SLEEP DISTURBANCE IN CHRONIC PAIN PATIENTS

By

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To my parents . . .
You've cheered me on in all that I do, supported me when I needed you to stand with me, given me the courage to the believe in myself and to stand on my own, and always told me that there was nothing I could not do.

You are my inspiration now and always.

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LIST OF ABBREVIATIONS

BDI	Beck Depression Inventory
BMI	Body mass index
BP	Back pain
CBT	Cognitive behavior therapy
CBT-I	Cognitive behavior therapy for insomnia
CNS	Central nervous system
CPH	Chronic paroxysmal hemicrania
CSQ	Coping Strategies Questionnaire
CSQ-R	Coping Strategies Questionnaire – Revised
DSM-IV-TR	Diagnostic and Statistical Manual of Mental Disorders, 4th edition, text revision
EEG	Electroencephalogram/electroencephalographic
FMS	Fibromyalgia
FP	Facial pain
HPA	Hypothalamic-pituitary-adrenal
ICSD	International Classification of Sleep Disorders
IL-1	Interleukin-1
MANOVA	Multivariate analysis of variance
MCV	Medical College of Virginia Pain Questionnaire
MPQ	McGill Pain Questionnaire
NK cell	Natural killer cell
NREM	Non-rapid eye movement
PASS	Pain Anxiety Symptom Scale
PDI	Pain Disability Index

PILL	Pennebaker Inventory of Limbic Languidness
PSG	Polysomnography
PSQI	Pittsburgh Sleep Quality Index
REM	Rapid eye movement
RM	Raphe magnus
RMSEA	Root mean square error of approximation
SE	Sleep efficiency
SEM	Structural equation modeling
SES	Socio-economic status
SF-36	Medical Outcomes Survey Short Form-36
SOL	Sleep onset latency
STAXI	State-Trait Anger Expression Inventory
TENS	Transcutaneous electrical nerve stimulation
TMD	Temporomandibular disorder
TST	Total sleep time
VAS	Visual analogue scale
WASO	Wake after sleep onset

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Chronic pain is a prevalent problem and it is associated with a number of negative consequences. Sleep disturbances are a common complaint reported by chronic pain patients, with 50-70% of patients endorsing significant sleep disturbance. The presence of concomitant sleep problems can significantly complicate both the course and the management of chronic pain. Further, there is evidence to suggest that the relationship between sleep disturbance and pain might be reciprocal, such that pain can disrupt sleep and poor or disrupted sleep may lead to increased pain.

Additionally, associations among pain, negative mood, and sleep disturbance among chronic pain patients have been inconsistent. Specifically, some investigators have reported greater negative mood (as well as higher pain intensity) among self-reported "poor sleepers," whereas other researchers have reported higher pain ratings but no differences on measures of negative mood among good and poor sleepers. More clearly defining the relationship between pain and sleep disturbance, as well as the roll of negative mood, may further clarify the shared pathophysiology of sleep and pain.

This study examined sleep, pain, and negative mood in 292 adults, 18 to 65 years of age, with chronic back pain, facial pain, or fibromyalgia. Additionally, a subset of 22 participants

completed two weeks of daily sleep diaries and actigraphy monitoring and participated in psychophysical pain testing procedures.

A generalized pattern of sleep disturbance (difficulties with sleep onset, sleep maintenance, and poor sleep quality) was reported by all groups of chronic pain patients, with facial pain patients reporting relatively less disturbed sleep overall. Results also indicated a direct relationship between poor sleep and increased pain, and further revealed that negative mood mediated the relationship between poor sleep and increased pain when it was included in the model. No significant results emerged from analyses examining pain response to psychophysical testing among good and poor sleepers, although moderate to large effect sizes were found. Findings suggest multiple pathways between sleep disturbance and individuals' pain experience, such that poor sleep may lead to increased pain but higher levels of negative mood may also lead to decreased sleep, resulting in more pain.

