Psychology and Health
February, 2006, 21(1): 79–86

Routledge
Taylor & Francis Group

Effects of partial sleep deprivation on food consumption and food choice

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(Received 9 February 2004; in final form 3 March 2005)

Abstract
Sleep deprivation alters food consumption in animals; however, little is known of the effects of partial sleep deprivation on food consumption and choice in humans. We examined 50 undergraduate students who recorded sleep quality, food consumption, and food choice in daily diaries for four days. On the second night of the study, participants were instructed to sleep for 4 h or less, which served as a partial sleep deprivation manipulation. Following sleep loss, participants reported consuming fewer calories. They also reported altering food choice following deprivation, choosing foods less for health and weight concerns. The results provide initial evidence that sleep deprivation impacts food consumption and choice, which may have subsequent health implications.

Keywords: *Sleep quality, sleep deprivation, food choice, food consumption*

Introduction

Adequate sleep is important for both good mental and physical health. Poor sleep quality is a significant predictor of depressed mood (Mendlowicz, Jean-Louis, von Gizycki, Zizi & Nunes, 1999). Sleep deprivation has been shown to worsen depressive symptoms in some individuals (Benedetti, Zanardi, Colombo & Smeraldi, 1999; Beutler, Cano, Miro & Buela-Casal, 2003) and increase disturbed mood (Crabbe, 2002; Dinges et al., 1997). Sleep deprivation can also result in increased anxiety (Miro, Cano-Lozano, Espinosa & Buela-Casal, 2002), fatigue, confusion, and tension (Dinges et al., 1997). Furthermore, sleep deprivation affects mood to a greater degree than either cognitive or motor performance (Pilcher & Huffcutt, 1996). Regarding physical health, poor sleep quality and sleep loss are associated with decreased immune function (Cruess et al., 2003; Irwin, 2002), the pathophysiology of cardiovascular disease and diabetes

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ISSN 0887-0446 print/ISSN 1476-8321 online
DOI: 10.1080/14768320500102301

(Roost & Nilsson, 2002), and also the development of overweight/obesity (Agras, Hammer, McNicholas & Kraemer, 2004).

Sleep deprivation also influences food consumption in studies of animals, although these studies have shown some conflicting results. For example, studies with rats have shown that sleep deprivation may lead to over eating (Brock et al., 1994; Tsai, Bergmann & Rechtschaffen, 1992). On the other hand, Johansson and Elomaa (1986) found a reduction in the amount of food consumed by rats when deprived of rapid eye movement (REM) sleep. In addition, some studies also demonstrated that sleep deprivation disturbs the light/dark eating pattern in rats rather than simply increasing or decreasing food intake (Elomaa, 1981; Martinez, Bautista, Phillips & Hicks, 1991). Overall, sleep deprivation seems to alter eating patterns among animals.

There are relatively few studies on the effects of sleep on food consumption or food choice in humans, but several pieces of indirect evidence exist to suggest a link between sleep and food consumption. Hicks, McTighe and Juarez (1986) found that short-sleeping college students (e.g., 6 h per night) were more likely to eat more small meals or snacks than long-sleepers who averaged 8 h or more of sleep per night. There is also evidence showing that individuals with eating disorders display abnormal sleep patterns. For example, Latzer, Tzischinsky, Epstein, Klein and Peretz (1999) found that women with bulimia nervosa reported more difficulty falling asleep, more early waking, more headaches on awakening, and more daytime sleepiness than women without bulimia.

Additional evidence for an association between sleep and eating comes from studies of the hypothalamic pituitary adrenal (HPA) axis stress hormone cortisol and other studies of psychosocial stress. There is a negative association between amount of REM sleep and cortisol levels (Lauer et al., 1989) and a positive association between cortisol levels and calories consumed (Epel, Lapidus, McEwen & Brownell, 2001). In addition, sleep loss may be thought of as a source of stress for some individuals, which may subsequently influence food choice and food consumption as well. Increases in stress lead to more snacking and a decrease in the consumption of typical meal-type foods (Oliver & Wardle, 1999). In sum, there is some evidence that loss of sleep, as a stressor, may influence eating patterns, but, to date, no study has examined the effects of sleep restriction on food choice and consumption.

