THE RELATIONSHIP BETWEEN SLEEP VARIABLES AND HEADACHE

Emily Ann Grieser, B.S.

Dissertation Prepared for the Degree of

DOCTOR OF PHILOSOPHY

UNIVERSITY OF NORTH TEXAS

August 2010

APPROVED:

Daniel J. Taylor, Major Professor
Frank L. Collins, Committee Member and Program Coordinator for Health Psychology
Adriel Boals, Committee Member
Vicki Cambell, Chair of the Department of Psychology
James D. Meernik, Acting Dean of the Robert B. Toulouse School of Graduate Studies

Grieser, Emily Ann. The Relationship Between Sleep Variables and Headache. Doctor of Philosophy (Health Psychology and Behavioral Medicine), August 2010, 39 pp., 13 tables, 1 illustration, references, 60 titles.

Headache pain impacts most of the population at some point in life, at an enormous cost to day-to-day functioning. Determination of the variables that are associated with prevalence and severity of headaches has been inconsistent. One area that deserves more attention is the relationship between headaches and sleep. For instance, several sleep parameters may precipitate or exacerbate headaches, but previous research often used inconsistent and limited assessments of both headaches and sleep, making results difficult to interpret and compare. The current study seeks to extend previous research by using more comprehensive and empirically validated assessment techniques to study the relationship between sleep and headaches in a healthy sample. Greater self-reported sleep quality is related to lower headache frequency and severity, and lower self-reported sleep quality is characteristic of individuals having migraine-type headaches. Greater sleep efficiency is related to lower headache severity and shorter headache duration. Greater sleep onset latency is related to longer headache duration and greater headache severity. Greater number of nighttime awakenings is related to greater headache severity and is characteristic of individuals having a diagnosable headache disorder (either tension-type or migraine-type). Stress appeared to be a partial mediator between self-reported sleep quality and headache severity. Further experimental studies may clarify causality between sleep and headache.

TABLE OF CONTENTS

Page

TABLES

ILLUSTRATIONS

Figure Page

INTRODUCTION

Headaches are highly prevalent in the general population - 90% report headaches at some point in life - making them a significant public health concern (Mannix, 2001). Headaches cause severe daytime consequences, such as an estimated 74.2 million restricted-activity days per year and 112 million bedridden days per year in the United States (Hu, Markson, Lipton, Stewart, & Berger, 1999; Stang & Osterhaus, 1993). The cost of missed workdays and decreased worker productivity due to headaches has been estimated in the range of $5-17 billion per year (Osterhaus, Townsend, Gandek, & Ware, 1994). In American undergraduate college populations, an estimated 17-50% of students experience one or more headaches per week, and approximately 20% have three to four headaches per week (Andrasik, Holroyd, & Abell, 1979; Curry & Green, 2007).

In the general population, sleep disturbance is associated with all types of headaches and their severity (Boardman, Thomas, Millson, & Croft, 2005). However, the exact nature of this relationship has not been thoroughly examined using a definition of headache that is consistent with current diagnostic criteria and sleep diaries that address multiple sleep parameters (i.e., total sleep time, sleep efficiency, sleep onset latency, number of awakenings, wake time after sleep onset, subjective sleep quality). Identification of sleep parameters associated with headaches can lead to future research investigating the directionality of this relationship – both by manipulating sleep to observe subsequent headache activity and by treating sleep parameters in an attempt to decrease headache severity, frequency, and duration.

Sleep and Headaches

Cross-sectional research shows that several sleep patterns are often related to increased headache prevalence including: one night of insufficient sleep (Blau, 1990); trouble falling

asleep, waking up several times per night, and unrefreshing sleep (Boardman et al., 2005); multiple nighttime awakenings or trouble staying asleep (Boardman et al., 2005; Kelman & Rains, 2005; Maizels & Burchette, 2004); fewer hours of sleep per night (Hale, May, Marks, Moore, & Stewart, 1987; Spierings & van Hoof, 1997). In addition, insomnia is one of the most frequent self-reported complaints among migraine sufferers, with 60% reporting insomnia associated with their headaches (Maizels & Burchette, 2004). Finally, some patients report using sleep to alleviate migraine headaches (Blau, 1982; Lin, Huang, & Wu, 2007).

By far the most consistent and strongest support is for the relationship between habitually shorter sleep times and headache difficulties. For instance, short sleepers ($\leq$ 6 hours of sleep per night) report more intense headaches than others (i.e., > 6 hours) and a greater tendency to awaken with headaches (Kelman & Rains, 2005). The largest study to date (N = 1283) found that self-reported shortened sleep patterns (6 hours per night, on average) were associated with more frequent and more severe headaches (Kelman & Rains, 2005). This study, however, did not prospectively assess sleep over several nights, but instead asked participants to estimate their average amount of sleep per night and rate frequency of sleep complaints (trouble falling asleep, trouble staying asleep, sleep disturbance, sleeping late/oversleep) on a four point scale from "*never*" to "*very frequent*." Such subjective labeling does not provide precise quantitative information; for example, exactly how many times a subject woke up during the night or exactly how long it took them to fall asleep.

In addition to the cross-sectional studies listed above, there are a few retrospective and prospective studies indicating that sleep difficulties may precipitate headaches. For instance, retrospective studies found that self-reported lack of sleep was attributed as a cause of headaches more frequently than excessive sleep (Blau, 1990; Inamorato, Minatti-Hannuch, & Zukerman,

1993; Paiva, Esperanca, Martins, & Batista, 1992; Spierings, Ranke, & Honkoop, 2001). Others found inconsistent sleep schedules were also related to a greater frequency of headaches (Paiva et al., 1992). Finally, one prospective longitudinal study using time-series analysis found that peak headache severity over a 28-day period was predicted by sleep disturbances 1-3 days before headache onset, giving further evidence to the idea that sleep disturbances are a risk factor for the onset of headaches (Penzien, Rains, Andrew, Galovski, Mohammed, & Mosley, 2001).

In each of these studies, additional factors were hypothesized to play a role in the sleep/headache relationship. Some of these factors may stem from the complex physiological ties between sleep and headache involving neurotransmitters and other neurological structures, which are not yet fully understood (Dodick, Eross, Parish, & Silber, 2003). Others hypothesize the relationship may be caused by somatization of psychological distress or by pathophysiology, underlying mood disorder, or primary sleep disorders (Kelman & Rains, 2005; Maizels & Burchette, 2004).

Physiological Processes Affecting Headaches and Sleep

One mechanism for a reciprocal relationship might be that sleep dysregulation lowers headache pain threshold, where headache pain may occur more easily in those individuals experiencing disturbed sleep (Dodick et al., 2003; Rains & Poceta, 2006). Complex fluctuations in neurotransmitters, especially melatonin and serotonin, have been hypothesized to impact the sleep/headache relationship, although the exact mechanisms of action are unclear (Brun, Claustrat, Saddier, & Chazot, 1995; Dodick et al., 2003; Labbe, Murphy, & O'Brien, 1997; Leone, D'Amico, Moschiano, Fraschini, & Bussone, 1996; Leone, Lucini, D'Amico, Moschiano, Maltempo, Fraschini et al., 1995; Peres, Sanchez del Rio, Seabra, Tufik, Abucham, Cipolla-Neto et al., 2001; Silberstein, 1994; Zurak, 1997). Additionally, neurological structures such as the

serotonergic dorsal raphe nuclei, noradrenergic locus ceruleus, and suprachiasmatic nucleus, which regulate those neurotransmitters' involvement in sleep-wake cycles and pain modulation, may be crucial to the sleep/headache relationship (Alberti, 2006; Zurak, 1997). However, support for those hypotheses is mixed. It is unclear if excess, deficient, or fluctuation of neurotransmitter levels are responsible for the relationship between sleep and headache (Brun et al., 1995; Dodick et al., 2003; Labbe et al., 1997; Leone et al., 1996; Leone et al., 1995; Olesen & Goadsby, 2000; Peres et al., 2001; Zurak, 1997). To date, a clear neurological model explaining the relationship between sleep and headache has not been developed.

