raviv, 2003; Eliasson, Eliasson, King, Gould & Eliasson, 2002; Loessl et al., 2008; Mayes, Calhoun, Bixler & Vgontzas, 2008). It must be noted that assessment of school achievement was limited to one item assessing the parent's global, qualitative assessment of their child's school performance rather than to a more thorough, objective assessment of specific grades and behaviors associated with school achievement (e.g., turns in schoolwork on time, earns A's on tests, earns full credit on homework assignments).

Memory

Memory functioning was evaluated using the Wide Range Assessment of Memory and Learning, Second Edition (WRAML2; Sheslow & Adams, 2003). The WRAML2 is a widely used measure employed to assess memory and learning functioning in individuals ages 5 through 90 years. External validity was demonstrated via correlations with the Wechsler Memory Scale—Third Edition, and ranged from 0.36-0.66 for indices proposed to measure similar constructs. More specifically, a 0.60 correlation was found between the WRAML2 General Memory index score and the WMS-III General Memory index score, and the same correlation was found between the

WRAML2 Working Memory index score and the WMS-III Working Memory index score (Sheslow & Adams, 2003). In the present study, the 6 core subtests that comprise the Verbal Memory, Visual Memory, and Attention/Concentration index scores were administered to child and adolescent participants. Reliability data from the WRAML2 using Pearson separation reliabilities ranged from 0.85 to 0.94 on the core subtests in the normative sample. The authors reported that internal consistency ranged from Cronbach's alpha coefficients of 0.82 to 0.96 on the core index scores and from 0.71 to 0.95 across the six core subtests.

Intelligence

The Wechsler Abbreviated Scale of Intelligence (WASI) was designed to screen intellectual functioning in individuals ages 6 to 89 years (Psychological Corporation, 1999). A full scale intelligence quotient can be estimated using an individual’s score on two subtests, Vocabulary (an index of crystallized, verbal intelligence) and Matrix Reasoning (an index of fluid, nonverbal intelligence; FSIQ-2). Concurrent validity between the WASI FSIQ-2 scores and WISC-III FSIQ scores was established among children at a correlation coefficient of 0.82 (Psychological Corporation, 1999). Test-retest reliability was also strong among children, with stability coefficients of 0.85 for FSIQ-2, 0.85 for the Vocabulary subtest, and 0.77 for the Matrix Reasoning subtest (Psychological Corporation, 1999). The authors reported high internal consistency reliability coefficients for children comprising the normative sample, ranging from 0.89 for the Vocabulary subtest, to 0.92 for the Matrix Reasoning subtest and 0.93 for FSIQ-2 (Psychological Corporation, 1999).

Data Analysis

Data analyses were performed in SPSS, Version 20. Four separate sequential multiple regression analyses were conducted to determine if the addition of sleep variables improved the prediction of WRAML2 index scores after controlling for demographic, physical activity, and intelligence variables. Selection of the independent variables comprising each block was based on a priori hypotheses about associations these variables would have with the dependent variables, as presented in Figure 1. For each analysis, the assumptions of linearity, independence of errors, homoscedasticity, unusual points and normality of residuals were met. Collinearity diagnostics indicated none of the variables were collinear; therefore all of the variables of interest were retained in the model. Demographic variables including race/ethnicity, highest level of education attained by parent, age, and sex were entered into the first block. Full scale IQ score was entered into the second block. The third block was comprised of variables used to estimate level of physical activity, namely number of sports teams in which the child participated, and total duration of time spent watching television daily. The fourth block was comprised of sleep indicators (parent reported sleep duration, child self-reported total sleep problems, and parent reported total sleep problems). Table 3 presents the standardized beta coefficients for each variable comprising the models used to predict the index scores.

In order to assess agreement between parent and child self-reports of sleep, Pearson's correlations were used to compare total scores on the CSHQ-A and SSR. Spearman's rank-order correlations were used to compare scores on corresponding items of the measures. The criterion for significance was set at $p < .05$ for all statistical tests, and tests of significance were two-tailed.