The present study examined the association between self-imposed sleep deprivation and eating among a sample of college students. We hypothesized that individuals would change their pattern of calorie consumption on the day following partial sleep deprivation. Due to the lack of conclusive evidence, as discussed above, we did not make an *a priori* hypothesis regarding the direction of change in calorie intake. We also predicted that individuals would choose foods differently following partial sleep deprivation; specifically, in concordance with the Oliver and Wardle (1999) study mentioned above, we predicted that they would choose foods based less on health and weight control and based more on mood and convenience.

Method

Participants

Participants were a convenience sample of 50 undergraduate students from a major, private east coast university. All of the students were participating to partially fulfill a research participation requirement for an introductory psychology class. Students in the psychology department subject pool were eligible to participate in this study. Participants who indicated

a current mood, sleep, or eating disorder or disturbance in the initial assessment were excluded from the study and referred to the university's counseling or health services.

Procedures

The Institutional Review Board approved this study before participants were recruited. After obtaining written consent, participants completed an initial battery of questionnaires in the lab. They were then given four daily take-home diaries consisting of an open ended eating diary and a sleep diary. The third daily diary also contained a self-report food choice questionnaire. Participants always began their diaries on either Monday or Tuesday to avoid obtaining information during the weekend when eating and sleeping patterns might be altered.

In order to obtain a reliable baseline, participants were instructed to sleep for seven hours or more on the first night. On the second night of the study (always Tuesday or Wednesday night) they were instructed to sleep for four hours or less. In an attempt to return the participants to baseline, they were asked to sleep for seven or more hours on the third night. The final night contained no sleeping instructions as no information was obtained the following day. Participants were instructed to complete the diary each evening and seal that day's diary in an envelope to prevent them from relying on past information to complete later diaries. After four days the participants returned the four sealed envelopes to the experimenter.

Measures

Demographic information. Participants provided their gender, age, height, and weight. Self-reported weight and height were used to calculate body mass index (BMI; $kg\,m^{-2}$). Self-reported weight has been shown to be a reliable estimate of measured weight, with correlations typically between 0.96 and 0.99 (Attie & Brooks-Gunn, 1989; U.S. Public Health Service, 1988).

Sleep quality. The Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman & Kupfer, 1989) is an 18-item questionnaire used to assess sleep quality over the past month with higher global scores indicating poorer sleep quality. Cronbach's alpha for the PSQI is 0.83, demonstrating sufficient internal consistency. The test–retest reliability for the PSQI is 0.85.

The PSQI is reliably associated with objective measures of disturbed sleep such as low salivary cortisol levels after morning awakening (Backhaus, Junghanns & Hohagen, 2004), pupillometric measures of sleepiness (Merritt, Schnyders, Patel, Basner & O'Neill, 2004), and also polysomnographic measures such as percent of REM sleep (Buysse et al., 1989).

The sleep diary completed by the participants was an abbreviated version of the PSQI. The sleep diary assessed five of the seven subscales from the PSQI: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, and daytime dysfunction.

Food choice. How participants chose the foods they ate was assessed with the Food Choice Questionnaire (FCQ; Steptoe, Pollard & Wardle, 1995). The FCQ asks individuals to rank how important 36 items were in what they chose to eat over the last week. Some items from the FCQ are "is easy to prepare", "is nutritious", and "tastes good". The FCQ is

composed of nine subscales: health, mood, convenience, sensory appeal, natural content, price, weight control, familiarity, and ethical concern. Higher scores on the subscales represent greater importance of that factor to food choice. In this study, the subscales have been standardized so that each subscale ranges from 0 to 3. The subscales have demonstrated good internal consistency (Cronbach alphas from 0.72 to 0.86) and test–retest reliability (Steptoe et al., 1995). A diary version of this questionnaire was included for one daily diary and was identical to the original FCQ except that the time frame was changed to indicate what influenced their food choice on that day rather than over the past week. This diary version was included only for the day following sleep loss to reduce any potential bias created by repeated administration of this main outcome measure and also to reduce subject burden.