Psychological Process Affecting Headaches and Sleep

When considering the link between psychological processes and headache and/or sleep, stress comes to the forefront as a major factor impacting both. Headache sufferers [as classified by the Headache Classification Committee of the International Headache Society (1988)] reported more work-related psychological stress, work overload and health-related stress than non-headache sufferers (Lin et al., 2007). In a college-aged sample, individuals with more severe headache symptoms were also more likely to have higher levels of perceived stress (Labbe et al., 1997). A thorough discussion of the role of stress in the progression of episodic headache into chronic daily headache can be found in Houle and Nash (2008). Overall, the review suggests that chronic headache sufferers report more daily hassles (but not more major life stressors) than non-headache control subjects, and that affective distress increases likelihood of chronic daily tension-type headache in predisposed individuals (Houle & Nash, 2008).

It is possible that stress may be a moderator or mediator between sleep and headache, and therefore should be taken into consideration. For example, stress might be a moderator if people higher in stress are more likely to show the relationship between sleep and headache than people

low in stress. Stress would be a mediator in the sleep/headache relationship if it can be determined that disrupted or abnormal sleep parameters lead to stress, which then itself leads to the headache occurrence. When headache sufferers are grouped by diagnosis (migraine versus tension-type), both lack of sleep and stress/tension are aggravating and precipitating factors for migraine over tension-type diagnoses (Spierings et al., 2001). It is important to note that this study did not elaborate upon or clarify if the "stress/tension" label referred to specific physical or psychological factors.

Conversely, an older review of the literature did not support the hypothesis that stress is importantly involved in headache (Dermit & Friedman, 1987). This review was based on the assumption that headache incidence should be significantly higher in populations presumed to experience high stress levels versus those presumed to experience low stress levels. The authors concluded that any stress-headache relationship found in the research could be explained by factors such as stress caused by head pain and the patients' own belief that stress is responsible for headache, and therefore the relationship is not due to external stressors.

Overall, the stress/headache relationship is difficult to disentangle, and associations with other mood issues such as depression and anxiety have also been found. Research has shown headache occurrence is a major stressor that may subsequently lead to depression and anxiety (Blanchard, 1992; Goadsby & Edvinsson, 1994). Similarly, other researchers have hypothesized the impact of headache pain on daily functioning may lead to feelings of helplessness, depression, and increased negative mood, which in turn increase subsequent pain sensitivity, making headaches more likely in the future (Janke, Holroyd, & Romanek, 2004; Williamson, Baker, & Cubic, 1993).

Limitations of Previous Research

Although classification of subjects according to diagnostic criteria is becoming common (Ferrari, Leone, Vergoni, Bertolini, Sances, Coccia et al., 2007; Hagen, Zwart, Vatten, Stovner, & Bovim, 2000; Inamorato et al., 1993; Kelman & Rains, 2005; Lin et al., 2007; Maizels & Burchette, 2004; Paiva, Batista, Martins, & Martins, 1995; Paiva et al., 1992), other studies reported above did not determine subjects' headache diagnosis (Blau, 1990; Boardman et al., 2005; Hale et al., 1987; Labbe et al., 1997; Spierings & van Hoof, 1997). In these studies, headaches were often classified regarding patterns of frequency (e.g., occasional, chronic daily, or cluster headache) or proximity to sleep (e.g., morning or nighttime headache), and not by specific headache diagnostic criteria suggested by the Headache Classification Subcommittee of the International Headache Society (2004). It is generally agreed that future research studies of headaches should define samples using these headache subtype definitions to allow for clarity and comparison of results between studies, as well as for the purpose of proper treatment referral (Task Force on Promotion and Dissemination of Psychological Procedures, 1995).

Rationale for the Current Study

It is important to identify which sleep parameters are most strongly related to headache because future experimental research can show that manipulation of these parameters does indeed cause an increase or decrease in headaches. The information gained from this study will help elucidate the relationship between sleep and headache in a population prone to shortened and inconsistent sleep patterns as well as frequent headache (Andrasik et al., 1979; Buboltz, Brown, & Soper, 2001; Curry & Green, 2007; Hawkins & Shaw, 1992; Irwin, 2007; Trockel, Barnes, & Egget, 2000; Tsai & Li, 2004; Valdez, Ramirez, & Garcia, 1996). A large sample size allows comparison of headache variables such as frequency, severity, and duration across sleep

parameters (e.g., total sleep time, inconsistent sleep patterns, and sleep disruption). It is also possible to make these comparisons across headache diagnoses of Tension-Type and Migraine-Type. Both of these analyses have been identified as lacking in the headache literature (Paiva et al., 1992). This study will also elucidate the role of stress as a moderator or mediator in the sleep/headache relationship.

Hypotheses

The prevalence of headache in the sample should be similar to or greater than the prevalence of headache in the general population, based on findings from previous research (Andrasik et al., 1979; Curry & Green, 2007; Irwin, 2007). Lower sleep efficiency (calculated as a composite of sleep onset latency, wake time after sleep onset, and total sleep time), shortened total sleep time, inconsistent sleep schedule and frequent nighttime awakenings will predict greater prevalence (presence and type), frequency, duration, and severity of headaches (Kelman & Rains, 2005). Stress will show a mediating role in the stress/headache relationship.

METHODS

Participants

The study was approved by the University of North Texas Institutional Review Board. Data was collected from undergraduate students at the University of North Texas (UNT) during the fall 2007 academic semester (August 2007 through December 2007). Students in psychology courses at UNT were awarded extra credit for completing an online health survey, a week-long sleep diary, and a battery of other questionnaires. The health survey was made up of questionnaires that assessed health behaviors, mood, sleep habits, and academic ability.

Procedure

The survey could be accessed and completed from any computer with an Internet connection. Each participant was sent a unique hyperlink to their own survey, which allowed them to save their progress and return at a later time to finish it if desired. Such an online format has several advantages over a paper survey. For example, the raw data is downloaded as a file which can then be transferred to a statistical package for data analysis. Also, the online method helps prevent data loss and data entry errors that may otherwise occur with hand-entered data. The following measures were selected for the proposed analysis.

Materials

Sleep Diaries

Sleep diaries were used to measure sleep patterns (Lichstein, Riedel, & Means, 1999). Participants completed diaries each morning for one week. The diaries asked participants to estimate their previous night's sleep (e.g., bedtime, sleep onset, number of awakenings, sleep quality). Independent variables for the subsequent analyses were sleep parameters derived from the completed sleep diaries: total sleep time (TST), sleep onset latency (SOL), wake time after

sleep onset (WASO), number of awakenings (NWAK), subjective sleep quality (SQ), objective sleep efficiency (SE), time between final awakening and getting out of bed (TWAK), and time in bed (TIB). Although objective measurement of sleep via polysomnography (i.e., overnight sleep studies) and to a lesser extent actigraphy would be ideal (Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2006), due to high expense this is rarely possible within epidemiological studies, and may not be warranted if the relationship is not strong enough to be found with less costly sleep diary assessment of sleep. In addition, sleep diaries have been validated against polysomnography (Coates, Killen, George, Marchini, Silverman, et al., 1982). Research has also found that sleep diaries are better estimates of sleep than single time point retrospective estimates (Coursey, Frankel, Gaarder, & Mott, 1980).