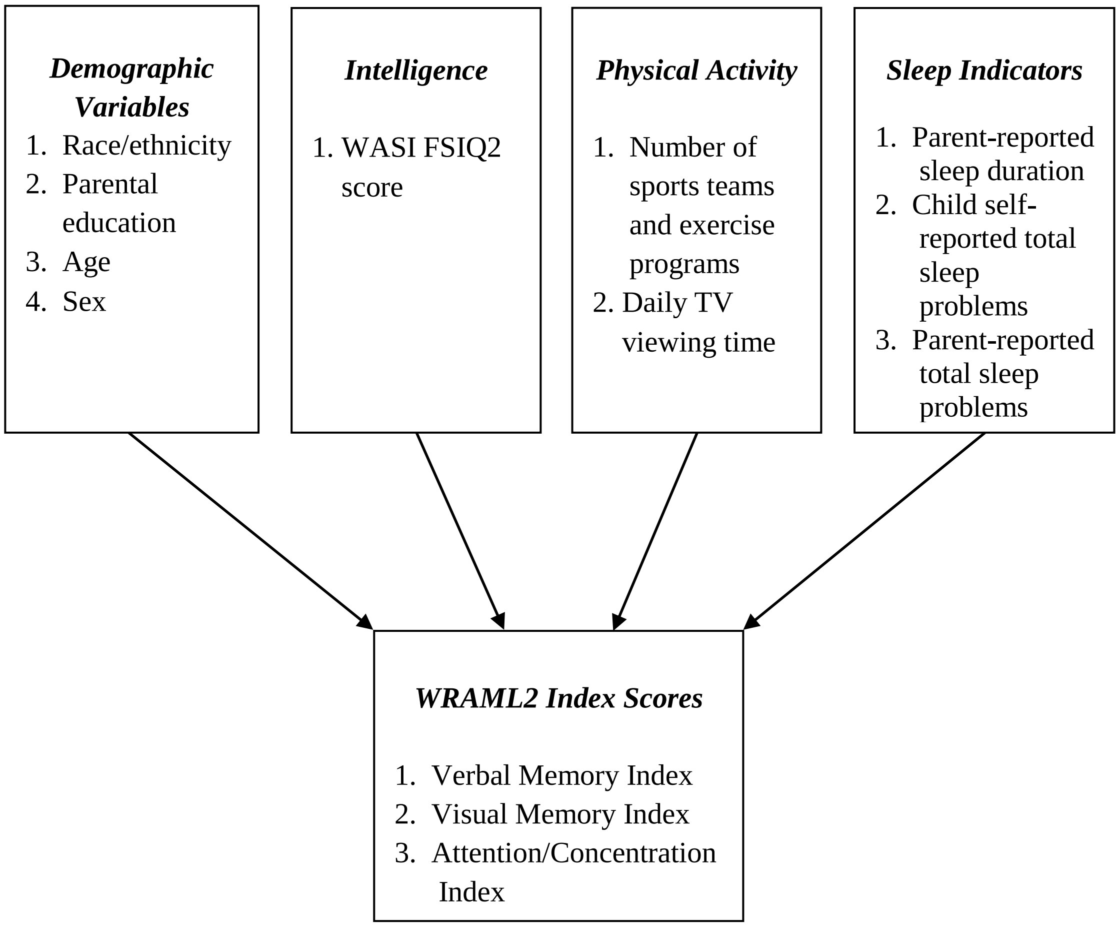

Figure 1. Schematic of model for hierarchical regression analyses.

CHAPTER THREE

Results

Verbal Memory Index

The model as a whole was not significant in predicting verbal memory, $R^2 = .397$, $F(10, 25) = 1.644$, $p = .151$. The addition of the sleep variables to the prediction of verbal memory did not result in a statistically significant increase in R^2, $R^2 = .046$, $F(3, 25) = 0.639$, $p = .597$. Standardized beta coefficients were largest for intelligence ($\beta = .423$, $p = .052$), parental education ($\beta = .284$, $p = .137$), and duration of daily television viewed ($\beta = -.267$, $p = .138$), though none of the standardized betas demonstrated a statistically significant difference from zero. Bivariate correlations revealed an association that trended toward significance between verbal memory and parental education, $r_s = .293$, $p < .06$. In addition, greater intelligence was significantly associated with stronger verbal memory, $r = .425$, $p < .05$.

Visual Memory Index

Overall, the model was not significant in predicting visual memory, $R^2 = .245$, $F(10, 25) = .812$, $p = .620$. Change in R^2 associated with the addition of the sleep variables was not statistically significant, $R^2 = .132$, $F(3, 25) = 1.453$, $p = .251$, but this block accounted for the greatest change in R^2. Standardized beta coefficients were largest for the total scores on the CSHQ-A ($\beta = .295$, $p = .192$) and SSR ($\beta = -.299$, $p = .189$), though statistical significance was not reached for any of the variables entered in the model. At the individual level, there were no significant associations between the independent variables and visual memory.

Attention/Concentration

The model was not significant in predicting Attention/Concentration scores, R^2 = .232, $F(10, 25) = .754$, $p = .670$. Change in R^2 associated with the addition of the sleep variables was not statistically significant, $R^2 = .005$, $F(3, 25) = .057$, $p = .982$. While none of the standardized betas were statistically significant, the largest associations were observed for age (β = -.287, $p = .222$), intelligence (β = .199, $p = .404$), and sex (β = .175, $p = .369$), with younger children demonstrating better attention/concentration than older children, and girls demonstrating better attention/concentration than boys. Bivariate correlational analyses revealed a significant association with age ($r = -.347$, $p < .05$). There was a statistically significant positive association between intelligence and attention/concentration, $r = .323$, $p < .05$. While the sample mean scores for visual (99.13) and verbal memory (98.29) were close to 100, indicating close to average performance in these areas, the sample's mean Attention/Concentration score was at least ten points lower than each of those index scores (88.91), indicating Attention/Concentration was an area of relative weakness for the sample as a whole. Table 3 shows the results of multiple regression analyses predicting Verbal, Visual, and Attention/Concentration index scores.