Food consumption. The eating diary consisted of four meal sections (breakfast, lunch, dinner, and snack) with blanks for the participants to write in the foods and drinks they consumed that day. A sheet containing instructions for estimating portion size was attached to each diary. Participants also received these instructions verbally after completing the initial questionnaires. Calories consumed for the day were calculated using a nutrition software program (BeNutrifit). The eating diary displayed very good internal consistency in number of calories consumed (Cronbach alpha of 0.83) and had a good test–retest reliability of 0.613 over a four-day period.

Results

Descriptive statistics

Of the 50 participants, 28 were female (M age = 19, SD = 0.9) and 22 were male (M age = 19.6, SD = 1.3). Females' mean height and weight were 64 inches and 127.6 pounds with standard deviations of 2.3 inches and 15.3 pounds, respectively. Males' mean height was 70 inches with a standard deviation of 3.4 inches and mean weight was 165.6 pounds with a standard deviation of 27.6 pounds. Thus, mean BMIs for women and men were 21.6 (SD = 2.7) and 23.3 (SD = 2.5), respectively.

A manipulation check indicated that participants did sleep less on the night they were asked to lose sleep. The mean number of hours slept were 6.4 (SD = 1.7) for Day 1, 6.5 (SD = 1.5) for Day 2, 4.6 (SD = 1.8) for Day 3, and 7.3 (SD = 1.7) for Day 4. Paired t-tests comparing number of hours slept on Day 1 to Day 3, Day 2 to Day 3, and Day 3 to Day 4 were significant, ts (49) = 6.23, 4.39, and 7.68, respectively, ps < 0.001. The range of number of hours slept on Day 3 was 2.33 to 10.5, indicating that a select few subjects did not restrict their sleep as instructed. However, if these subjects are removed from the analyses, there is no effect on the results of this study. Thus, we decided to keep these subjects in the study to provide a more inclusive approach.

Effects of sleep loss on food consumption and food choice

A repeated measures ANOVA indicated there was a significant difference in calories consumed on different days F (3, 48) = 2.79, p = 0.05. Post hoc analyses revealed that there was a significant difference between calories consumed on Day 1 and Day 4, t (51) = 2.82, p < 0.01 with a decrease in consumption on Day 4. There was also a significant difference between Day 2 and Day 4 in calories consumed, t (51) = 2.17,