Headache Severity Questionnaire (HSQ)

The HSQ was designed to assess aspects of headache (a – c below) in the manner recommended by the International Headache Society Clinical Trials Subcommittee (2000), and address diagnostic criteria (d – e below) for tension-type and migraine-type headaches as described by the Headache Classification Subcommittee of the International Classification of Headache Disorders (2004):

a. Frequency. Number of days with headache in a four-week period (HSQ item 2).
b. Severity. Severity of attacks, rated on a four-level scale [no headache, mild headache (normal activity), moderate headache (disturbing but not prohibiting normal activity, bed rest not necessary), severe headache (normal activity discontinued, bed rest may be necessary)] (HSQ item 4).
c. Duration. Headache duration in hours (HSQ item 3).

d. Migraine headache**.** Peripheral vascular abnormalities, biochemical abnormalities, neurotransmitter/receptor dysfunction, and neuronal suppression may play pivotal roles (Olesen & Goadsby, 2000). Migraine headache is typically associated with unilateral location, moderate to severe intensity, nausea or vomiting, and aggravation due to physical activity, light, and sound (HSQ items 6a, 6c, and 6e-j).

e. Tension-type headache. Tension-type headaches are grouped by chronicity (episodic vs. chronic) and identifiable muscle involvement (tender upon palpation or elevated electromyograph vs. muscle involvement not present) (Headache Classification Committee of the International Headache Society, 1988). Factors that may precipitate or exacerbate tension-type headaches include oromandibular dysfunction, sleep, psychosocial stress, anxiety, depression, delusion, muscular stress, drug overdose, or other headache condition (Headache Classification Committee of the International Headache Society, 1988). This type of headache is typically associated with bilateral location, mild to moderate intensity, no nausea/vomiting, and no aggravation due to physical activity, light, or sound. Tension-type headache, more than migraine headache, has been associated with sleep disorders (Langemark, Olesen, Poulsen, & Bech, 1988) (HSQ items 6b, 6d).

Responses to items on the HSQ corresponding to diagnostic criteria d & e above were dichotomized into diagnosable headache absent (DHA) or diagnosable headache present (DHP), with the latter further dichotomized into tension-type headache (TTH) or migraine-type headache (MTH).

Perceived Stress Scale (PSS)

The PSS is a widely used, brief, and easily administered psychological instrument that measures the degree to which a subject appraises situations in their life as stressful. The PSS questions ask about frequency of stressful events, current (within the last month) level of stress, and are relatively general in nature. The PSS has adequate internal reliability (Cohen, Kamarck, & Mermelstein, 1983).

Alcohol Use Disorders Identification Test (AUDIT)

The AUDIT was designed as a screening instrument to detect alcohol consumption that has become harmful to health rather than alcoholism. It was investigated as a possible covariate with headache variables. The AUDIT consists of 10 multiple-choice and yes-no questions that use a 5-point Likert scale (range 0 – 4). Reliability was established on undergraduate students with a Cronbach's alpha of 0.80. In clinical and non-clinical populations, the AUDIT was highly correlated with other self-reports of alcohol problems such as the Michigan Alcoholism Screening Test (r = 0.88) (Saunders, Aasland, Babor, et al., 1993).

RESULTS

Participants

The sample consisted of 156 males and 355 females (N = 511), with a mean age of 20 (SD = 4.49). The sample was 65.7% European American, 12.1% Hispanic, 10.6% African American, 7.9% Asian/Pacific Islander, 0.6% Native American, and 1.5% "Other." A total of 80.0% (n = 420) reported experiencing some sort of headache within the past 12 months, with 35.1% (n = 182) meeting the International Classification of Headache Disorders diagnostic criteria for either tension-type headache (17.0%, n = 88) or migraine-type headache (18.1%, n = 94). A total of 29.7% (n = 154) reported experiencing a headache, but symptoms fully met neither tension-type nor migraine-type diagnostic criteria. In addition, 16.2% (n = 84) reported experiencing headaches, but did not report specific symptoms. Descriptive statistics for sleep parameters can be seen in Table 1 and for the headache and substance use variables in Table 2.

Headache Variables and Sleep Variables

Pearson product-moment correlations were run between sleep variables (total sleep time [TST], time in bed [TIB], sleep efficiency [SE], sleep onset latency [SOL], wake time after sleep onset [WASO], time between final awakening and getting out of bed [TWAK], number of awakenings[NWAK], and sleep quality[SQ]) and headache variables (headache frequency, headache severity, and headache duration). Results can be seen in Table 3. Decreased SE was related to increased headache duration and severity; increased SOL was related to increased headache frequency, duration, and severity; increased WASO was related to increased headache duration and severity; increased NWAK was related to increased headache frequency and severity; decreased SQ was related to increased headache frequency, duration, and severity. A measure of sleep schedule irregularity was calculated based on how many nights per week a

person got ± 2 hours from their personal average TST. This variable was not significantly correlated with any of the headache variables; therefore it was not included in subsequent analyses.

Multiple Linear Regressions

To test how well sleep parameters predict the different headache variables and to indicate how much of the variance of the headache variables can be accounted for by the linear combination of the sleep parameters, three multiple linear regression analyses were performed with sleep parameters of interest (TST, SE, SQ) as independent (predictor) variables and either headache frequency, severity, or duration as dependent (criterion) variables (Table 6).

The total variance in headache frequency explained by the model of TST, SQ, and SE as a whole was 4.1%, F (3, 465) = 6.549, $p < .001$. In this model, only SQ was statistically significant (beta = -.190, $p < .001$). In this and all subsequent regression results, beta values are standardized coefficients that indicate the number of standard deviations that scores in the dependent variable would change if there was a one standard deviation unit change in the predictor. In this case, for every one standard deviation increase in self-reported SQ, there was a .19 standard deviation decrease in headache frequency.

The total variance in headache duration explained by the model of TST, SQ, and SE was 2.6%, F (3, 465) = 5.269, $p < .01$. In this model, only SE was statistically significant (beta = -.127, $p < .05$). For every one standard deviation increase in SE, there was a .127 standard deviation decrease in headache duration.

The total variance in headache severity explained by the model of TST, SQ, and SE was 3.1%, F (3, 468) = 5.056, $p < .01$. In this model, two independent variables were statistically significant, with SE recording a higher beta value (beta = -.120, $p < .05$) than SQ (beta = -.096, p

< .05). For every one standard deviation increase in SE, there was a .12 standard deviation decrease in headache severity. In addition, for every one standard deviation increase in SQ, there was a .096 standard deviation decrease in headache severity.

Follow-up Multiple Linear Regressions with Sleep Efficiency Components

These analyses investigated whether any of the specific components of sleep efficiency (SOL, WASO, TWAK, NWAK, and TIB) significantly contribute to each of the headache variables for which SE was found to make a significant contribution (headache duration and headache severity).

The total variance in headache duration explained by the model of SOL, WASO, TWAK, NWAK, and TIB was 3.0%, F (5, 468) = 2.851, $p < .05$. In this model, only SOL was statistically significant (beta = .111, $p < .05$). For every one standard deviation increase in SOL, there was a .111 standard deviation increase in headache duration.

The total variance in headache severity explained by the model of SOL, WASO, TWAK, NWAK, and TIB was 4.3%, F (5, 471) = 4.204, $p = .001$. In this model, two independent variables were equally statistically significant, SOL (beta = .109, $p < .05$) and NWAK (beta = .109, $p < .05$). For every one standard deviation increase in SOL there was a .109 standard deviation increase in headache severity. In addition, for every one standard deviation increase in NWAK there was a .109 standard deviation increase in headache severity.

Hierarchical Multiple Regressions

Subsequent to the above multiple linear regressions, covariates discovered (Tables 4 and 5) were controlled for in separate analyses (e.g., hierarchical linear regressions, with covariates entered into the model first to control for their effect on the dependent variable). As expected, gender was a significant covariate with all three headache variables, but it cannot be

experimentally manipulated and therefore will not be controlled for in subsequent analyses (Miller & Chapman, 2001). Stress (as measured by the PSS total score) was a significant covariate with headache frequency and severity only. Alcohol use (as measured by the Alcohol Use Disorders Identification Test [AUDIT] total score) did not appear to be a covariate with any of the headache variables.