CHAPTER 1
INTRODUCTION

Chronic pain conditions constitute a major challenge facing the health care system. These conditions are often associated with substantial disability and distress for the individual and also result in significant burdens on the health care system, as well as considerable economic and social costs. Similarly, sleep disturbances are prevalent among the general population and can also substantially impact individuals' physical, emotional, social, and occupational functioning, particularly when these difficulties evolve into chronic problems. Recent attention has begun to focus on the relationship between sleep disturbances and chronic pain conditions. When these occur in concert, the resultant impact on the individual is even greater, leading to higher levels of physical and emotional disability and greater functional impairments. Research needs to clarify the relationship between sleep disturbances and chronic pain, in order to better understand the potential reciprocal influences of these conditions on one another, as well as to develop ways to intervene more effectively. As pain and sleep can be assessed in various ways, it is important to consider both subjective and objective measures of sleep, and to consider subjective pain reports as well as response to experimentally controlled painful stimuli. The following review will examine the literature on these topics to date, and highlight the rationale and proposed contribution of the current study.

Prevalence and Impact of Chronic Pain

Chronic nonmalignant pain is a prevalent problem among the adult population and is associated with a number of negative physical, emotional, and social consequences. A review of epidemiological studies conducted by Verhaak and colleagues (1998) found that the median prevalence rate of chronic pain for adults across all studies was 15% (Verhaak, Kerssens, Dekker, Sorbi, & Bensing, 1998). Subsequent epidemiological studies have reported similar

prevalence rates (Breivik, Collett, Ventafridda, Cohen, & Gallacher, 2005; Moulin, Clark, Speechley, & Morley-Forster, 2002). Several studies have noted higher rates among females and among older age groups (Moulin et al., 2002; B. H. Smith et al., 2001; Verhaak et al., 1998).

Andersson and colleagues (1999) examined health care and medication use among Swedish adult reporting chronic pain (H. I. Andersson, Ejlertsson, Leden, & Schersten, 1999). Results indicated that individuals with chronic pain were more likely to consult a physician or physiotherapist, which is consistent with findings from other studies (Breivik et al., 2005). In particular, perception of pain intensity was noted to be the most important factor motivating health-seeking behaviors, although ethnicity, SES, age, and depressive symptoms were also found to be important. Another commonly report among chronic pain samples is that, despite increased health care usage, many patients report that their pain is inadequately managed (Breivik et al., 2005).

Increased levels of chronic pain have been associated with increasingly negative associations with employment, interference with daily activities, and general health (B. H. Smith et al., 2001). Similarly, individuals with chronic pain also report decreased ability to participate in social and occupational acitivities due to pain (Breivik et al., 2005; Moulin et al., 2002).

When it was examined, positive associations were also noted between chronic pain and psychological symptoms (Verhaak et al., 1998). Psychological disorders are common correlates of chronic pain conditions (Breivik et al., 2005; Duquesnoy, Allaert, & Verdoncq, 1998), and when assessed, negative effects of pain on sexual activity are also frequently noted (Duquesnoy et al., 1998).

Subtypes of Pain Disorders

Back Pain

Research has suggested that as many as 80% of adults will experience significant back pain over the course of their lives (Lanes et al., 1995), and recurrence rates for low back pain have been reported to be as high as 85% (Binkley, Finch, Hall, Black, & Gowland, 1993). In an epidemiologic review of several cross-sectional studies (evidence level 1) by Anderson (1999), the annual incidence of back pain of at least moderate intensity and duration was estimated to be 10-15% among the adult population (G. B. Andersson, 1999). Further, this review also estimated the point prevalence of back pain of at least moderate intensity and duration to be 15-30% among adults.

Low back pain is a commonly experienced pain condition, which involves substantial social and economic costs (Malanga & Nadler, 1999). Grabois (2005) reported that, in the United States, back pain accounts for expenditures of $14 billion per year, 19 million physician visits, and half of all workers' compensation cases (Grabois, 2005). In addition, approximately 10 million Americans are disabled by chronic low back pain, and 250 million workdays are lost per year due to this condition (Kriegler & Ashenberg, 1987). While 90% of patients with back pain recover over a 3 month period, the remaining 10% of patients have a slow recovery process, which involves large resource-intensive demands being placed on the healthcare system (G. B. Andersson, 1999). According to Gallagher and Verma (1999), major depression commonly accompanies chronic pain and can increase patients' level of impairment and disability (Gallagher & Verma, 1999). Thus, a review by Verma and Gallagher (2002) concluded that, if present, depression and anxiety need to be addressed in order to obtain a good functional outcome from treatment (Verma & Gallagher, 2002).

