The Impact of Increased Sleep on Cognitive Function in Adolescents

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Abstract

The majority of adolescents do not habitually obtain sufficient sleep. In adolescents, insufficient sleep has been linked with increased risk for depressed mood, car accidents, and poor academic achievement. There is a lack of research regarding the impact of sleep on adolescent functioning, and it remains to be determined if extending sleep could serve as a protective factor for teens. The purpose of this study was to determine if increasing time-in-bed for sleep to 10h/night for one week using an individualized approach would improve mood and cognitive performance in high-school students. Eight high school students (14-17y) exhibiting habitual short sleep (<7.5h/night) were enrolled in the study. During orientation and follow-up visits, participants completed the Profile of Mood States and a battery of cognitive tests. For one week (between orientation and follow-up visits) participants were prescribed a bed time and wake time, provided with time management and sleep hygiene strategies, and received payment contingent upon adherence to the assigned sleep schedule in order to ensure that participants increased time-in-bed for sleep to 10 hours per night. A paired-sample t-test was used to compare mood ratings and cognitive performance before and after the week-long sleep extension protocol. Six of the 8 enrolled participants completed the study. Mood was significantly improved after sleep extension (anger-hostility: p=0.013, fatigue-inertia: p=0.027, total mood disturbance p=0.055); however, cognitive performance did not change (all p > 0.05). Findings provide additional evidence about the importance of helping teens obtain sufficient sleep for promoting optimal mood.

Background

It is currently recommended that children aged 6-12 y obtain 9-12 hours of sleep per night and children aged 13-18 y obtain 8-10 hours of sleep per night. Unfortunately, many adolescents (~75%) do not meet these recommendations (1).

Evidence consistently demonstrates that obtaining insufficient sleep associates with adverse physical and psychological health outcomes. In adolescents, insufficient sleep has been linked with increased risk for depressed mood and suicidality, car accidents, and poor academic achievement (2) .Even one night without sleep increases anger, fatigue, confusion, anxiety and decreases energy levels in this age group (3).

One way to increase sleep duration in teenagers is to delay school start time. However, this requires major transportation and school scheduling changes and findings have been mixed in terms of its efficacy. Individualized approaches, taking into account the teen's busy schedule and providing time management tools, may be more beneficial. For example, individualized approaches take into account each teen's academic, social, and work obligations in order to determine consistent bedtime and wake time goals that should be set in order to achieve sufficient sleep.

The purpose of this study is to determine if increasing time-in-bed for sleep to 10h/night for one week using an individualized approach will impact mood and cognitive performance in adolescents. It is hypothesized that, relative to baseline, adolescents who are short sleepers will exhibit improved mood, decision-making and sustained attention and decreased risk taking after one week of increased sleep.

References

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Methods and Materials

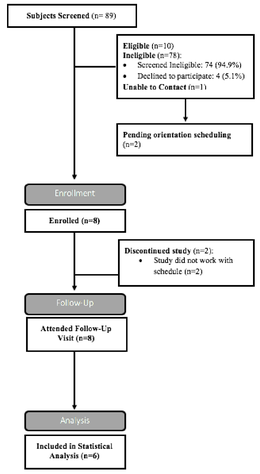
Participants: Subjects were recruited from the New Brunswick, New Jersey area. Individuals were contacted for a phone screening and eligible individuals were invited to the sleep center for an orientation. To be included, subjects were between the ages of 14 and 17, sleep approximately 7 hr/night on school nights, willing to wear a wrist actigraph daily and complete all study related tasks. If a subject exhibited a sleep disorder, had excessive intake of caffeine (>300mg/day), participated in drug or alcohol use, or had participated in trans meridian travel during past month, they were excluded from the study. **See Figure 1** for a diagram of participant flow and **Table 1** for participant characteristics.

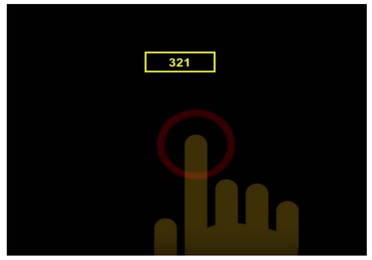
Procedures: Enrolled participants completed the Profile of Mood States, Balloon Analogue Risk Task (BART) and Psychomotor Vigilance Test (PVT) (4) during an orientation visit and then a follow-up visit that occurred after one week of sleep extension. During the week of sleep extension, participants followed a prescribed bedtime and wake time in order to be in bed for 10 hours per night. Study staff worked with each participant on sleep hygiene and time management strategies to help them achieve the desired schedule and participants were paid based on adherence (up to $10/day). Sleep was objectively measured using a wrist actigraph. The device was worn on the participant's non-dominant wrist across the 24-hour period and monitors motor activity to obtain continuous recordings of sleep-wake states.

Outcome Variables: The **POMS** captures both stable/trait mood, for examining between-subjects variability, as well as transitory/state mood, for examining within-subjects variability over time. See **Table 2** for POMS outcome variables. The **BART** measures risk taking and decision making. During the BART, participants need to inflate a balloon on the screen to maximize the receipt of a monetary reward but receive nothing if the balloon pops. Like a real balloon, the risk for the popping becomes greater as it inflates.. The **PVT** measures sustained attention. During the PVT, participants were shown an empty rectangle and then at random intervals, a counter would appear within the rectangle which counted up in msec. Participants were instructed to respond by tapping the screen as soon as they saw the stimulus (msec counter) appear in the rectangle as quickly as possible but also not to respond unless they saw the counter appear .