A hierarchical multiple regression was used to assess the ability of a model consisting of TST, SQ, and SE to predict headache frequency, after controlling for the influence of stress. Stress was entered at Step 1, explaining 4.6% of the variance in headache frequency. After entry of TST, SQ, and SE at Step 2 the total variance explained by the model as a whole was 6.6%, F (4, 464) = 8.175, $p < .001$. TST, SQ, and SE explained an additional 2.0% of the variance in headache frequency, after controlling for stress, R^2 change = .020, F change (3, 464) = 3.308, $p <$ .05. In the final model, both stress and SQ were statistically significant, with stress recording a higher beta value (beta = .168, $p < .001$) than SQ (beta = -.142, $p < .005$). For every one standard deviation increase in stress there was a .168 standard deviation increase in headache frequency. Holding all other variables constant, for every one standard deviation increase in SQ there was a .142 standard deviation decrease in headache frequency.

A hierarchical multiple regression assessed the ability of a model consisting of TST, SQ, and SE to predict headache severity, after controlling for the influence of stress. Stress was entered at Step 1, explaining 4.2% of the variance in headache severity. After entry of TST, SQ, and SE at Step 2, the total variance explained by the model as a whole was 5.9%, F (4, 467) = 7.257, $p < .001$. TST, SQ, and SE explained an additional 1.6% of the variance in headache severity, after controlling for stress, R^2 change = .016, F change (3, 467) = 2.687, $p < .05$. In the final model both stress and SE were statistically significant, with stress recording a higher beta

value (beta = .174, $p < .001$) than SE (beta = -.111, $p < .05$). For every one standard deviation increase in stress there was a .174 standard deviation increase in headache severity. Holding all other variables constant, for every one standard deviation increase in SE there was a .111 standard deviation decrease in headache severity.

Follow-up Hierarchical Multiple Regressions with Sleep Efficiency Components

These analyses investigate whether any of the specific components of SE (SOL, WASO, TWAK, NWAK, and TIB) significantly contribute to the headache variable for which SE was found to make a significant contribution (headache severity).

Hierarchical multiple regression assessed the ability of a model consisting of SOL, WASO, TWAK, NWAK, and TIB to predict headache severity, after controlling for the influence of stress. Stress was entered at Step 1, explaining 4.2% of the variance in headache severity. After entry of SOL, WASO, TWAK, NWAK, and TIB at Step 2, the total variance explained by the model as a whole was 7.5%, $F(6, 470) = 6.383$, $p < .001$. SOL, WASO, TWAK, NWAK, and TIB explained an additional 3.3% of the variance in headache severity, after controlling for stress, R^2 change = .033, F change (5, 470) = 3.362, $p < .01$. In the final model, only stress was statistically significant (beta = .184, $p < .001$). Holding all other variables constant, for every one standard deviation increase in stress, there was a .184 standard deviation increase in headache severity.

Headache Diagnostic Groups and Sleep Variables

Logistic Regressions

Logistic regressions were performed to determine if sleep parameters predict the categorical headache dependent variables (diagnosable headache present [DHP] versus diagnosable headache absent [DHA] and tension-type headache [TTH] versus migraine-type

headache [MTH]) and to provide an indication of the relative importance of each predictor variable in the interaction among the predictor variables.

Direct logistic regression was performed to assess the impact of a number of factors on the likelihood that respondents would report that they had a diagnosable headache. The model contained three independent variables (TST, SE, and SQ). The full model containing all predictors was not statistically significant, χ^2 (3, n = 478) = 5.461, p = .141, indicating that this model was not able to distinguish between respondents who did or did not report a diagnosable headache. A corresponding discriminant function analysis with the dependent variable DHP and the independent variables of SE, SQ and TST showed a nonsignificant Wilks's lambda (p = .136), indicating no differences among groups across the three predictor variables.

Direct logistic regression was performed to assess the impact of a number of factors on the likelihood that the respondents would report that they had DHP versus DHA (Table 8). The model contained five independent variables (SOL, WASO, TWAK, NWAK and TIB). The full model containing all predictors was statistically significant, χ^2 (5, n = 491) = 14.92, $p < .05$, indicating that the model was able to distinguish between respondents who did and did not report a diagnosable headache. The model as a whole explained between 3.0% (Cox & Snell R^2) and 4.1% (Nagelkerke R^2) of the variance in headache status. As shown in Table 8, only one of the independent variables (NWAK) made a unique statistically significant contribution to the model and was the strongest predictor of headaches, recording an odds ratio of 1.33. This indicated that respondents who had frequent nighttime awakenings were 1.33 times more likely to report a diagnosable headache than those who did not have frequent nighttime awakenings, controlling for all other factors in the model. For every unit increase in nighttime awakenings, the odds of having a diagnosable headache increase by a factor of 1.33.

Direct logistic regression was performed to assess the impact of a number of factors on the likelihood that respondents would report TTH versus MTH (Table 9). The model contained three independent variables (TST, SE, and SQ). The full model containing all predictors was statistically significant, χ^2 (3, n = 176) = 9.41, p < .05, indicating that the model was able to distinguish respondents who reported TTH from those who reported MTH. The model as a whole explained between 5.2% (Cox & Snell R^2) and 6.9% (Nagelkerke R^2) of the variance in headache diagnosis. As shown in Table 9, only one of the independent variables (SQ) made a statistically significant contribution to the model, recording an odds ratio of 1.67. This indicated the respondents who had higher self-reported sleep quality were 1.67 times likely to fall into the TTH category rather than the MTH category, controlling for all other factors in the model.

Direct logistic regression was performed to assess the impact of a number of factors on the likelihood that respondents would report TTH versus MTH (Table 10). The model contained five independent variables (SOL, WASO, TWAK, NWAK, and TIB). The full model containing all predictors was statistically significant, χ^2 (5, n = 176) = 18.55, p <.005, indicating the model was able to distinguish respondents who reported TTH from those who reported MTH. The model as a whole explained between 10.0% (Cox & Snell R^2) and 13.3% (Nagelkerke R^2) of the variance in headache diagnosis. As shown in Table 10, two independent variables (TWAK and WASO) made statistically significant contributions to the model. The strongest predictor of headache diagnosis was TWAK, recording an odds ratio of 1.04. This indicated respondents who spent more time awake in bed after waking up in the morning were 1.04 times more likely to have a diagnosis of TTH, controlling for all other factors in the model.

Mediation Analyses

As previously mentioned, stress may play a role as either a mediator or moderator in the sleep/headache relationship. If a mediating effect (i.e., stress accounts for the relationship between sleep and headache) exists, the correlation between the sleep parameters and headache severity, frequency, or duration should be positive, but the correlation between those variables partialling out the effects of stress should approach zero.

The mediator analyses followed the method described by Baron and Kenny (1986). In the first set of analyses, sleep variables were regressed onto headache variables (frequency, duration, severity) (Table 11). In the next set of analyses, sleep variables shown to be significantly related to headache variables in the first set of analyses (SQ, SOL, SE, NWAK, WASO) were regressed onto stress (Table 12). All of the variables were significantly associated with stress except WASO, which will not be included in subsequent analyses. The final analyses regressed both individual sleep variables (SQ, SOL, SE, NWAK; based on the significance results shown in Tables 11 and 12) and stress onto each of the three headache variables (Table 13). In this table, b(YX) is the total effect of the independent variable on the dependent variable and is represented by *c* in the mediation figure (Figure 1). The term b(MX) is the effect of the independent variable on the mediator, and is represented by *a* in the mediation figure. The term b(YM.X) is the effect of the mediator on the dependent variable, after controlling for the independent variable, and is represented by *b* in the mediation figure. The term b(YX.M) is the direct effect of the independent variable on the dependent variable after controlling for the mediator, and is represented by *c'* in the mediation figure.

Stress appears to be a significant mediator between SQ and headache severity. This was the only case in which stress appears to have a mediating effect.