Farasyn and Meeusen (2005) examined pressure pain thresholds in a group of 87 patients with sub-acute low back pain, compared to 64 healthy control subjects. Results indicated that the low back pain group had significantly lower pressure pain thresholds than the healthy controls at several body sites (Farasyn & Meeusen, 2005). Flor and colleagues (2004) found support for the idea of enhanced central and peripheral reactivity among chronic back pain patients, due to lower pressure pain threshold and tolerance levels in these patients compared to partients with tension headaches or healthy controls (Flor, Diers, & Birbaumer, 2004). Clauw and colleagues (1999) found that, even after accounting for structural, demographic, and psychosocial variables, pain sensitivity (threshold and tolerance) accounted for a significant amount of variance in chronic low back pain patients' pain scores (from SF-36 subscale) and functional status (Clauw et al., 1999).

Facial Pain

In a large random sample of adults, Macfarlane and colleagues (2002a) reported an overall prevalence of 26% for orofacial pain, but found that only 46% of these individuals reported seeking professional advice regarding their pain (Macfarlane, Blinkhorn, Davies, Kincey, & Worthington, 2002). Prevalence of orofacial pain symptoms was noted to be higher among women, and among men and women in the 18-25 year old age group. A review of 23 epidemiological studies by Pau and colleagues (2003) reported similar estimates for the prevalence of "oral and facial pain" (40-44%) (Pau, Croucher, & Marcenes, 2003). While gender was not associated with dental pain in this review, younger subjects and subjects from lower SES groups were noted to be more likely to report pain. The impact of orofacial pain includes, an inability to engage in normal activities, having to take time off from work due to pain, and higher levels of psychologic distress (Macfarlane, Blinkhorn et al., 2002; Macfarlane, Kincey, & Worthington, 2002).

Experimental pain testing in facial pain patient samples has produced conflicting findings. A study by Bragdon and colleagues (2002) reported that women with TMD and women without pain did not exhibit significant differences in pain threshold or tolerance measures to either heat or ischemic pain (Bragdon et al., 2002). Similarly, Curran and colleagues (1996) found no differences in pain or any psychological variables between TMD patients and matched controls undergoing a pressure-pain task (Curran, Carlson, & Okeson, 1996). However, Maixner and colleagues (1995) found significantly lower thermal pain thresholds (and a trend for lower thermal pain tolerance), as well as significantly lower ischemic pain threshold and tolerance levels in a group of TMD patients compared to matched controls (Maixner, Fillingim, Booker, & Sigurdsson, 1995). Moreover, findings from a study conducted by Widerstrom-Noga and colleagues (1998) suggested that psychological variables, such as stress or anxiety, can attenuated the degree of analgesia obtained from various methods (acupuncture, TENS) in patients with tooth pain (Widerström-Noga et al., 1998).

Fibromyalgia and Rheumatic Conditions

According to a multi-site prospective study conducted by Wolfe and colleagues (1997), the average yearly cost per patient (in 1996 dollars) was $2,274, although this number was affected by those patients who utilized services at a higher level (Wolfe et al., 1997). Overall, fibromyalgia patients reported attending an average of 10 outpatient medical visits per year, with this number increasing even further when non-traditional treatments were included. Additionally across the entire sample of fibromyalgia patients, an average of 2.7 disease-related drugs were used in each 6-month study period, and hospitalization frequency averaged one stay every 3 years, with over half of the hospitalizations stemming from fibromyalgia-related symptoms. The number of comorbid conditions reported by fibromyalgia patients has been associated with the total costs and health care usage (Wolfe et al., 1997). Further, total cost and utilization level was

associated with both functional disability ratings, and global disease-severity in this sample of fibromyalgia patients.