Table 3

Multiple Regression Analyses of Sleep Measures and Memory Function in Obese Youth

Predictors	Verbal Memory	Visual Memory	Attn/ Conc.
Block 1			
R^2	.141	.065	.184
Race/Ethnicity	.004	-.163	.124
Parental Education	.284	.026	-.141
Age	.256	.068	-.287
Gender	.239	.238	.175
Block 2			
R^2 Change	.127	.040	.031
Intelligence	.423†	.258	.199
Block 3			
R^2 Change	.083	.009	.012
Sports Teams	-.028	.141	.130
Daily Television	-.267	-.047	.020
Block 4			
R^2 Change	.046	.132	.005
Sleep Duration	.056	-.231	.025
CSHQ-A Total	-.070	.295	.069
SSR Total	-.193	-.299	.008
Cumulative R^2	.397	.245	.232

Note: Betas presented are standardized betas for the full model.
†Trending significant at $p = .052$.

Agreement between Parent and Child Sleep Measures

Correlations between total scores and corresponding items of these measures are presented in Table 4. Total scores produced by the informants demonstrated a strong positive association, $r = .525$, $p < .01$. At the item level, correlations were strong for fear of the dark ($r = .496$, $p < .01$), frequency of visits to a family member's bed during the night ($r = .461$, $p < .01$), and frequency of daytime sleepiness ($r = .424$, $p < .01$). There were moderate associations between parent and child reports of bedtime consistency ($r = .314$, $p < .05$) and of falling asleep alone ($r = .328$, $p < .05$). The strongest correlations were between items assessing behaviors that occur when both the child and the parent tend to be fully awake and interacting with one another.

Table 4
Correlations Between Total Scores and Corresponding Items of the Children's Sleep Habits Questionnaire-Abbreviated (CSHQ-A) and Sleep Self-Report (SSR)

Item Description	Item No. CSHQ-A	Item No. SSR	Correlation Coefficient	*p* Value
Total Score	N/A	N/A	.525**	<.01
Same bedtime	1	4	.314*	<.05
Asleep within 20 minutes	2	8	-.033	.830
Falls asleep alone	3	6	.328*	<.05
Sleeps in family member's bed	4	7	.251	.097

(continued)

Item Description	Item No. CSHQ-A	Item No. SSR	Correlation Coefficient	*p* Value
Sleeps with special object	6	12	.239	.113
Afraid of sleeping alone	7	14	-.124	.418
Fights with parents about/ resists bedtime	8	9	-.286	.057†
Afraid of dark	9	13	.496**	<.01
Goes to someone else's bed during the night	12	22	.461**	<.01
Naps during the day	16	25	.137	.370
Wakes during the night	17	18	.184	.225
Trouble waking up	19	23	.070	.650
Tired during the daytime	21	24	.424**	<.01

Note. Spearman's rank order correlations were used for all individual item correlations, whereas Pearson's product-moment correlation was used to compare total scores on the sleep measures.
*Significant at $p < .05$ level
**Significant at $p < .01$ level
†Trending significant at $p < .06$

CHAPTER FOUR

Discussion

The present study assessed associations between sleep and memory in a clinical sample of obese youth. This study is timely, given the rising prevalence of childhood obesity (Ogden et al., 2010), recent research indicating that children are sleeping for shorter periods than ever before (Iglowstein et al., 2003), and the link between short sleep duration and obesity in children (Chen et al., 2008). In addition, research indicates nearly one in five school-aged children suffer from undiagnosed fragmented sleep (Sadeh, Raviv & Gruber, 2000) and that many sleep problems are more common among overweight children than among their normal-weight peers (Beebe et al., 2006). The present study adds to the relatively limited body of research exploring the effects of sleep differences on cognitive and neurobehavioral functioning in school-aged youth (Sadeh, Raviv, & Gruber, 2000; Wolfson, 1996).

Verbal Memory Index Scores

In the present study, neither sleep duration nor sleep quality contributed significantly to prediction of verbal memory ability. The lack of association for sleep duration was in line with a recent meta-analysis that concluded there was no association between sleep duration and explicit memory in school-aged children (Astill et al., 2012). It contrasted, however, with studies reporting a significant relationship between objective indicators of sleep quality and verbal memory ability (Hannon et al., 2012; Sadeh et al., 2002). In their meta-analysis, Astill and colleagues suggested the use of subjective, rather than objective, sleep quality indicators might preclude identification of a true relationship between these variables (2012). Future research on the influence of sleep quality on verbal memory should utilize actigraphy or other objective measures over an extended assessment period in order to more definitively capture or rule out this association. The significant correlation between intelligence and level of parental education with this outcome variable in the present study is consistent with the well-documented associations of intelligence and socioeconomic status with verbal memory ability (Brooks-Gunn, Klebanov, & Duncan, 1996; Sameroff, Seifer, Barocas, Zax, & Greenspan, 1987).