Moderation Analysis

Upon further reading, it seems that a moderation analysis may be inappropriate for this data set. According to Judd, Kenny, & McClelland (2001), moderation analyses are based on the presumption that the independent variable (in this case, sleep variables) is manipulated and randomized, and that there is a direct causal relationship between the independent and dependent variables. Regarding causality, it is emphasized that if the direction of the causal relationship is not clearly known and is actually the opposite of what is presumed, then the moderator effect may be flipped and the statistical results will be incorrect.

DISCUSSION

Eighty percent of our sample reported experiencing headaches within the past 12 months, which is somewhat less than the Mannix (2001) figure (90%; which represents headache at any point in life), but greater than other one-year prevalence findings (13.4%, Kryst & Scherl, 1994; 38%, Hagen et al., 2000; 46%, Ojini, Okubadejo, & Danesi, 2009). Lower sleep efficiency (SE) was related to increased headache duration and headache severity. Of the sleep efficiency components, increased sleep onset latency (SOL) contributed the most to the variation in headache duration, and both increased SOL and increased number of awakenings (NWAK) contributed to the variation in headache severity, which corresponds to previous research findings (Boardman et al., 2005; Paiva et al., 1992; Penzien et al., 2001). Self-reported sleep quality (SQ) was inversely related to both headache severity and headache frequency. Total sleep time (TST) was neither significantly correlated with, nor predictive of, any of the headache variables. The strongest predictor of reporting a diagnosable headache was NWAK; respondents who had frequent nighttime awakenings were more likely to report a diagnosable headache than a non-diagnosable headache. One mechanism underlying this relationship may be that NWAK's contribution to headache severity, as addressed above, is the most important factor in whether or not an individual meets diagnostic criteria. The strongest predictor of reported headache diagnosis was self-reported SQ; respondents with lower self-reported SQ were more likely to report migraine-type headache (MTH) versus tension-type headache (TTH). Conversely, higher SQ was predictive of TTH. Additionally, although SE itself was not predictive of headache type, one of the SE components, greater time between final awakening and getting out of bed (TWAK), was predictive of TTH.

SQ has not often been addressed in the literature and its value as a predictor may be questionable since it is a subjective self-reported value, but its strength as a holistic measure of sleep and as an indicator of future investigations must be acknowledged. SQ may vary from person to person even when all other sleep variables are the same, based on individual interpretation of how critical sleep is on that night. For example, poor objective sleep on the night before a major exam may receive a lower SQ rating than the same sleep parameters experienced the night before no major obligations. In addition, if sleep could be objectively measured via actigraphy or PSG and then compared to subjective SQ, it may be possible to obtain an index of degree of "correctness" of sleep perception. Perhaps individuals who over-report poor sleep quality also over-report distressing headache symptoms. Personality measures that tap into somatization tendencies may also elucidate this relationship.

The lack of relationship between TST and headache is surprising given the strong support for the relationship in the current literature (Blau, 1990; Inamorato, Minatti-Hannuch, & Zukerman, 1993; Kelman & Rains, 2005; Paiva et al., 1992; Spierings, Ranke, & Honkoop, 2001). The results of this study suggest that absolute time spent asleep is not as important a relationship to headache as some of the more specific aspects of sleep (SOL, wake time after sleep onset [WASO], and NWAK). Currently, this is the only study known to show the relationships between these specific sleep variables and headache.

Mediating/Moderating Role of Stress

It was hypothesized that stress would play either a mediating and/or moderating role in the sleep/headache relationship. Stress only appears to be a mediator between SQ and headache severity, indicating that stress partially accounts for the relationship between SQ and headache severity. This mediating effect may be due to the impact of stress on the subjective natures of

both headache severity and SQ, and the holistic nature of SQ. High levels of stress may cause individuals to interpret their sleep as being of poorer quality than similar sleep in someone without such stress, or their headache at a greater severity. Despite these hypotheses, it must be noted that it is not appropriate to make statements of causality based on this cross-sectional data.

Strengths

This study was the most comprehensive assessment of both sleep (i.e., sleep variables such as SOL, WASO, NWAK, etc. obtained via week-long sleep diaries) and headaches (i.e., headache frequency, duration, severity and diagnosis utilizing International Classification of Headache Disorders [ICHD] diagnostic criteria) to date. It also consisted of a large sample size, used week-long sleep diaries instead of single time-point retrospective sleep reporting, used ICHD diagnostic criteria for MTH and TTH, and addressed the relationship between headache diagnosis and specific sleep variables.

Limitations

Since the study was cross-sectional causality cannot be inferred – it is still unclear if headache pain causes or intensifies sleep disturbance, or the reverse. However, this was an important first step in establishing relationships between the two phenomena.

It may have been useful to collect polysomnograph (PSG) and/or actigraph data as objective assessments of sleep, but this is generally untenable in such a large study due to cost restrictions. Further, the headache data was all recall, which may have introduced inaccuracies in symptom reporting.

Finally, this study did not collect lifetime headache prevalence data; it is not clear if that data would have added significant value to the study, but as previously mentioned, it may have made comparison to other studies easier. Although previous studies give headache frequency

over varying time frames (e.g., one month, six months, lifetime), the current study follows ICHD diagnostic criteria (i.e., days per month and months in the past year), which is arguably the standard time, making our results comparable to future studies, which will likely also follow the ICHD standards.

Future Directions

Future studies should adopt an experimental design in which sleep variables are manipulated in a sleep laboratory and changes in headache observed, in order to establish a causal relationship between the two. With a smaller sample size, it may be possible and financially feasible to measure participants' sleep via actigraphy and headaches via a diagnostic headache questionnaire on a hand-held computer used as a data collection device. Such hand-held devices have been used to track fibromyalgia pain in an investigation of the relationship between fibromyalgia and sleep (Hamilton et al., 2008). In this study, the hand-held devices were also used to wake the participants each morning and administer a series of sleep quality and total sleep time questions. Actigraphy in combination with sleep quality and headache questionnaires may provide the best quality data for future studies short of actively manipulating participants' sleep.

Summary

This study supports previous research showing that links do exist between sleep variables and headache variables, and that some sleep variables may even predict headache diagnosis. Although there were a few minor limitations (i.e., non-experimental design, lack of objective sleep measures, etc.), this is the most comprehensive incorporation of week-long sleep diary data and ICHD headache diagnostic information.

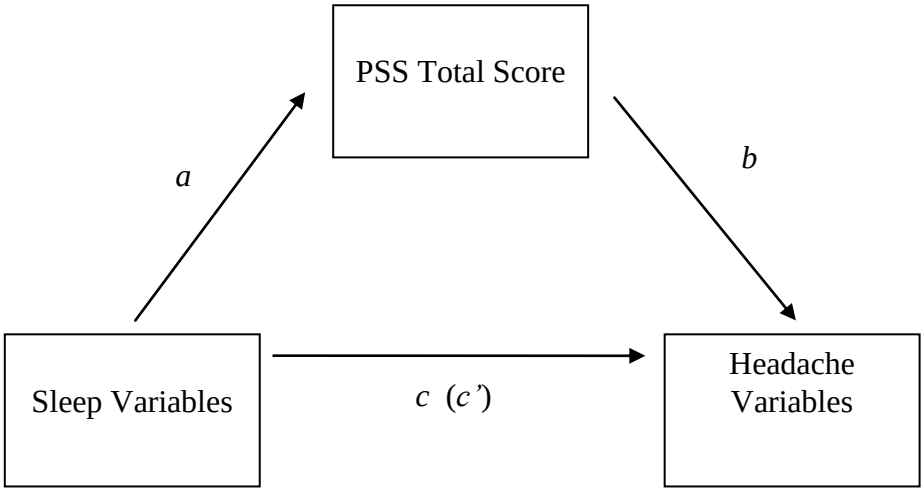

Figure 1. Mediation of stress between sleep and headache.