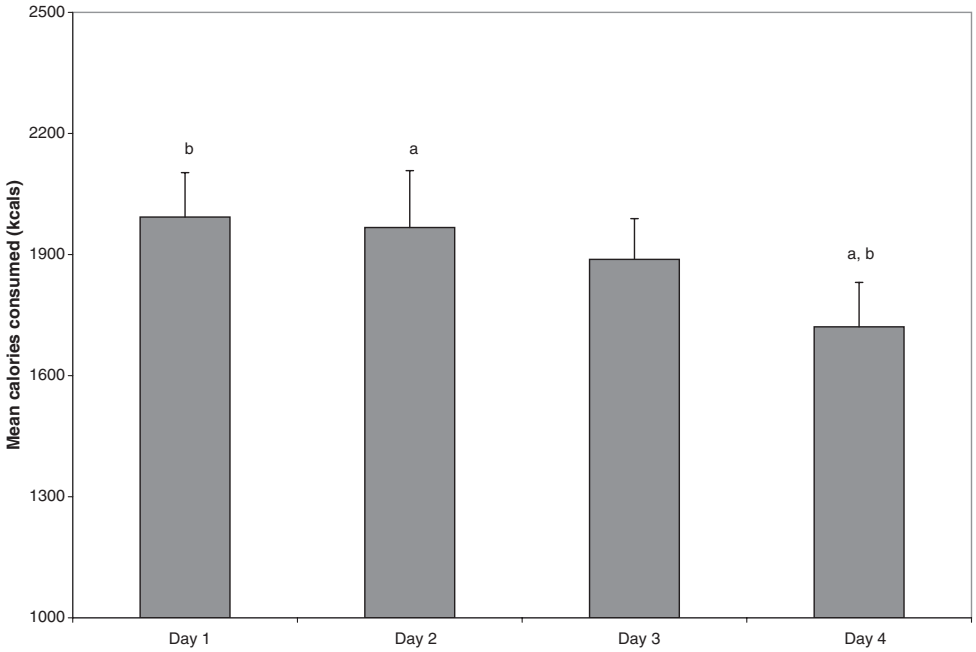

Figure 1. Mean calories (kcals) consumed with standard error bars, a = significant difference of $p < 0.05$, b = significant difference of $p < 0.01$. Note that the *Y*-axis begins at 1000 calories.

$p < 0.05$ with a decrease in consumption on Day 4. However, there were no significant differences between Day 1 and Day 3 or Day 2 and Day 3, $p > 0.1$. Thus, participants consumed fewer calories on the final day of the study but did not evidence a significant change in calorie consumption on the day immediately following sleep loss. These results can be seen in Figure 1.

The average decrease over the four days was 272 calories, which represented a 13.6% drop in caloric intake. This decrease is large enough to be considered both statistically significant and meaningful. For example, this would be the approximate equivalent of eating one fewer McDonald's hamburger (at 280 calories) per day (McDonald's Corporation, 2004).

There were also significant differences in some aspects of food choice between the initial assessment and the diary assessment after the night of lost sleep. Paired *t*-tests indicated that on the day following sleep loss, participants chose food less for health, $t\ (46) = 8.54$, $p < 0.001$, sensory appeal, $t\ (46) = 4.76$, $p < 0.001$, natural content, $t\ (46) = 5.74$, $p < 0.001$, price, $t\ (46) = 5.26$, $p < 0.001$, weight control, $t\ (46) = 6.21$, $p < 0.001$, familiarity, $t\ (46) = 3.29$, $p < 0.01$, and ethical concern reasons, $t\ (46) = 2.79$, $p < 0.01$. The mood and convenience subscales showed no significant differences between initial assessment and the day following sleep, *t*s $(46) = 1.37$ and 1.25 respectively, *p*s > 0.1. These results are depicted in Figure 2.

Discussion

In the present study, the effects of self-induced partial sleep deprivation among an undergraduate sample were examined. The results showed significant differences in food

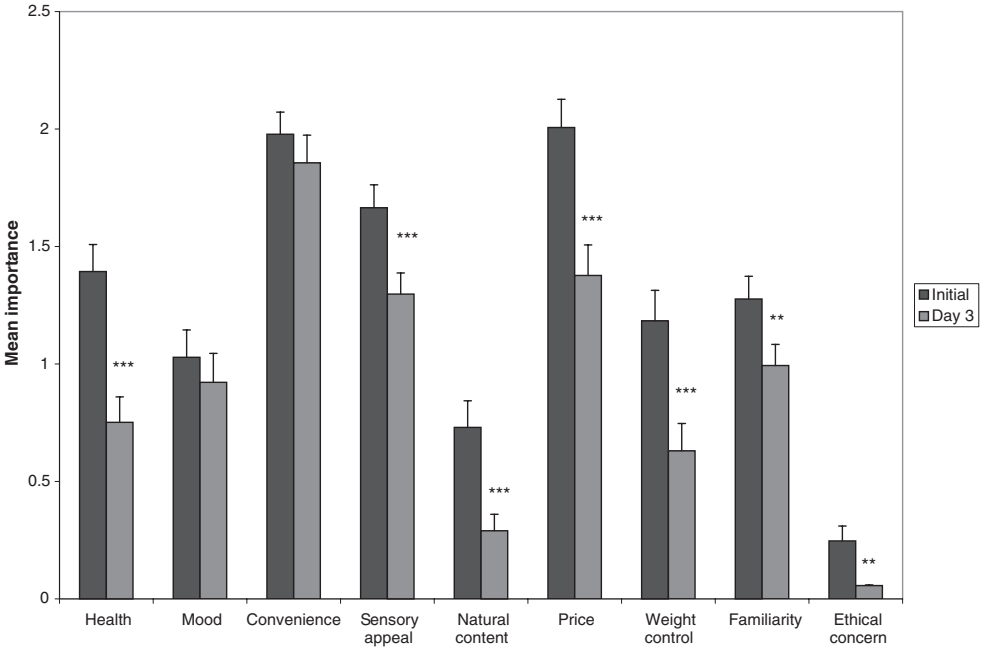

Figure 2. Mean food choice scores with standard error bars, ** = significant difference of $p < 0.01$, *** = significant difference of $p < 0.001$.