Visual Memory Index Scores

While the variables comprising the model did not significantly predict visual memory, the model did reveal that the sleep measures explained the greatest amount of variation in scores in this memory index. The finding that indicators of sleep quality and quantity explained more of the variation in visual memory scores than demographic variables, intelligence, or physical activity indicators was unexpected in light of the conclusion from a meta-analytic review that there was no statistically significant relationship between sleep duration and visual memory among school-aged children (Astill et al., 2012). Moreover, previous studies have failed to identify deficits in visual memory among children with fragmented sleep secondary to sleep disordered breathing (Archbold et al., 2004; Twigg et al., 2010). However, there is some evidence that the effects of sleep on children’s memory may be greater in certain vulnerable populations. Buckhalt and colleagues found no differences in working memory between children of high and low SES when sleep was optimal, but when actigraphy analyses revealed sleep had been disrupted, children of higher SES earned significantly higher scores (2007). Similarly, children of African American descent demonstrated greater vulnerability of working memory to differences in sleep quality (Buckhalt et al., 2007). A substantial proportion of the sample obtained in the present study was comprised of ethnic minority children (76.7%) and of children whose parents had not earned a college degree (81.3%). As a result, the present finding could echo that of Buckhalt and colleagues (2007). Apart from ethnic minority and socioeconomic status, it is also possible that obesity, like SES and ethnic minority status, could represent a state associated with particular neurocognitive vulnerability to sleep differences. While children appear to partially compensate for short periods of sleep restriction, the biological mechanisms for this phenomenon are not well-understood in pediatric obesity and could be affected by developmental, stress-response, inflammatory, or other processes (Randazzo et al., 1998; Voderholzer et al., 2011). Results of the present study suggest obese children could be more vulnerable to adverse neurocognitive outcomes associated with shortened or disrupted sleep, and that this vulnerability may be particularly apparent in visual memory tasks. Given the small sample size and other limitations of the present study, this finding is considered preliminary. It will be important for future investigations with obese youth to explore the associations among sleep duration/quality and visual memory.

Attention/Concentration Index Scores

The substantially lower mean Attention/Concentration Index score obtained by the sample, relative to the mean Verbal and Visual Memory Index scores, was consistent with previous reports documenting impaired executive functioning among obese youth (Smith, Hay, Campbell, & Troller, 2011). However, results of the multiple regression analysis contrasted with previous reports of the particular sensitivity of these neurobehavioral functions to sleep differences. It was hypothesized that Attention/Concentration would be the index most sensitive to variations in sleep quality (Chervin & Archbold, 2001; Gozal, 1998; Jones & Harrison, 2001; Stores et al., 1998; Wesensten, Balkin, & Belenky, 1999) and sleep restriction (Drummond & Brown, 2001; Pilcher & Huffcutt, 1996). However, in the present study, intelligence and age explained relatively more variation in the Attention/Concentration Index scores than did sleep duration/quality. It must be noted that the present sample was relatively small, and it is possible that with more subjects, a significant association between sleep duration and attention/concentration could be detected. In addition, the use of sleep questionnaires may have been inadequate for identifying a significant relationship between sleep quality and neurobehavioral functioning.

The association between FSIQ and Attention/Concentration Index score was in line with the well-established association between these variables (Farah et al., 2006; Noble, McCandliss, & Farah, 2007; Sheslow & Adams, 2003). The finding that younger obese children earned significantly higher Attention/Concentration Index scores than their older counterparts may suggest that older children have been subject to greater cumulative effects of obesity including sustained chronic low-grade inflammation, insulin and leptin resistance, and altered glucose metabolism on cognitive functioning (Dicou et al., 2001; Doyle et al., 1995; Gonzales et al., 2010; Unger, Livingston & Moss, 1991). On the other hand, Sadeh, Gruber and Raviv found stronger associations between sleep and neurobehavioral functioning in younger normal-weight children relative to older normal-weight children. These authors interpreted that finding as evidence that older children may have developed ways to compensate for sleep disruption and shortened sleep duration (2002). In sum, while obese children may suffer more impairment in attention/concentration as they age, these functions may also grow less dependent on sleep duration/quality. It is possible that the competing effects of these age-related processes may have resulted in the nonsignificant finding reported. Further research is indicated to confirm these associations.

Parent-Child Agreement

A secondary goal of the present study was to assess agreement between parent report and child self-report of the child's sleep quality. The present study found agreement between 38% of the corresponding items on these measures, and a strong association between total scores. The strongest associations were between items assessing fear of the dark, frequency of visits to a family member's bed during the night, and frequency of daytime sleepiness. Associations for items assessing bedtime consistency and falling asleep alone were moderate. These results indicate parent-child agreement tended to be better for behaviors occurring in preparation for bedtime over those assessing sleep latency, bedtime resistance, night waking, morning rise, and daytime naps. In Owens and colleagues study of elementary school-aged children, 54% of the corresponding items demonstrated statistically significant agreement and the strongest associations were found for items assessing difficulty getting out of bed, needing a special object for sleep, and moving to another bed during the night. Parent-child agreement was not assessed for total scale scores. Though slightly fewer items evidenced clinically significant agreement in the present study, those items demonstrated stronger associations with one another. Methodological differences between these studies may have contributed to these differences in findings. Owens mailed the CSHQ-A and SSR forms to study participants and instructed parents to read the items to their children if necessary, possibly biasing their children's responses (Owens, Spirito, et al., 2000). This explanation may find further support from another study by Owens and colleagues with children with ADHD, which used the same sleep measures and found significant agreement between 80% of corresponding items. Because difficulty initiating and sustaining attention is the crux of the disorder, it seems likely that parents of children with ADHD would have had to provide a higher level of involvement to ensure that the measure was completed, promoting greater parental bias.