Table 1

Descriptive Statistics for Sleep Variables

	Mean	*SD*	Range
SE (%)	93.37	4.78	61.05-100.00
SQ	3.40	.86	1.00-5.00
TST (minutes)	444.10	69.70	106.25-679.00
SOL (minutes)	14.88	12.56	0.00-100.00
WASO (minutes)	4.20	6.41	0.00-75.00
TWAK (minutes)	10.48	9.73	0.00-75.86
NWAK	1.03	1.19	0.00-11.00
TIB (minutes)	452.05	112.02	0.00-687.14

Note: SE = Sleep efficiency; SQ = Sleep quality; TST = Total sleep time; SOL = Sleep onset latency; WASO = Wake time after sleep onset; TWAK = Time between final awakening and getting out of bed; NWAK = Number of awakenings; TIB = Time in bed.

Table 2

Descriptive Statistics for Headache and Substance Use Variables

	Mean	*SD*	Range
Number of months in the past 12 months with headache	5.72	4.858	0-12
Estimated FREQUENCY of attacks per month (in days per month).	4.00	5.36	0-30
Estimated DURATION of pain (in hours) for each attack.	2.55	5.27	0-72
Estimated SEVERITY of pain for each attack (1=mild, 5=severe).	2.32	1.17	1-5
PSS-Total	17.71	7.15	0-36
AUDIT-Total	3.52	4.40	0-23

Note: PSS-Total = Total score on Perceived Stress Scale; AUDIT-Total = Total score on Alcohol Use Disorders Identification Test

Table 3

Pearson Product-Moment Correlation Coefficients between Sleep Variables and Headache Variables

	TST	TIB	SE	SOL	WASO	TWAK	NWAK	SQ
Headache Frequency	-.039	.033	-.086	.117*	.037	.057	.215**	-.199**
Headache Duration	-.046	.019	-.143**	.142**	.122**	.083	.058	-.108*
Headache Severity	-.067	.036	-.151**	.154**	.125**	.047	.155**	-.131**

Note: TST = Total sleep time; TIB = Time in bed; SE = Sleep efficiency; SOL = Sleep onset latency; WASO = Wake time after sleep onset; TWAK = Time between final awakening and getting out of bed; NWAK = Number of awakenings; SQ = Sleep quality.
*p<.05, **p<.01

Table 4

Pearson Product-Moment Correlation Coefficients between Headache Variables and Potential Covariates

	Age	PSS-Total	AUDIT-Total
Headache Frequency	.017	.214**	-.039
Headache Duration	.046	.034	.024
Headache Severity	.056	.206**	.024

Note: PSS-Total = Total score on Perceived Stress Scale; AUDIT-Total = Total score on Alcohol Use Disorders Identification Test
*p<.05, **p<.01

Table 5

Independent Sample t-*Test for Gender and Headache Variables*

	Males (n = 156)		Females (n = 355)		
	Mean	*SD*	Mean	*SD*	*t*
Headache Frequency	2.06	3.51	4.88	5.802	-6.57**
Headache Duration	1.5	2.09	3.03	6.14	-4.04**
Headache Severity	1.89	1.09	2.51	1.16	-5.59**

*p<.05, **p<.01

Table 6

Regression Analysis Summary for Sleep Variables Predicting Headache Variables

	Sleep Variable	*B*	SEB	Beta
Headache Frequency	TST	-.001	.004	-.013
	SE	-.030	.058	-.027
	SQ	-1.185	.296	-.190**
Headache Duration	TST	.001	.004	.013
	SE	-.140	.058	-.127*
	SQ	-.451	.293	-.074
Headache Severity	TST	.000	.001	-.009
	SE	-.029	.013	-.120*
	SQ	-.132	.065	-.096*

Note: TST = Total sleep time; SE = Sleep efficiency; SQ = Sleep quality.
*p<.05, **p<.01

Table 7

Regression Analysis Summary for Sleep Efficiency Components Predicting Headache Variables

	Sleep Variable	*B*	SEB	Beta
Headache Duration	SOL	.047	.021	.111*
	WASO	.070	.040	.085
	TWAK	.020	.026	.038
	NWAK	.028	.214	.006
	TIB	.000	.002	-.004
Headache Severity	SOL	.010	.005	.109*
	WASO	.013	.009	.070
	TWAK	.000	.006	-.002
	NWAK	.108	.047	.109*
	TIB	.000	.000	.011

Note: SOL = Sleep onset latency; WASO = Wake time after sleep onset; TWAK = Time between final awakening and getting out of bed; NWAK = Number of awakenings; TIB = Time in bed.

Table 8

Logistic Regression for Sleep Efficiency Components Predicting Likelihood of Reporting a Diagnosable Headache

							95% C.I. for Odds Ratio	
	B	S.E.	Wald	*df*	*p*	Odds Ratio	Lower	Upper
SOL	.006	.008	.540	1	.462	1.006	.990	1.022
WASO	.001	.016	.003	1	.955	1.001	.970	1.032
TWAK	.011	.011	1.075	1	.300	1.011	.990	1.032
NWAK	.284	.096	8.757	1	.003	1.329	1.101	1.604
TIB	.000	.001	.047	1	.828	1.000	.998	1.003
Constant	-1.229	.661	3.453	1	.063	.293		

Note: SOL = Sleep onset latency; WASO = Wake time after sleep onset; TWAK = Time between final awakening and getting out of bed; NWAK = Number of awakenings; TIB = Time in bed.

Table 9

Logistic Regression Predicting Tension-type Headache versus Migraine-type Headache

							95% C.I. for Odds Ratio	
Sleep Variables	*B*	S.E.	Wald	*df*	*p*	Odds Ratio	Lower	Upper
TST	-.002	.003	.765	1	.382	.998	.992	1.003
SE	.020	.037	.283	1	.595	1.020	.949	1.096
SQ	.510	.208	6.051	1	.014	1.666	1.109	2.502
Constant	-2.547	2.839	.805	1	.370	.078		

Note: TST = Total sleep time; SE = Sleep efficiency; SQ = Sleep quality.

Table 10

Logistic Regression for Sleep Efficiency Components Predicting Tension-type Headache versus Migraine-type Headache

							95% C.I. for Odds Ratio	
Sleep Variables	*B*	S.E.	Wald	*df*	*p*	Odds Ratio	Lower	Upper
SOL	-.006	.015	.153	1	.696	.994	.965	1.024
WASO	-.106	.045	5.592	1	.018	.900	.824	.982
TWAK	.043	.019	5.356	1	.021	1.044	1.007	1.084
NWAK	-.220	.155	2.007	1	.157	.803	.592	1.088
TIB	-.004	.003	2.015	1	.156	.996	.992	1.001
Constant	1.951	1.180	2.732	1	.098	7.033		

Note: SOL = Sleep onset latency; WASO = Wake time after sleep onset; TWAK = Time between final awakening and getting out of bed; NWAK = Number of awakenings; TIB = Time in bed.

Table 11

Regression Analyses Testing the Effects of Sleep Variables on Headache Variables

Headache Variables	Predictors	r^2	*B*	Beta	*t*	*p*
Headache Frequency	SQ	.039	-1.239	-.199	-4.435	<.001
	TST	.002	-.003	-.039	-.838	.403
	TIB	.001	.002	.033	.708	.479
	SE	.007	-.098	-.086	-1.860	.064
	SOL	.014	.053	.117	2.566	.011
	WASO	.001	.031	.037	.811	.418
	TWAK	.003	.031	.057	1.243	.215
	NWAK	.046	1.064	.215	4.813	<.001
Headache Duration	SQ	.012	-.666	-.108	-2.386	.017
	TST	.002	-.004	-.046	-1.000	.318
	TIB	.000	.001	.019	.405	.685
	SE	.020	-.160	-.143	-3.117	.002
	SOL	.020	.064	.142	3.133	.002
	WASO	.015	.100	.122	2.674	.008
	TWAK	.007	.045	.083	1.816	.070
	NWAK	.003	.280	.058	1.260	.208
Headache Severity	SQ	.017	-.178	-.131	-2.900	.004
	TST	.004	-.001	-.067	-1.453	.147
	TIB	.001	.001	.036	.791	.429
	SE	.023	-.038	-.151	-3.314	.001
	SOL	.024	.015	.154	3.415	.001
	WASO	.016	.023	.125	2.753	.006
	TWAK	.002	.006	.047	1.024	.306
	NWAK	.024	.167	.155	3.431	.001

Note: SQ = Sleep quality; TST = Total sleep time; TIB = Time in bed; SE = Sleep efficiency; SOL = Sleep onset latency; WASO = Wake time after sleep onset; TWAK = Time between final awakening and getting out of bed; NWAK = Number of awakenings.

