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Sleep deprivation lowers reactive aggression and testosterone in men

Kimberly A. Cote*, Cheryl M. McCormick, Shawn N. Geniole, Ryan P. Renn, Stacey D. MacAulay

Psychology Department, Brock University, St. Catharines, Ontario, L2S 3A1, Canada

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ABSTRACT

The role of sleep deprivation in aggressive behavior has not been systematically investigated, despite a great deal of evidence to suggest a relationship. We investigated the impact of 33 h of sleep loss on endocrine function and reactive aggression using the Point Subtraction Aggression Paradigm (PSAP) task. PSAP performance was assessed in 24 young men and 25 women who were randomly assigned to a sleep deprivation or control condition. Sleep deprivation lowered reactive aggression and testosterone (but not cortisol) in men, and disrupted the positive relationship between a pre-post PSAP increase in testosterone and aggression that was evident in rested control men. While women increased aggression following provocation as expected, no influence of sleep deprivation was found. This is the first experimental study to demonstrate that sleep deprivation lowers reactive aggression in men. Testosterone, but not cortisol, played a role in the relationship between sleep and reactive aggression in men.

1. Introduction

Human sleep deprivation leads to decreased arousal, reduced visual and motor acuity, and cognitive deficits including slower and more variable response time, impaired memory and attention (Bonnet, 2011). Imaging and behavioral data illustrate that sleep loss impairs pre-frontal cortex (PFC) function in particular (Drummond and Brown, 2001; Harrison and Horne, 2000). Since the earliest report of human sleep deprivation (Patrick and Gilbert, 1896), one of the most reliable findings has been changes to mood. In support of this, a meta-analysis reported that the negative effects on mood were greater than those on cognitive functioning (Pilcher and Huffcutt, 1996). Despite this robust finding of changes to subjective mood following sleep loss, researchers have only recently begun to investigate the impact of sleep loss on objective measures of emotion regulation and processing such as reactivity to stimuli.

Behavioral response data to emotional stimuli as a result of sleep deprivation are mixed; compared to rested controls, researchers have reported that sleep deprivation leads to lower accuracy for happy and angry faces (Van der Helm et al., 2010), and less facial expressiveness to both positive and negative emotional video clips (Minkel et al., 2011), yet increased hit rate and response time to negative stimuli in a go-no-go task using emotional words (Anderson and Platten, 2011), and a tendency to rate neutral pictures as more negative (Tempesta et al., 2010). Franzen et al. (2009) showed that sleep deprived participants had greater autonomic reactivity in pupil diameter compared to controls to blocks of negative emotional stimuli, but not positive or neutral stimuli from the International Affective Picture Set (IAPS). Using fMRI, Yoo et al. (2007) examined brain activation to emotionally neutral and negative pictures from the IAPS. Sleep deprived participants showed greater amygdala activation to negative pictures, and less connectivity between the amygdala and the medial prefrontal cortex (mPFC), compared to controls. Subsequently, Gujar et al. (2011) demonstrated that sleep deprived participants showed greater activation in brain regions involved in reward and less connectivity to frontal brain regions compared to rested controls when presented with emotionally positive pictures from the IAPS; these data show that sleep deprivation leads to an affective imbalance, where there is greater reactivity to pleasure evoking or rewarding stimuli as well as emotionally negative or threatening stimuli. Together, these data indicate that sleep deprived participants are highly reactive to emotional stimuli; thus, they may also be more prone to reactive aggression.

In a recent review, Kamphuis et al. (2012) demonstrated that there is a great deal of anecdotal evidence for a relationship between sleep deprivation and aggression in particular, yet few systematic studies. In children, better sleep quality was associated with better control over aggressive behaviors (Meijer et al., 2000); poor sleep has been associated with more conduct problems in a number of studies (Kamphuis et al., 2012). Other correlative evidence exists including associations between sleep duration or quality and negative mood in adults, and the presence of sleep disruption in various groups who often display aggression (e.g., people with psychiatric and personality disorders) (Kamphuis et al., 2012). There is some experimental evidence to support the association

* Corresponding author at: Psychology Department, Brock University, 500 Glenridge Ave., St. Catharines, Ontario, L2S 3A1, Canada. Tel.: +1 905 688 5550x4806; fax: +1 905 688 6922.
E-mail address: kcote@brocku.ca (K.A. Cote).