Laursen and colleagues (2005) found significantly lower pressure pain thresholds among chronic pain patients of diverse etiologies compared to healthy female controls, and noted significantly higher VAS ratings of habitual pain among female fibromyalgia/whiplash patients compared to other female chronic pain patients (Laursen, Bajaj, Olesen, Delmar, & Arendt-Nielsen, 2005). Carli and colleagues (2002) examined pain thresholds, using different modalities of noxious stimuli (pressure, heat, cold, and ischemic), in fibromyalgia patients and control participants (Carli, Suman, Biasi, & Marcolongo, 2002). The fibromyalgia patients were further divided into 5 groups, based on tender point evaluations and how diffuse their pain was noted to be. Fibromyalgia subjects had significantly lower heat pain threshold and cold pressure pain threshold, and lower ischemic pain tolerance, compared to healthy subjects. Additionally, 4 of the 5 fibromyalgia groups also demonstrated lower pressure pain threshold levels compared to healthy subjects. Similarly, in a study by Hurtig and colleagues (2001) differences were noted between fibromyalgia patients and healthy controls in cold and heat pain threshold levels, but not in perception levels for warmth and cold (Hurtig, Raak, Kendall, Gerdle, & Wahren, 2001). Sleep quality was not examined in relationship to pain threshold measures in this study.

Basic Sleep Information

Insomnia symptoms are among the most common sleep complaints, with prevalence estimates commonly reported among 20-40% of adults (Bailey, 1997; Ohayon, 2002). Rates of insomnia symptoms are also generally noted to be higher among women, and among elderly individuals (Ohayon, 2002). The Diagnostic and Statistical Manual of Mental Disorders, 4th edition, text revision's (DSM-IV-TR; (American Psychiatric Association, 1994) description of insomnia includes difficulties with either the initiation or maintenance or sleep, as well as

complaints of nonrestorative sleep. In terms of duration, insomnia can be intermittent, last for a short duration, or become a chronic problem (Bailey, 1997).

Sleep bruxism is a movement disorder whose primary symptom is clenching or grinding the teeth during sleep (Bailey, 1997), and prevalence estimates have indicated that 5-20% of the population is affected by this disorder (Glaros, 1981). Patients with sleep bruxism present with almost daily complaints, which may include musculoskeletal pain or temporomandibular disorders (Bailey, 1997), and as the severity and chronicity of this condition increases, there is decreased likelihood of experiencing restorative sleep.

Assessment of Sleep Patterns and Sleep Problems

Sleep patterns and sleep problems can be assessed in a number of different ways, each involving certain strengths and limitations. The three main methods of sleep assessment are subjective measures (e.g., questionnaires, sleep diaries), behavioral measures (e.g., actigraphy), and physiological measures (e.g., polysomnography; PSG), and the recent research has demonstrated the utility of employing a multi-dimensional approach to the study of sleep, particularly in the evaluation of insomnia complaints (see (Morin, 2003) for a review).

Questionnaires involve low burden on participants, and so are widely used measures for the assessment of sleep, as well as factors related to sleep (e.g., emotional status, daytime sleepiness, functioning, quality of life). Daily sleep diaries are widely used measures of sleep patterns, especially in the evaluation of insomnia complaints, and can be especially useful tools for assessing individuals' sleep patterns prior to, during, and following the implementation of a treatment for a sleep problem. Although daily diary reports may evidence significant discrepancies with information obtained via PSG, they permit evaluation of individuals' perception of their sleep, and allow for prospective monitoring over longer periods of time.

Actigraphy is a behavioral measure of sleep, and can also be useful for assessing an individual's response to treatment for a sleep problem. Research has demonstrated that actigraphy provides accurate estimates of several global sleep parameters (such as total sleep time, time in bed, total wake time) relative to PSG, while remaining unobtrusive as a measurement device (Hauri & Wisbey, 1992; Sadeh, Hauri, Kripke, & Lavie, 1995; Vallieres & Morin, 2003). Ancoli-Israel and colleagues (2003) reviewed research on the use of actigraphy for sleep research, and reported correlations between actigraphy and polysomnography ranging from 0.81 to 0.97 for total sleep time; 0.61 to 0.78 for percent of sleep; 0.53 to 0.94 for sleep onset latency (Ancoli-Israel et al., 2003). It is important to note that correlations between actigraphy and PSG, and between actigraphy and sleep diaries, are often moderate, especially when estimating more specific sleep parameters (e.g., sleep latency, 0.12 to 0.69; time awake after sleep onset; 0.22 to 0.37) (de Souza et al., 2003; Lockley, Skene, & Arendt, 1999). However, for the assessment of certain sleep problems, particularly the night-to-night variability prominent among insomnia patients, actigraphy may actually be a more appropriate diagnostic tool than traditional PSG (Ancoli-Israel et al., 2003). Additionally, a recent validation study conducted by Lichstein and colleagues (2006) concluded that actigraphy is a satisfactory objective measure of number of awakenings, wake time after sleep onset (WASO), total sleep time (TST), and sleep efficiency in insomnia patients, relative to PSG recordings (Lichstein et al., 2006).