Table 12

Regression Analyses Testing the Effects of Sleep Variables on PSS-Total

	r^2	*B*	Beta	*t*	*p*
SQ	.092	-2.518	-.304	-6.996	<.001
SOL	.017	.079	.131	2.887	.004
SE	.026	-.242	-.160	-3.510	<.001
NWAK	.012	.710	.108	2.377	.018
WASO	.002	.052	.047	1.025	.306

Note: SQ = Sleep quality; SOL = Sleep onset latency; SE = Sleep efficiency; NWAK = Number of awakenings; WASO = Wake time after sleep onset.

Table 13

Regression Analyses Testing Direct and Total Mediation Effects

	Predictors		Coefficient	S.E.	*t*	*p*
Headache Frequency	SQ	b(YX)	-1.2393	.2795	-4.4345	.0000
		b(MX)	-2.4726	.3628	-6.8149	.0000
		b(YM.X)	.1277	.0347	3.6744	.0003
		b(YX.M)	-.9236	.2890	-3.1965	.0015
	SOL	b(YX)	.0531	.0207	2.5658	.0106
		b(MX)	.0775	.0275	2.8177	.0050
		b(YM.X)	.1508	.0338	4.4621	.0000
		b(YX.M)	.0414	.0205	2.0238	.0436
	NWAK	b(YX)	1.0637	.2210	4.8126	.0000
		b(MX)	.6929	.2986	2.3202	.0207
		b(YM.X)	.1445	.0333	4.3370	.0000
		b(YX.M)	.9636	.2182	4.4157	.0000
Headache Duration	SQ	b(YX)	-.6658	.2790	-2.3859	.0174
		b(MX)	-2.4660	.3637	-6.7800	.0000
		b(YM.X)	.0014	.0351	.0398	.9683
		b(YX.M)	-.6623	.2924	-2.2649	.0240
	SE	b(YX)	-.1605	.0515	-3.1166	.0019
		b(MX)	-.2395	.0689	-3.4753	.0006
		b(YM.X)	.0058	.0346	.1671	.8673
		b(YX.M)	-.1591	.0522	-3.0473	.0024
	SOL	b(YX)	.0635	.0203	3.1331	.0018
		b(MX)	.0779	.0275	2.8328	.0048
		b(YM.X)	.0106	.0338	.3127	.7546
		b(YX.M)	.0627	.0205	3.0639	.0023
Headache Severity	SQ	b(YX)	-.1782	.0614	-2.8999	.0039
		b(MX)	-2.5179	.3599	-6.9959	.0000
		b(YM.X)	.0300	.0077	3.9112	.0001
		b(YX.M)	-.1027	.0636	-1.6162	.1067
	SE	b(YX)	-.0376	.0113	-3.3135	.0010
		b(MX)	-.2418	.0689	-3.5104	.0005
		b(YM.X)	.0290	.0075	3.8790	.0001
		b(YX.M)	-.0305	.0113	-2.6994	.0072

(table continues)

Table 13 *(continued)*.

Headache Variables	Predictors		Coefficient	S.E.	*t*	*p* (two-tailed)
Headache Severity *(continued)*	SOL	b(YX)	.0154	.0045	3.4148	.0007
		b(MX)	.0794	.0275	2.8866	.0041
		b(YM.X)	.0304	.0073	4.1469	.0000
		b(YX.M)	.0129	.0045	2.9005	.0039
	NWAK	b(YX)	.1675	.0488	3.4307	.0007
		b(MX)	.7101	.2987	2.3772	.0178
		b(YM.X)	.0307	.0073	4.1789	.0000
		b(YX.M)	.1457	.0483	3.0175	.0027

Note: SQ = Sleep quality; SE = Sleep efficiency; SOL = Sleep onset latency; NWAK = Number of awakenings.

REFERENCES

Alberti, A. (2006). Headache and sleep. *Sleep Medicine Reviews, 10*(6), 431-437.

Andrasik, F., Holroyd, K. A., & Abell, T. (1979). Prevalence of headache within a college student population: A preliminary analysis. *Headache, 19*(7), 384-387.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173-1182.

Blanchard, E. B. (1992). Psychological treatment of benign headache disorders. *Journal of Consulting and Clinical Psychology, 60*(4), 537-551.

Blau, J. N. (1982). Resolution of migraine attacks: Sleep and the recovery phase. *Journal of Neurology, Neurosurgery, and Psychiatry, 45*(3), 223-226.

Blau, J. N. (1990). Common headaches: Type, duration, frequency and implications. *Headache, 30*(11), 701-704.

Boardman, H. F., Thomas, E., Millson, D. S., & Croft, P. R. (2005). Psychological, sleep, lifestyle, and comorbid associations with headache. *Headache, 45*(6), 657-669.

Brun, J., Claustrat, B., Saddier, P., & Chazot, G. (1995). Nocturnal melatonin excretion is decreased in patients with migraine without aura attacks associated with menses. *Cephalalgia, 15*(2), 136-139.

Buboltz, W. C., Jr., Brown, F., & Soper, B. (2001). Sleep habits and patterns of college students: A preliminary study. *Journal of American College Health, 50*(3), 131-135.

Buysse, D. J., Ancoli-Israel, S., Edinger, J. D., Lichstein, K. L., & Morin, C. M. (2006). Recommendations for a standard research assessment of insomnia. *Sleep, 29*(9), 1155-1173.

Coates, T. J., Killen, J. D., George, J., Marchini, E., Silverman, S., & Thoresen, C. (1982). Estimating sleep parameters: A multitrait--multimethod analysis. *Journal of Consulting and Clinical Psychology, 50*(3), 345-352.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior, 24*(4), 385-396.

Coursey, R. D., Frankel, B. L., Gaarder, K. R., & Mott, D. E. (1980). A comparison of relaxation techniques with electrosleep therapy for chronic, sleep-onset insomnia a sleep-EEG study. *Biofeedback and Self-Regulation, 5*(1), 57-73.

Curry, K., & Green, R. (2007). Prevalence and management of headache in a university undergraduate population. *Journal of the American Academy of Nurse Practitioners, 19*(7), 378-382.

Dermit, S., & Friedman, R. (1987). Stress and headache: A critical review. *Stress Medicine, 3*, 285-292.

Dodick, D. W., Eross, E. J., Parish, J. M., & Silber, M. (2003). Clinical, anatomical, and physiologic relationship between sleep and headache. *Headache, 43*(3), 282-292.

Ferrari, A., Leone, S., Vergoni, A. V., Bertolini, A., Sances, G., Coccia, C. P., et al. (2007). Similarities and differences between chronic migraine and episodic migraine. *Headache, 47*(1), 65-72.

Goadsby, P. J., & Edvinsson, L. (1994). Human in vivo evidence for trigeminovascular activation in cluster headache: Neuropeptide changes and effects of acute attacks therapies. *Brain, 117*(3), 427-434.

Hagen, K., Zwart, J. A., Vatten, L., Stovner, L. J., & Bovim, G. (2000). Prevalence of migraine and non-migrainous headache--head-HUNT, a large population-based study. *Cephalalgia, 20*(10), 900-906.

Hale, W. E., May, F. E., Marks, R. G., Moore, M. T., & Stewart, R. B. (1987). Headache in the elderly: An evaluation of risk factors. *Headache, 27*(5), 272-276.