consumption and food choice following partial sleep deprivation as compared to nights of normal sleep.

As expected, there was a change in food consumption, as measured by calories consumed, following a night of partial sleep deprivation. We found that consumption of calories decreased after sleep loss as shown in Johansson and Elomaa's (1986) study with rats. It is noteworthy to point out that the decrease in calories did not become statistically significant until two days after sleep deprivation rather than the day after. It could be argued that this indicates that sleep deprivation was not the cause of this decline in calories, but that some other factor played a role. One possible explanation is that people consume more calories following the weekend and eat less as the weekend approaches. However, it is important to note that the decrease in calories did not begin until after sleep loss. Also, some participants began the diaries on Monday while others began on Tuesday, making it less likely that the finding was due only to the time frame of the study.

Other explanations for the observed decrease in calorie consumption could include diary fatigue and increased awareness of intake. Diary fatigue could have resulted in the participants eating the same amount but recording less in the diary or they could have actually consumed less because of an aversion to writing in the diary. Similarly, a heightened awareness of calorie intake could have led to a decrease in food consumption due to health or weight concern reasons. Due to the fact that there was no control group that kept diaries but did not experience sleep loss, the decrease in calories cannot be attributed solely or exclusively to sleep deprivation.

Finally, as predicted, participants exhibited a change in food choice immediately after sleep deprivation. Findings indicated that after losing sleep, participants chose foods based less on reasons of health, sensory appeal, natural content, price, weight control, familiarity, and ethical concern. However, food choice based on mood and convenience remained

unchanged. These findings correspond with evidence that short-sleeping college students eat more snacks than long-sleepers (Hicks et al., 1986) and that increased stress leads to increased snacking (Oliver & Wardle, 1999). This indicates that sleep-deprived individuals may be more likely to consume less healthy foods than those who get an adequate amount of sleep.

A limitation of this study is that it relied solely on self-report data. While there is no reason to doubt the veracity of the data provided by the participants, it may not be as accurate as data recorded objectively. However, the fact that some participants did indeed report a failure to adhere to the instructions and slept for more than the 4 h requested may indicate that most participants felt comfortable reporting and non-adherence and that, in fact, most participants did adhere to the instructions. To avoid these possible deceptions altogether, future studies might use wrist actigraphs in addition to self-report to monitor sleep duration and quality, or perhaps participants could be examined in a sleep lab where they could be more extensively monitored. Similarly, in a laboratory setting, the nutritional content and portion sizes of meals consumed could be more accurately recorded. Furthermore, these data reflect changes after partial sleep deprivation and may not generalize to more chronically sleep-deprived populations. Also, as discussed above, the lack of a control group limits the ability to conclude that the change in calorie intake was due solely to sleep deprivation. Even with these limitations, this is one of the first studies to show that sleep deprivation impacts on food choice and consumption in humans.

Future studies should consider a diurnal assessment of sleep, stress, and calorie intake in a more controlled setting to further elucidate the relationships found in this study. It may be important for these effects to be studied further, for if there is a strong relationship between sleep and eating it could have implications for major health problems such as obesity and diabetes. For while sleep disorders are sometimes the result of health problems such as diabetes (Sridhar & Madhu, 1994) there is increasing evidence that sleep disorders and disturbances may be causal factors in the development of diabetes, cardiovascular disease, and overweight/obesity (Agras et al., 2004; Roost & Nilsson, 2002). In this way, prevention or treatment of sleep problems might also benefit individuals by reducing the risk or severity of these health problems.

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