Kushida and colleagues (2001) reported that measurement of total sleep time and sleep efficiency did not differ significantly between PSG data and combined data from actigraphy and questionnaire reports in a group of 100 consecutive sleep-disordered patients (Kushida et al., 2001). Further, when actigraphy parameters included a high-threshold (low-wake-sensitivity)

algorithm, the number of awakenings recorded was similar to those measured using PSG. These researchers concluded that both subjective data and actigraphy data should be used to estimate sleep parameters in sleep-disordered patients.

Studies have also compared the use of sleep logs and actigraphy in the assessment of sleep patterns (Lockley et al., 1999; Wilson, Watson, & Currie, 1998). Lockley and colleagues (1999) demonstrated good correlations between sleep logs and actigraphy for timing of sleep (r = 0.77 for sleep onset and r = 0.88 for sleep offset) and sleep duration (r = 0.57), as well as good agreement in measurement of changes in sleep patterns over time. However, these methodologies were not as highly correlated in measuring transitional variables during sleep, such as sleep latency and number and duration of awakenings. Wilson and colleagues (1998) also compared sleep reports using a diary measure and actigraphy in a group of patients with chronic musculoskeletal pain (82.5% back pain). Results indicated that the two measures provided similar estimates of TST, WASO, sleep efficiency, but differed in estimation of sleep onset latency and number of awakenings. Pain severity was noted to be the variable that evidenced the strongest association with sleep disturbance overall (as measured by sleep diary). PSG is beneficial in the screening for sleep disorders such as obstructive sleep apnea or periodic limb movement disorder, but is still not routinely used in the clinical evaluation of insomnia complaints (Reite, Buysse, Reynolds, & Mendelson, 1995; Sateia, Doghramji, Hauri, & Morin, 2000). Despite its usefulness for screening purposes, PSG involves significant burden on participants, which increases with the number of recording nights and if the recording is being conducted in a lab versus the individual's home. Furthermore, while PSG provides a wealth of valuable physiological data, it does not adequately address the subjective experience that is often a central component to insomnia complaints.

An additional benefit provided by PSG evaluation of sleep is the ability to examine not only the macrostructure of sleep architecture (stage REM, NREM stages 1-4), but also the ability to assess sleep microstructure using advances in technology of EEG analysis. Sleep microstructure analysis permits examination of the proportion of different frequencies of brain waves (alpha, beta, gamma, delta, theta) throughout an individual's sleep. Different frequencies of brain waves are associated with different stages of sleep (for example, lower frequency delta waves are most often associated with stage 3 or 4 NREM "slow wave" sleep), and abnormalities in the brain wave patterns during sleep have been noted in individuals who complain of certain sleep disturbances.

Experimentally Induced Sleep Disturbances in Healthy Participants

Experimental studies have found that selective disruption of stage 4 NREM sleep (slow wave sleep) in healthy participants led to musculoskeletal tenderness the next day in these participants; furthermore, these symptoms mimicked the symptoms of fibromyalgia (Moldofsky & Scarisbrick, 1976). A more recent, and very carefully conducted, study by Onen and colleagues (2001a) reported that healthy males (PSQI and BMI in normal range) who had undergone 40 hours of sleep deprivation showed hyperalgesia to mechanical stimuli, but not to thermal stimuli (Onen, Alloui, Gross, Eschallier, & Dubray, 2001). In addition, these participants also showed a robust analgesic effect following selective slow wave recovery sleep after undergoing slow wave sleep interruption. Additional studies have supported these findings of hyperalgesia to painful stimuli following sleep deprivation in healthy subjects, with no changes noted in somatosensory threshold detection levels (Kundermann, Spernal, Huber, Krieg, & Lautenbacher, 2004).