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between sleep and aggression. Early animal research showed that sleep deprived, especially REM deprived, rats engaged in more aggressive behavior (e.g., Hicks et al., 1978), although the possibility that factors other than sleep were at play prohibits drawing causal inferences (Kamphuis et al., 2012). One experimental study has shown an impact of sleep loss on aggressive behavior in humans. Using a projective type of test, Kahn-Greene et al. (2006) examined the impact of 55 h of wakefulness on subjective responses to cartoons depicting a frustrating situation. Sleep deprived individuals were more likely to provide aggressive responses and were also more likely to blame others when presented with frustrating scenarios. The authors suggested that sleep deprivation alters the ability to inhibit aggressive behavior due to decreased PFC function. Another experimental study by Vohs et al. (2011) examined the effects of 24 h sleep deprivation and self-regulation on aggressive responding using a computer game where the level of volume chosen to blast one's opponent following a win was considered an index of retaliatory aggression. The authors found no effect of sleep deprivation using this measure of aggression.

In the current study, we investigated the effects of sleep deprivation on aggressive behavior using the Point Subtraction Aggression Paradigm (PSAP), a well-validated laboratory measure of reactive aggression (Cherek, 1981; Cherek et al., 1996; Zhou et al., 2006; Kivisto et al., 2009; New et al., 2009). Although there is evidence for a relationship between baseline testosterone and measures of behavioral aggression (reviewed in Archer, 2006), including increased aggression on the PSAP after administration of testosterone (Pope et al., 2000), there may be stronger relationships between dynamic endocrine function and aggression (Carré et al., 2009; Geniole et al., 2011). Specifically, we have found that changes from baseline in salivary testosterone and salivary cortisol are positively correlated with increased aggression on the PSAP (e.g., Carré and McCormick, 2008; Geniole et al., 2011). These relationships, however, depended on situational factors (e.g., win/loss, Carré et al., 2009; social exclusion, Geniole et al., 2011), and may therefore be influenced by sleep deprivation.

Very few systematic investigations have been carried out to examine the impact of sleep deprivation on aggression in humans despite a great deal of evidence to suggest a relationship exists. Moreover, the mechanisms underlying this relationship have not been investigated; Kamphuis et al. (2012) suggest PFC and hypothalamic–pituitary–adrenal (HPA) axis function as potential mechanisms of the role of sleep loss in increased aggression. It is important to understand the role of sleep in emotion regulation and aggressive behavior in particular, given our society is increasingly sleep deprived and because many psychiatric disorders are co-morbid with sleep disturbances (Walker, 2009). In the present study, we investigated the impact of 33-h of total sleep deprivation on reactive aggression using the PSAP task and the role of hormones. Because sleep deprivation impairs PFC function (Drummond and Brown, 2001; Harrison and Horne, 2000), and based on the literature showing sleep loss leads to mood changes (Pilcher and Huffcutt, 1996), increased emotional reactivity (Yoo et al., 2007; Franzen et al., 2009; Gujar et al., 2011), and increased aggressive responding and blame to frustrating scenarios (Kahn-Greene et al., 2006), we hypothesized that sleep deprivation would increase aggressive behavior upon provocation in the PSAP task. We also sought to investigate how sleep deprivation altered the endocrine-aggression relationship. There is evidence that sleep deprivation alters endocrine function (e.g., increased cortisol, Redwine et al., 2000; Spiegel et al., 1999, and decreased testosterone, Anderson and Platten, 2011; Leproult and Van Cauter, 2011; Wu et al., 2011), which may in turn influence endocrine reactivity and relationships with aggressive behavior; thus, we collected morning and evening saliva samples before and after sleep deprivation, and before and after the PSAP task. Given the fundamental sex differences in hormonal factors, we carried out analyses separately in men and women. We expected sleep deprivation would increase aggressive behavior in both men and women, and be related to baseline levels of and task-related changes in testosterone and estradiol respectively. Lastly, cortisol was measured to investigate the role of stress in the relationship between sleepiness and aggressive behavior.