Clinical Implications

The present study provided support for impaired attention/concentration in obese youth. The finding that older obese children demonstrated lower attention/concentration relative to younger children sheds light on the challenges associated with long-term improvements in weight status. While cultural and developmental norms are associated with increasing independence for children as they age, the cumulative neurocognitive effects of obesity appear to result in greater deficits in attention/concentration. In order to initiate changes and consistently demonstrate healthier eating and exercise habits, one must demonstrate such executive functions as goal-setting, monitoring one's behavior in service of that goal, prioritizing long-range goals over immediate gratification, and inhibiting impulses to act in ways discordant with the goal (Lezak, Howieson, & Loring, 2004). When working with obese youth, particularly those who have been obese for long periods of time, weight loss treatment providers should tailor their interventions to impairments in attention/concentration. This could include helping the child to develop a schedule for their day that limits sedentary time and prompts engagement in physical activity. Such a schedule could also incorporate a list of healthy foods available in the school setting. Smart phone applications could be developed and utilized to provide external reminders and prompts to engage in the desired activities. These applications could incorporate feedback from the user regarding their compliance and "unlock" reinforcing feedback to keep the user motivated. This increase in structure would provide accommodations designed to meet the needs of the child with attention/concentration deficits, thus improving treatment outcomes.

Teachers and parents should strive both to understand the obese child's challenges from the perspective of executive impairment, and to accommodate these needs. Children with difficulties with attention/concentration may have difficulty generating a problem solving strategy and plan of action for attaining complex or abstract goals (Reader, Harris, Schuerholz, & Denckla, 1994). An apparently simple command such as "straighten up your room" might set up the child with attention/concentration difficulties for failure. These children will meet with greater success when these overarching goals are broken down into their component parts (Diamond & Lee, 2011). A child with attention/concentration difficulties would fare better when provided a list of steps to reference as they progress with the task (e.g., 1. Put your dirty clothes in the hamper, 2. Bring your used dishes to the kitchen sink, 3. Put your toys in the chest). At school, children with problems with attention/concentration may benefit from increased prompting to use and reference a planner for timely work completion, explicit reminders to turn in their homework on the due date, reminders to check that they have answered the question posed before moving on to the next one, and additional instruction in strategies for organizing their approach to an essay or other complex assignment. Such accommodations can often be incorporated into the educational 504b plan for the child who is struggling to meet academic expectations.

The finding that older obese children present with greater difficulties than younger children underscores the importance of prevention and early intervention in pediatric obesity. This study converges with other reports in identifying clear areas of relative weakness in neurobehavioral functioning among obese children that adversely impact their functioning at home and at school (Smith et al., 2011). The findings identified in the present study indicate prevention and early intervention would decrease children's risk for developing difficulties with sustaining attention/concentration. More effective prevention and early intervention in childhood obesity would also decrease children's risk of the serious medical complications and psychosocial effects associated with obesity.

Results of the present investigation also raised the possibility that visual memory in obese youth may be particularly vulnerable to the neurocognitive effects of sleep disruption and shortened sleep duration. The present study found that sleep differences accounted for more variation in Visual Memory Index scores than did demographic variables, intelligence, or physical activity indicators. It is possible that targeting improvements in sleep could promote improvements in visual memory. Beebe and colleagues suggested that improved nighttime sleep could reduce hormonally driven nighttime eating behavior (2013). For these reasons, it will be particularly important that treatment providers and parents incorporate psychoeducation on sleep hygiene, as well as providing supports and rewards to promote related behaviors. Parents should be informed of the American Academy of Pediatrics's recommendations for the number of hours of sleep children should obtain at various stages of their development (American Academy of Pediatrics, 1999) and should be encouraged to restrict their child's access to televisions, computers, video games, and cell phones at least one hour prior to bedtime (Taheri, 2006). Parents should inform treatment providers of behaviors associated with their child's sleep, and treatment providers should refer children with compromised sleep quality for a sleep study to determine whether medical interventions are warranted. Successful sleep interventions have been associated with improvements in academic, behavioral, and emotional functioning and as such, interventions targeting improvements in sleep hold the potential to optimize the child's neurocognitive functioning during the daytime (Gozal, 1998; Minde, Faucon, & Falkner, 1994).

Strengths/Limitations

Methodological strengths of the study include the multiple perspectives from which sleep was measured (i.e., both child and parental). The use of multiple indices of memory also constituted a strength, as distinct brain regions are implicated in memory for different information (e.g., verbal, visual, procedural). There are several limitations to the present study. The small sample size potentially limited the ability to detect statistically significant differences. It is also important to note the wide age range of the sample (6-16 years) could have obscured effects due to developmental differences in sleep architecture, sleep needs, and varying effects of sleep disruptions. For example, differences in daytime sleepiness have been associated with pubertal level (i.e., Tanner stage 3, Randazzo et al., 1998), and younger children may be more vulnerable to the effects of sleep disruption than older children (Sadeh, Gruber, & Raviv 2002).