Experimental studies examining the effects of painful stimuli on sleep have consistently shown that pain causes microarousal, which was measured by increased high frequency EEG

activity (in the alpha and beta ranges) at the expense of slow frequency EEG activity (delta range) (Drewes, Nielsen, Arendt-Nielsen, Birket-Smith, & Hansen, 1997). These results have led researchers to conclude that pain can cause changes to the sleep architecture of normal controls in ways that lighten sleep and diminish the reputed restorative effects of slow wave sleep. However, results have not been consistent and no significant effects on either EMG activity (measuring bruxism) or on pressure pain thresholds were noted in a group of 10 healthy males undergoing slow-wave sleep deprivation (Arima et al., 2001).

Sleep Disturbances in Pain Patients

Sleep disturbances are among the most common complaints reported by patients experiencing chronically painful conditions (M. T. Smith & Haythornthwaite, 2004). "Sleep disturbance" is a term used to denote subjective reports of problems in either sleep quality or quantity (Cohen, Menefee, Doghramji, Anderson, & Frank, 2000). Studies commonly report that at least 50% of patients with diverse chronic pain conditions complain of significant sleep disturbance, with many studies reporting an even higher prevalence of sleep disturbance in chronic pain patients, along the order of 70% (Atkinson, Ancoli-Israel, Slater, Garfin, & Gillin, 1988; Pilowsky, Crettenden, & Townley, 1985). Sleep efficiency (total sleep time/time in bed * 100) has also been noted to be significantly affected in chronic pain patients (Wittig, Zorick, Blumer, Heilbronn, & Roth, 1982). The presence of concomitant sleep problems can significantly complicate both the course and the management of chronic pain patients (Cohen et al., 2000). Experimental data gathered from studies of healthy participants and cross-sectional research in clinical populations suggests that the relationship between sleep disturbance and pain might be reciprocal. In some cases, disturbed or poor sleep appears to contribute to the pain problem, whereas in others ongoing pain diminishes individuals' ability to sleep and leads to a cycle of increasing pain and continued degradation of sleep quality (Bailey, 1997). In other

words, pain may disrupt sleep continuity and/or sleep quality, and poor sleep may contribute to the exacerbation of pain in these patients.

Additional support for the hypothesis that sleep disturbance contributes to chronic pain comes from clinical studies, which have demonstrated that chronic pain patients often demonstrate reduced delta (i.e. slow wave) sleep and/or increased alpha sleep (Harding, 1998; Moldofsky, Lue, & Smythe, 1983). The abnormalities found in these studies appear to be similar to the experimental studies in healthy participants, where sleep disruption appears to alter pain sensitivity. Similarly, correlational studies involving clinical samples have consistently found a positive association between sleep disturbance and pain severity (Pilowsky et al., 1985).

Back Pain

Studies in samples of chronic back pain patients have demonstrated high rates of sleep problems, including difficulties with both the initiation of sleep and difficulties with sleep maintenance (Lobbezoo, Visscher, & Naeije, 2004; Widerstrom-Noga, Felipe-Cuervo, & Yezierski, 2001). Interpretation of these results is made difficult by the fact that there was no indication of whether these groups were composed of different individuals, or whether the groups contained the same participants presenting with both types of sleep problems. The patients who reported frequent interference (3 or more times per week) in falling asleep due to pain also indicated higher average pain intensity ratings, and used more descriptors when describing their pain. Other studies involving patients with chronic back pain have combined difficulties falling asleep and difficulties maintaining sleep into an overarching description termed “insomnia”, which prevents examination of patients’ specific sleep problems (Lobbezoo et al., 2004). Atkinson and colleagues (1988) also examined potential influential factors involved in sleep disturbances among a sample of chronic low back pain patients. Results indicated that sleep dissatisfaction was most strongly associated with greater depressed mood

and shorter duration of pain. Furthermore, patients who reported high pain intensity also reported shorter TST, longer sleep latency, and more frequent awakenings, compared to the low pain intensity patients. Wilson and colleagues (1998) also noted that patients with chronic musculoskeletal pain (82.5% back pain) who had high pain severity reported greater sleep impairment than those patients with low pain severity.

Facial Pain

Studies have documented sleep disturbances in patients with facial pain (Riley et al., 2001; Yatani, Studts, Cordova, Carlson, & Okeson, 2002), although the exact nature of these disturbances has not been well-defined. Riley and colleagues (2001) conducted both cross-sectional and longitudinal analyses to examine the relationships between pain, sleep disturbance, and depression in a sample of orofacial pain patients. Results indicated that reduced amount of sleep (sleep quantity) was associated with depression and pain, and reduced sleep quality was associated with negative affect. Additionally, when longitudinal analyses were conducted, initial depression and pain predicted sleep disturbance at follow-up, and initial pain also predicted negative affect at follow-up. However, in this study, sleep at time one did not predict pain at follow-up.