Hamilton, N. A., Affleck, G., Tennen, H., Karlson, C., Luxton, D., Preacher, K. J., et al. (2008). Fibromyalgia: The role of sleep in affect and in negative event reactivity and recovery. *Health Psychology, 27*(4), 490-497.

Hawkins, J., & Shaw, P. (1992). Self-reported sleep quality in college students: A repeated measures approach. *Sleep, 15*(6), 545-549.

Headache Classification Committee of the International Headache Society. (1988). Classification and diagnostic criteria for headache disorders, cranial neuralgias and facial pain. *Cephalalgia, 8*(Suppl 7), 1-96.

Headache Classification Subcommittee of the International Headache Society. (2004). The International Classification of Headache Disorders, 2nd edition. *Cephalalgia, 24*(Suppl 1), 9-160.

Houle, T., & Nash, J. M. (2008). Stress and headache chronification. *Headache, 48*(1), 40-44.

Hu, X. H., Markson, L. E., Lipton, R. B., Stewart, W. F., & Berger, M. L. (1999). Burden of migraine in the United States: Disability and economic costs. *Archives of Internal Medicine, 159*(8), 813-818.

Inamorato, E., Minatti-Hannuch, S. N., & Zukerman, E. (1993). The role of sleep in migraine attacks. *Arquivos de Neuro-Psiquiatria, 51*(4), 429-432.

International Headache Society Clinical Trials Subcommittee. (2000). Guidelines for controlled trials of drugs in migraine: Second edition. *Cephalalgia, 20*(9), 765-786.

Irwin, E. L. (2007). Adaptive and maladaptive cognitions and physical activity in relation to quality of life and headache frequency in undergraduate students. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 67*(9-B), 5407.

Janke, E. A., Holroyd, K. A., & Romanek, K. (2004). Depression increases onset of tension-type headache following laboratory stress. *Pain, 111*(3), 230-238.

Judd, C. M., Kenny, D. A., & McClelland, G. H. (2001). Estimating and testing mediation and moderation in within-subject designs. *Psychological Methods, 6*(2), 115-134.

Kelman, L., & Rains, J. C. (2005). Headache and sleep: Examination of sleep patterns and complaints in a large clinical sample of migraineurs. *Headache, 45*(7), 904-910.

Kryst, S., & Scherl, E. (1994). A population-based survey of the social and personal impact of headache. *Headache, 34*(6), 344-350.

Labbe, E. E., Murphy, L., & O'Brien, C. (1997). Psychosocial factors and prediction of headaches in college adults. *Headache, 37*(1), 1-5.

Langemark, M., Olesen, J., Poulsen, D. L., & Bech, P. (1988). Clinical characterization of patients with chronic tension headache. *Headache, 28*(9), 590-596.

Leone, M., D'Amico, D., Moschiano, F., Fraschini, F., & Bussone, G. (1996). Melatonin versus placebo in the prophylaxis of cluster headache: A double-blind pilot study with parallel groups. *Cephalalgia, 16*(7), 494-496.

Leone, M., Lucini, V., D'Amico, D., Moschiano, F., Maltempo, C., Fraschini, F., et al. (1995). Twenty-four-hour melatonin and cortisol plasma levels in relation to timing of cluster headache. *Cephalalgia, 15*(3), 224-229.

Lichstein, K. L., Riedel, B. W., & Means, M. K. (1999). Psychological treatment of late-life insomnia. In R. Shulz, G. Maddox & M. P. Lawton (Eds.), *Annual review of gerontology and geriatrics* (Vol. 18, pp. 74-110). New York: Springer.

Lin, K. C., Huang, C. C., & Wu, C. C. (2007). Association between stress at work and primary headache among nursing staff in Taiwan. *Headache, 47*(4), 576-584.

Maizels, M., & Burchette, R. (2004). Somatic symptoms in headache patients: The influence of headache diagnosis, frequency, and comorbidity. *Headache, 44*(10), 983-993.

Mannix, L. K. (2001). Epidemiology and impact of primary headache disorders. *Medical Clinics of North America, 85*(4), 887-895.

Ojini, F. I., Okubadejo, N. U., & Danesi, M. A. (2009). Prevalence and clinical characteristics of headache in medical students of the University of Lagos, Nigeria. *Cephalalgia, 29*(4), 472-477.

Olesen, J., & Goadsby, P. J. (2000). Synthesis of migraine mechanisms. In J. Olesen, P. Tfelt-Hansen & K. M. A. Welch (Eds.), *The headaches* (pp. 331-336). Philadelphia, PA: Lippincott, Williams, & Wilkins.

Osterhaus, J. T., Townsend, R. J., Gandek, B., & Ware, J. E., Jr. (1994). Measuring the functional status and well-being of patients with migraine headache. *Headache, 34*(6), 337-343.

Paiva, T., Batista, A., Martins, P., & Martins, A. (1995). The relationship between headaches and sleep disturbances. *Headache, 35*(10), 590-596.

Paiva, T., Esperanca, P., Martins, I., & Batista, A. (1992). Sleep disorders in headache patients. *Headache Quarterly, 3*(4), 438-442.

Penzien, D. B., Rains, J. C., Andrew, M. E., Galovski, T. E., Mohammed, Y., & Mosley, T. H. (2001). Relationships of daily stress, sleep, and headache: A time-series analysis [abstract]. *Cephalalgia, 21*, 262-263.

Peres, M. F., Sanchez del Rio, M., Seabra, M. L., Tufik, S., Abucham, J., Cipolla-Neto, J., et al. (2001). Hypothalamic involvement in chronic migraine. *Journal of Neurology, Neurosurgery, and Psychiatry, 71*(6), 747-751.

Rains, J. C., & Poceta, J. S. (2006). Headache and sleep disorders: Review and clinical implications for headache management. *Headache, 46*(9), 1344-1363.

Saunders, J. B., Aasland**,** O. G., Babor, T. F., de la Fuente, J. R. (1993). Development of the Alcohol Use Disorders Identification Test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption. *Addiction, 88*(6), 791-804.

Silberstein, S. D. (1994). Serotonin (5-HT) and migraine. *Headache, 34*(7), 408-417.

Spierings, E. L., Ranke, A. H., & Honkoop, P. C. (2001). Precipitating and aggravating factors of migraine versus tension-type headache. *Headache, 41*(6), 554-558.

Spierings, E. L., & van Hoof, M. J. (1997). Fatigue and sleep in chronic headache sufferers: An age- and sex-controlled questionnaire study. *Headache, 37*(9), 549-552.

Stang, P. E., & Osterhaus, J. T. (1993). Impact of migraine in the United States: Data from the National Health Interview Survey. *Headache, 33*(1), 29-35.

Task Force on Promotion and Dissemination of Psychological Procedures. (1995). Training in and dissemination of empirically-validated psychological treatments: Report and recommendations. *Clinical Psychologist, 48*, 3-23.

Trockel, M. T., Barnes, M. D., & Egget, D. L. (2000). Health-related variables and academic performance among first-year college students: Implications for sleep and other behaviors. *Journal of American College Health, 49*(3), 125-131.

Tsai, L. L., & Li, S. P. (2004). Sleep patterns in college students: Gender and grade differences. *Journal of Psychosomatic Research, 56*(2), 231-237.

Valdez, P., Ramirez, C., & Garcia, A. (1996). Delaying and extending sleep during weekends: Sleep recovery or circadian effect? *Chronobiology International, 13*(3), 191-198.

Williamson, D. A., Baker, J. P., & Cubic, B. A. (1993). Assessment in pediatric headache research. In T. H. Ollendick & P. J. Prinz (Eds.), *Advances in clinical child psychology* (Vol. 15, pp. 275-304). New York: Plenum Press.

Zurak, N. (1997). Role of the suprachiasmatic nucleus in the pathogenesis of migraine attacks. *Cephalalgia*, *17*(7), 723-728.