Generalizability is limited by the fact that the vast majority of the sample was recruited from a clinical population of obese youth. As a result, parents with more concerns about their children's sleep, cognitive, and behavioral functioning may have been more likely to participate (Beebe, 2006) and it is probable that the sample studied may have more severe difficulties in these areas than obese children and adolescents who do not present to specialty medical clinics. The sample was not representative of the national population in terms of sex, race, education, or socioeconomic status. Females were over-represented (71.1%) in our sample. The proportion of Caucasian participants was smaller (22.2%) than in Texas or in the U. S. (U.S. Census Bureau, 2011; U. S. Department of Homeland Security, Office of Immigration Statistics, 2011). There was also an overrepresentation of African American participants (26.7%) and participants who classified themselves as "Other" (24.4%) relative to state and national demographics. The sample also reported lower educational attainment than the national average. However, levels of education were representative of Bell County, Texas.

There were also noteworthy limitations in the measurement employed to assess both sleep quantity and sleep quality in the present study. The present study utilized the abbreviated version of the CSHQ; while the full CSHQ has well-established reliability and validity, there is less support for the shortened form of the measure (Owens, Maxim et al., 2000). In spite of the high correlation between total scores on the CSHQ-A and SSR in the current study, the low correlations between corresponding items of the measures also indicate measures-related limitation. In addition, parent ratings of child sleep and daytime functioning are vulnerable to bias, and can be influenced by the respondent's mood, stress level, and the influence of test conditions (Sadeh, 1994; 1996).

Parents have been shown to overestimate their children's sleep duration (Nixon et al., 2008) and children and parents have been shown to differ in their accounts of the child's sleep problems (Owens et al., 2000). Parents were asked to indicate their child's "usual bedtime," and were not asked to provide information about the child's adherence to the bedtime; this, too, could have inflated estimates of child sleep duration. Moreover, factors such as sleep latency and night wakings are important variables impacting sleep quantity and quality, but are difficult to measure via self- and parent-report because of limitations in both the child's and parents' awareness of these phenomena (Sadeh, 1994; 1996). In spite of the high test-retest reliability of the self-report of sleep used in the present study (Amschler & McKenzie, 2005), the accuracy of the subjects' reports may be compromised by limitations in the child's ability to accurately assess their present sleep patterns in relation to their own past experiences, as well as to the experience of others (Sadeh, 1994; 1996). Astill and colleagues suggested that while their meta-analysis did not identify a significant association between sleep efficiency and neurobehavioral functioning, use of actigraphy over an extended assessment period could reveal an existing relationship (Astill et al., 2012). Use of an objective indicator of sleep duration and sleep quality, such as polysomnography, actigraphy, spectral EEG analysis, or indicators of sub-cortical arousal would have provided more precise indicators than the survey reports utilized in this study; however, the time and expense of research-validated devices precluded their use for the majority of the study participants. The results of the actigraphy analyses performed on two of the participants are preliminary and are limited by the study's small number of participants, as well as by the few nights for which each participant was monitored.

In addition, subjects were tested at varying times of day and scores may therefore have been impacted by circadian effects (Sadeh, Gruber & Raviv, 2002). This study would have been strengthened by incorporating additional indicators of physical activity and sedentary time. Activities spent in such sedentary activities as reading, playing videogames, and surfing the internet have been incorporated into estimates of sedentary time in previous studies (Agras, Hammer, McNicholas, & Kraemer, 2004). Number of sports teams was also used as an indicator of the child's amount of physical activity, but did not account for physical activities that are solitary in nature (e.g., daily walks, dance and karate classes, tennis lessons). Time spent in physical education weekly also varies a great deal from school to school, and would have contributed important information about the child's typical daily energy expenditure.

Finally, the cross-sectional, observational design of the present study precludes causal inferences about the relationships between childhood obesity, sleep variables, and memory abilities. It is impossible to know from the present study how changes in weight status, in sleep duration, or sleep quality might impact memory functioning. It is also important to note that cross-sectional studies make the assumption that data collected at one point in time is representative of the subject's behaviors, when in fact, they may not be stable.

Future Directions

Much remains to be learned about the factors contributing to childhood obesity. One area of research of particular relevance to the present study concerns the biological mechanisms involved in the link between short sleep duration and obesity in childhood. While some studies have associated short sleep duration with higher levels of ghrelin and evening cortisol levels, lower levels of parasympathetic activity, lower levels of leptin, and insulin resistance, other studies have failed to replicate these associations (Bunt et al., 2003; Folsom et al., 1999). The systems governing these hormonal interactions, as well as the ways they are affected by sleep, require further study. In addition, the direction of causality between shortened sleep and obesity remains to be elucidated. In light of the persistence of sleep habits across time, longitudinal frameworks may represent the next steps necessary for investigating these questions.

Results of this study suggest a need for future investigations to further study the cortical structures involved in executive and visual spatial memory functioning. Mechanisms by which the prefrontal cortex, posterior parietal cortex, and visual cortex are affected by obesity and shorter/poorer quality sleep are currently poorly understood. A greater understanding of these relationships could potentially illuminate treatments for tempering the effects of these problems on cognitive and neurobehavioral functioning. Such treatments could, in turn, result in greater success with weight loss efforts and well as longer term maintenance of improvements in weight status.