2. Methods

2.1. Participants

University undergraduate students between the ages of 18 and 30 were recruited through posters on campus, the Psychology Department's online recruiting system, as well as classroom presentations. Participants were required to be healthy, good sleepers (i.e., regularly sleeping approximately 11 p.m./midnight to 7/8 a.m.), right-handed, non-smokers, and not taking any medications. They must not have worked shifts in the past year, nor had a history of neurological or psychiatric conditions. Sixty-eight individuals were screened for the study: two were removed after polysomnography (PSG) due to periodic limb movements; two were excluded for poor sleep efficiency; and seven chose not to schedule participation in the main study. Of the 57 individuals scheduled for the study, 2 withdrew from the study (for lack of interest) and 1 was cancelled by experimenters (for technical reasons) following the baseline night; 1 withdrew and 1 was removed following the experimental night because of poor tolerance to sleep deprivation; 1 withdrew midway through the experimental day because the schedule conflicted with personal plans; and, 2 were removed from analysis because of poor EEG recordings and a general lack of compliance. The final sample consisted of 49 participants (24 men and 25 women); they were randomly assigned to the Sleep Deprivation (Men: $n = 11$; $M_{age} = 20.55$, SD = 2.21; Women: $n = 13$; $M_{age} = 19.15$, SD = 1.57) and the Control Group (Men: $n = 13$; $M_{age} = 19.23$, SD = 1.48; Women: $n = 12$; $M_{age} = 19.25$, SD = 1.29).

2.2. Materials

The Point Subtraction Aggression Paradigm (PSAP) is a laboratory measure of reactive aggression (Cherek, 1981) that involves a computer game in which participants compete with a fictitious player of the same sex. The participant's goal is to make button presses to earn points exchangeable for money. Throughout the game, participants are provoked by the fictitious player who steals points at random intervals. Participants have the option to press another button to protect their points for a variable amount of time or press a third button to, in turn, steal points from the player. Stealing is considered aggressive because participants are told that they do not keep stolen points. Further, there is no advantage to stealing points; use of the steal button decreases earnings (e.g., Carré et al., 2009; Pinto et al., 2012). Participants typically steal at about twice the rate they are stolen from and there is a significant increase in use of the steal button but not of the protection button after provocation (McCloskey et al., 2005; New et al., 2009; Geniole et al., 2011). Stealing points from one's opponent is thus considered a measure of reactive aggression. PSAP aggression is well-validated: PSAP aggression is higher in violent than in non-violent parolees (e.g., Cherek et al., 1996), and it is higher in clinical groups known to exhibit more aggressive behavior than non-clinical groups (e.g., Zhou et al., 2006; Kivisto et al., 2009; New et al., 2009).

2.3. Procedures

2.3.1. Screening

All procedures were approved by the local research ethics board; participants received a $110.00 honorarium. The aggression and hormone data reported here were collected during a larger study designed to investigate the impact of sleep loss on attention and emotion. Participants first completed a telephone interview and online screening questionnaires to ensure inclusion criteria were met. Eligible participants were then scheduled for a PSG test in the Sleep Research Laboratory to screen for sleep disorders.

2.3.2. Sleep deprivation protocol

The study was scheduled on a Thursday (baseline night) and Friday evening (experimental night); performance on a variety of tasks was monitored throughout the day on Saturday. Participants were run in groups of 2–3, all being in the same condition for a given weekend. Participants arrived to the laboratory at 21:00 on a Thursday night and had electrodes and sensors applied to monitor sleep before being allowed to sleep from 23:00 to 07:00. A questionnaire was administered to women to collect information on phase of the menstrual cycle and use of birth control (Baker et al., 2001; Driver and Baker, 1998). On Friday morning, electrodes were removed, breakfast was provided, and participants were given instructions to avoid caffeine, alcohol, medications, napping or exercise during the day while away from the laboratory. On Friday night, participants returned at 21:00 and were notified as to which condition they were randomly assigned. Participants in the control group had the same montage of electrodes applied and were again permitted to sleep from