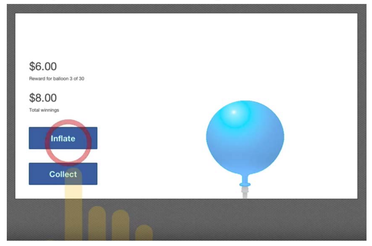
Statistical Analysis: Paired-samples t-tests compared each POMS, BART and PVT variable before (pre) and after (post) the week-long sleep extension protocol. A p value < 0.05 will considered a statistically significant difference.

Figure 1. Consort Diagram





Psychomotor Vigilance Test



Balloon Analog Risk Task

Results

Table 1. Demographics of n=6 Participants

Variables	Mean ± SD or N (%)
Participant age	16.38±1.061
BMI	29.838 ± 8.63
Gender	
Male	5(62.5)
Female	3(37.5)
Grade in school	
Freshman	1(12.5)
Junior	1(12.5)
Senior	6(75)
Ethnicity	
Hispanic or Latino	2(25)
Not Hispanic or Latino	6(75)
Race	
Asian	2(25)
White or Caucasian	4(50)
Other	1(12.5)
More than 1	1(12.5)

Figure 2. *Profile of Mood States Before and After Week-long Sleep Extension*

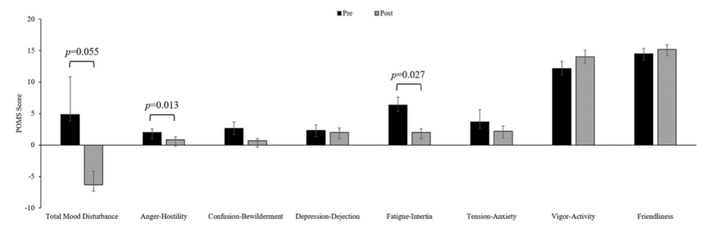


Table 2. *Profile of Mood States*

Variables	Pre Mean ± SD	Post Mean ± SD	P value
Total Mood Disturbance	4.83 ± 14.66	-6.33 ± 5.28	0.055
Anger-Hostility	2.00 ± 1.41	0.83 ± 1.17	0.013
Confusion-Bewilderment	2.67 ± 2.42	0.67 ± 0.82	0.119
Depression-Dejection	2.33 ± 2.16	2.00 ± 1.67	0.750
Fatigue-Inertia	6.33 ± 3.14	2.00 ± 1.41	0.027
Tension-Anxiety	3.67 ± 4.72	2.17 ± 2.14	0.287
Vigor-Activity	12.17 ± 2.64	14.00 ± 2.61	0.110
Friendliness	14.50 ± 2.07	15.17 ± 1.72	0.530

Note. Total mood disturbance = (Anger-Hostility + Confusion-Bewilderment + Depression-Dejection + Fatigue-Inertia + Tension-Anxiety) – (Vigor-Activity + Friendliness) x 100.

Table 4. *Sleep Variables Measured using Wrist Actigraphy during the Intervention Week*

Variables	Mean ± SD
Bedtime (h:min)	20:59 ± 0:31
Wake time (h:min)	6:32 ± 0:32
Total sleep time (min)	507.07 ± 38.80
Wake after sleep onset (min)	65.93 ± 23.60
Sleep efficiency[a] (%)	88.43 ± 4.40

Note. [a]Sleep efficiency is total sleep time / time in bed.

Table 3. *Cognitive Performance*

Variable	Pre Mean ± SD	Post Mean ± SD	p value
BART			
Mean Pumps Optimal Difference	-1.07 ± 0.47	-1.06 ± 0.74	0.96
Total Pumps	148.00 ± 14.24	148.33 ± 22.34	0.96
PVT			
Mean Reciprocal Reaction Time (RRT)	4.61 ± 0.77	4.67 ± 0.53	0.73
Mean Fastest Reaction Time	172.72 ± 22.85	167.20 ± 17.08	0.53
Mean Slowest RRT	2.93 ± 0.99	2.99 ± 0.42	0.88
PVT lapses	2.67 ± 3.45	1.50 ± 1.05	0.40
Aggregate Score	82.17 ± 11.64	86.33 ± 9.48	0.18

Discussion

This study was conducted in order to determine if increasing sleep in adolescents would impact their mood and cognitive function. Participants, who previously averaged 7 hours of sleep per night before starting this study, followed a prescribed bed time and wake time. We found that one week of sleep extension led to significant improvements in mood, specifically decreased mood disturbance. Mood disturbance is the difference between negative and positive mood such that high scores reflect greater negative mood whereas lower scores reflect greater positive mood. When examining each component of the Profile of Mood States test, we found that Anger-Hostility and Fatigue-Inertia were significantly decreased (**Figure 2 and Table 2**)..

No changes in BART or PVT performance were observed before and after week-long sleep extension in high school students (**Table 3**). Although we did not observe significant changes on the Psychomotor Vigilance Test, we did observe faster response speeds, reductions in attention lapses, and improved overall score after week-long sleep extension in high school students. These findings are consistent with a large number of studies showing that performance on the PVT is worse in the context of sleep loss and improves with better sleep, sleep recovery and sleep extension.

The sleep data collected objectively during the week-long sleep extension period (**Table 4**) show that participants followed their prescribed bedtime and wake time for the entire week and were able to increase sleep to 8.5 hours/night. The sleep efficiency of participants remained above 85%, which is considered good quality sleep.

Findings support the importance of obtaining sufficient sleep for optimizing mood and sustained attention in high school students and that the individualized approach to sleep extension is effective in this age group.

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