It is possible that the present findings could have been influenced by factors affecting both sleep and neurobehavioral functioning. Parenting style, stress, and psychological adjustment (i.e., depression, anxiety) all hold the potential to influence sleep and memory variables and could have contributed to the relationships reported herein. As such, investigations of the relative associations between these variables and sleep duration/quality, as well as with cognitive/neurobehavioral functioning will inform our understanding of the mechanisms driving these phenomena. Parenting style, stress, and psychological adjustment also represent potential targets for psychological intervention that could result in improvements in both sleep and weight status. Interventions targeting changes in these areas could monitor the impacts of these improvements on sleep as well as on weight status to further advance the field.

More broadly, there is a striking dearth of research on children's sleep needs across development. While there is consensus that typically developing children tend to sleep for shorter periods as they age (Sadeh, Gruber, & Raviv, 2002), there is relatively little empirical research on how sleep needs evolve across development. Given the immaturity of the brain in childhood, it is likely that shorter sleep duration would have differential effects across different phases of childhood, yet there is little research on these developmental differences in sleep (Sadeh, Gruber, & Raviv, 2002). Aside from age-related evolution in sleep needs, it remains possible that individuals may vary in the amount of sleep required for optimal daytime functioning (Klerman & Derk-Jan Dijk, 2005). Future research on individual variations in sleep architecture could shed light on the reasons for these differences.

Future studies on the executive functioning of obese children should utilize assessments with more direct relevance to dieting and increasing physical activity. For example, the Iowa Gambling Task assesses an individual's affective decision making by offering him/her the choice between a low payoff, low risk opportunity and an alternative that occasionally offers a high payoff, but ultimately results in net loss (Bechara, Damasio, Damasio, & Anderson, 1994). This test, which is thought to require intact prefrontal cortex functioning, would offer greater information about the obese child's reward sensitivity. Conners' Continuous Performance Test requires that an individual inhibit a reaction that, under most circumstances, is associated with reward (Conners &

MHS Staff, 2000). Hypothetically, a child's performance on this task could speak to his/her ability to inhibit eating behavior that has become automatic or habitual. Both tasks seem to hold direct implications for the child's ability to resist temptation in order to achieve success in weight loss interventions, and strong correlations in performance with weight loss success would confirm that the same brain systems are involved in the computerized and real-world tasks. As such, use of these assessment tools could inform the intensity or type of interventions required by an individual child.

Lastly, it would be useful for future studies to administer sleep questionnaires to parents and children concurrently with objective indicators such as actigraphy devices. While actigraphy devices are becoming more widely available, their significant expense remains a barrier to scientific investigations of sleep quality. Comparing the actigraphy measures with the reports of children and parents on child sleep behaviors offers the opportunity to validate indicators of sleep quality. Validation of a brief sleep measure, as well as factor analysis of the items comprising it, holds important clinical implications, as widespread use of a validated measure by the child's primary care provider could inform judicious referrals for sleep studies. These more thorough assessments could lead to identification of a clinically significant sleep condition, such as obstructive sleep apnea, and life-changing treatment.

APPENDICES

APPENDIX A

Children's Sleep Habits Questionnaire items by subscale.

Subscale	Item Number	Item Content
Bedtime Resistance	1	Child goes to bed at the same time every night.
	3	Child falls asleep alone in own bed.
	4	Child falls asleep in parent's or sibling's bed.
	7	Child needs parent in room to fall asleep (note also anxiety).
	8	Child resists going to bed at bedtime.
Sleep Onset Delay	2	Child falls asleep within 20 minutes after going to bed.
Sleep Duration	N/A	Write in your child's usual amount of sleep each day (combining nighttime sleep and naps).
	16	Child naps during the day (write in number of minutes the nap usually lasts).
Sleep Anxiety	3	Child falls asleep alone in own bed.
	7	Child needs parent in the room to fall asleep (note also resistance).
	9	Child is afraid of sleeping in the dark.
Night Wakings	12	Child moves to someone else's bed during the night (parent, sibling, etc.)
	17	Child wakes up once during the night.
	18	Child wakes up more than once during the night.

Parasomnias	11	Child is restless and moves a lot during sleep.
	13	Child grinds teeth during sleep (your dentist may have told you this).
	15	Child awakens during the night and is sweating, screaming, and inconsolable.
Sleep Disordered Breathing	14	Child snores loudly.
Daytime Sleepiness	16	Child naps during the day (write in number of minutes the nap usually lasts).
	19	Child wakes up by him/herself.
	21	Child seems tired during the daytime.
	22	Child falls asleep while involved in activities.

APPENDIX B

NICHD SECCYD—Wisconsin

CHILDREN'S SLEEP HABITS QUESTIONNAIRE (ABBREVIATED)

The following statements are about your child's sleep habits and possible difficulties with sleep. Think about the past week in your life when you answer the questions. If last week was unusual for a specific reason, choose the most recent typical week. Unless noted, check Always if something occurs every night, Usually if it occurs 5 or 6 times a week, Sometimes if it occurs 2 to 4 times a week, Rarely if it occurs once a week, and Never if it occurs less than once a week.