As reported by Bailey (1997), a variety of headache disorders have been found to be related to sleep disorders in different ways, which can be useful in both the diagnosis and treatment of these disorders. In fact, the International Classification of Sleep Disorders (1990) (ICSD; (Diagnostic Classification Steering Committee, 1990) includes a broad category of classification entitled Sleep-Related Headaches under neurologic disorders, and this group of headaches is defined as occurring during sleep with their onset most often during REM sleep. The relationship between sleep disturbance and headache conditions is complex and difficult to assess, with symptoms of both conditions potentially having causal relations or having mutual

reinforcements in an individual (Paiva, Batista, Martins, & Martins, 1995); see (Sahota & Dexter, 1990) for a detailed review). The onset of certain types of headache conditions, such as chronic paroxysmal hemicrania (CPH), cluster headache, and migraine headache, are known to be associated with specific sleep stages (Sahota & Dexter, 1990). There are also well-established effects of sleep disruptions (Blau, 1990; Headache Classification Committee of the International Headache Society, 1988), as well as sleep disturbances (such as somnambulism, see (Paiva, Martins, Batista, Esperanca, & Martins, 1994), on headache conditions. In fact, the presence of early awakening or morning headaches has been conceptualized as possibly suggesting the presence of a sleep disturbance in some patients (Paiva et al., 1995). Additionally, patients with chronic headache complaints also indicate long-standing experiences of subjective sleep problems (Paiva, Esperanca, Martins, Batista, & Martins, 1992). However, complicating the picture is the fact that, for some individuals, sleep can also serve as an effective treatment for some headaches, such as migraine (Blau, 1982).

A review by Bailey (1997) identified the nature and prevalence of sleep disorders that are most often associated with orofacial pain conditions, and indicated that the presence of a concurrent sleep disorder in patients with a pain condition necessitates the treatment of both conditions. This review also reported that alpha intrusion on the EEG sleep recordings is one of the most consistent findings displayed by chronic pain patients. This alpha rhythm is seen in a condition of relaxed wakefulness, but normally disappears when an individual moves into stage 1 NREM sleep (Bailey, 1997). Alpha waves are also reportedly seen during arousals, which are frequently found in individuals with pain conditions, and a condition termed alpha-delta sleep, which is associated with subjectively nonrestorative sleep and feelings of fatigue, is also reportedly found among pain patients (Bailey, 1997). While fibromyalgia has been strongly

linked with this phenomenon of alpha intrusion, and is reportedly the most common pain condition associated with subjectively nonrestorative sleep, many researchers are noting similarities between fibromyalgia and myofascial pain. Additionally, bruxism is commonly found in patients with TMD, and because of the wide range of symptoms that can be produced by TMD, sleep disturbances are often found in these patients (Bailey, 1997).

In a study by Paiva and colleagues (1995), 13 of the 25 patients from an outpatient headache clinic who reported morning or nocturnal headaches received a change in their diagnosis after PSG data were obtained. In 10 patients, the onset (or period of worsening) of their headaches coincided with the onset of the sleep disturbances. However, the majority of cases in this study reflected a complex association between patients' sleep disturbances and headache conditions. A subsequent study by Paiva and colleagues (1997) examined the sleep of patients with headache complaints who identified the onset of their headaches as occurring during the night or early morning at least 75% of time (Paiva, Farinha, Martins, Batista, & Guilleminault, 1997). In this sample, 53% of patients were identified as having a primary sleep disorder, and all of these patients reported fragmented sleep. There were no significant differences in total sleep time or percentage of REM sleep, as measured by polysomnography, found between the headache group with a sleep disorder and the headache group without sleep disorders. However, on a self-report sleep questionnaire, the patients who were identified as having a sleep disorder reported a greater number of sleep complaints compared to the group of headache patients who did not evidence any objective evidence of a sleep disorder.