BEDTIME

Write in your child's usual bedtime: Weeknights _____:_____ am/pm

Weekends _____:_____ am/pm

	7 Always	5-6 Usually	2-4 Sometimes	1 Rarely	0 Never
1. Child goes to bed at the same time at night.	( )	( )	( )	( )	( )
2. Child falls asleep within 20 minutes after going to bed.	( )	( )	( )	( )	( )
3. Child falls asleep alone in own bed.	( )	( )	( )	( )	( )
4. Child falls asleep in parent's or sibling's bed.	( )	( )	( )	( )	( )
5. Child falls asleep with rocking or rhythmic movements.	( )	( )	( )	( )	( )
6. Child needs special object to fall asleep (doll, special blanket, stuffed animal, etc.).	( )	( )	( )	( )	( )
7. Child needs parent in the room to fall asleep.	( )	( )	( )	( )	( )
8. Child resists going to bed at bedtime.	( )	( )	( )	( )	( )
9. Child is afraid of sleeping in the dark.	( )	( )	( )	( )	( )

SLEEP BEHAVIOR

Write in your child's usual amount of sleep each day (combining nighttime sleep and naps): _____ hours and _____ minutes

	7 Always	5-6 Usually	2-4 Sometimes	1 Rarely	0 Never
10. Child sleeps about the same amount each day.	( )	( )	( )	( )	( )
11. Child is restless and moves a lot during sleep.	( )	( )	( )	( )	( )

NICHD SECCYD—Wisconsin

	7 Always	5-6 Usually	2-4 Sometimes	1 Rarely	0 Never
12. Child moves to someone else's bed during the night (parent, sibling, etc.).	( )	( )	( )	( )	( )
13. Child grinds teeth during sleep (your dentist may have told you this).	( )	( )	( )	( )	( )
14. Child snores loudly.	( )	( )	( )	( )	( )
15. Child awakens during the night and is sweating, screaming, and inconsolable.	( )	( )	( )	( )	( )
16. Child naps during the day.	( )	( )	( )	( )	( )
Write in the number of minutes the nap usually lasts: _____ minutes					

<u>WAKING DURING THE NIGHT</u>

	7 Always	5-6 Usually	2-4 Sometimes	1 Rarely	0 Never
17. Child wakes up once during the night.	( )	( )	( )	( )	( )
18. Child wakes up more than once during the night.	( )	( )	( )	( )	( )

<u>MORNING WAKE UP</u>

Write in the time child usually wakes up in the morning: Weekdays _____:_____ am/pm

Weekends _____:_____ am/pm

	7 Always	5-6 Usually	2-4 Sometimes	1 Rarely	0 Never
19. Child wakes up by him/herself.	( )	( )	( )	( )	( )
20. Child wakes up very early in the morning (or, earlier than necessary or desired).	( )	( )	( )	( )	( )
21. Child seems tired during the daytime.	( )	( )	( )	( )	( )
22. Child falls asleep while involved in activities.	( )	( )	( )	( )	( )

APPENDIX C

SLEEP SELF REPORT
(Child's Form)

____
Coding

R = REVERSE SCORING
HIGHER SCORE INDICATES MORE PROBLEMATIC SLEEP

These questions are about <u>your</u> sleep. The researcher will explain the form and read you the questions in class. Please mark your answer to each question in the box. There are no right or wrong answers. Please ask if you do not understand a question. Thank you!

1. Who in your family sets the rules about when you go to bed?
   ☐ Mom ☐ Dad ☐ You ☐ Other: __________________________

2. Do you think you have trouble sleeping? ☐ Yes ☐ No

3. Do you like to go to sleep? ☐ Yes ☐ No

	(3) Usually (5-7)/ week	**(2) Sometimes (2-4)/ week**	**(1) Rarely (0-1)/ week or never**
<u>BEDTIME</u>			
4. Do you go to bed at the same time every night on school nights? **(R)**	☐	☐	☐
5. Do you fall asleep in the same bed every night? **(R)**	☐	☐	☐
6. Do you fall asleep alone? **(R)**	☐	☐	☐
7. Do you fall asleep in parents', brothers', or sisters' bed?	☐	☐	☐
8. Do you fall asleep in about 20 minutes? **(R)**	☐	☐	☐
9. Do you fight with your parents about going to bed?	☐	☐	☐
10. Is it hard for you to go to bed?	☐	☐	☐
11. Are you ready for bed at your usual bedtime? **(R)**	☐	☐	☐
12. Do you have a special thing (doll, blanket, etc.) you bring to bed?	☐	☐	☐
13. Are you afraid of the dark?	☐	☐	☐
14. Are you afraid of sleeping alone?	☐	☐	☐
15. Do you stay up late when your parents think you are asleep?	☐	☐	☐
<u>SLEEP BEHAVIOR</u>			
16. Do you think you sleep too little?	☐	☐	☐
17. Do you think you sleep too much?	☐	☐	☐
18. Do you wake up at night when your parents think you're asleep?	☐	☐	☐
19. Do you have trouble falling back to sleep if you wake up during the night?	☐	☐	☐
20. Do you have nightmares?	☐	☐	☐
21. Does pain wake you up at night? Where is that pain?	☐	☐	☐
22. Do you sometimes go to someone's bed during the night? If yes, who? ____________________________________	☐	☐	☐
<u>DAYTIME SLEEPINESS</u>			
23. Do you have trouble waking up in the morning?	☐	☐	☐
24. Do you feel sleepy during the day?	☐	☐	☐
25. Do you take naps during the day?	☐	☐	☐
26. Do you feel rested after a night's sleep? **(R)**	☐	☐	☐

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