Fibromyalgia and Rheumatic Conditions

Subjective sleep complaints, such as nonrestorative sleep and insomnia complaints, among fibromyalgia patients have been reported by numerous studies (Campbell, Clark, Tindall, Forehand, & Bennett, 1983; Drewes et al., 1995; Schaefer, 1995). Further studies have reported

links between sleep difficulties and pain in fibromyalgia, such that reports of restful sleep have been associated with less reported discomfort and fatigue (Moldofsky, 1989) and nonrestorative sleep is associated with exacerbation of pain in fibromyalgia patients (Affleck, Urrows, Tennen, Higgins, & Abeles, 1996). Polysomnographic studies have also found specific differences between the sleep architecture of fibromyalgia patients and that of healthy controls, including polysomnographic evidence of increased sleep onset latency (Horne & Shackell, 1991), increased amounts of stage 1 sleep (Horne & Shackell, 1991; Shaver et al., 1997), reduced amounts of stage 3 and 4 sleep (Branco, Atalaia, & Paiva, 1994; Horne & Shackell, 1991; Shapiro, Devins, & Hussain, 1993), and increased number of arousals (Branco et al., 1994; Jennum, Drewes, Andreasen, & Nielsen, 1993; Shapiro et al., 1993) in fibromyalgia patients. Shapiro and colleagues (1993) also reported that fibromyalgia patients evidenced lower amounts of age-corrected REM sleep, and total sleep time, and long awakenings (>10 minutes), and an EEG pattern of intrusive alpha frequency waves, compared to healthy controls. As has been demonstrated in previous studies, patients with fibromyalgia frequently exhibit an alpha-delta sleep rhythm, which is also produced during stage 4 sleep deprivation, and by deep pain induced during sleep, in normal control subjects (Harding, 1998). The alpha wave anomaly has long been hypothesized to be involved in the pathophysiology of fibromyalgia (Moldofsky, Scarisbrick, England, & Smythe, 1975), and more recent data has supported the hypothesis that alpha intrusion is an inherent characteristic of NREM sleep in fibromyalgia patients (Branco et al., 1994; Smythe, 1995). This alpha intrusion sleep anomaly is associated with indications of vigilance during sleep and reports of nonrestorative sleep (Anch, Lue, MacLean, & Moldofsky, 1991), as well as pain, energy, and mood in fibromyalgia patients (Moldofsky & Lue, 1980). The amount of alpha frequency that occurred during sleep has also been shown to correlate with

increases in overnight pain measures (Moldofsky & Lue, 1980). Furthermore, Harding (1998) concluded that the compilation of evidence suggests this alpha intrusion is found in the majority of patients with fibromyalgia, the amount of alpha intrusion correlates with objective measurements of pain, and decreasing the amount of alpha intrusion results in improvements in pain.

Landis and colleagues (2003) found that the women with fibromyalgia reported poorer sleep quality and more fatigue than controls, although actigraphy sleep indicators were not different between groups (Landis et al., 2003). In the women with fibromyalgia only, self-reported sleep quality was directly related to actigraphy indicators of TST, and was inversely related to sleep fragmentation. Additionally, fatigue in the women with fibromyalgia was directly related to the actigraphy indicators of wake after sleep onset, and inversely related to sleep efficiency.

According to Wolfe and colleagues (1990), nonrestorative sleep is a prevalent complaint among patients with fibromyalgia (Wolfe et al., 1990). Harding (1998) reviewed the literature regarding sleep in fibromyalgia, and further stated that, although sleep disturbance is a prominent aspect in the clinical picture of fibromyalgia and that pain in fibromyalgia may increase due to a lack of sleep, it is still unclear whether sleep disturbance plays a causal role in fibromyalgia, or is simply an outcome resulting from the disorder.

Neurobiology Findings on the Sleep-Pain Relationship

Studies have implicated a number of areas in the central nervous system, as well as several different chemical substances, in both the control/disturbance of the sleep/wake cycle and in the experience of chronic pain. The mesencephalic periaqueductal gray area, the thalamus, and the reticular nucleus of the thalamus have been implicated in the generation and maintenance of sleep, and also in pain modulation. The mesencephalic periaqueductal gray area has been

shown to modulate both sleep states (Sastre, Buda, Kitahama, & Jouvet, 1996) and nociception (Demarco, Baghdoyan, & Lydic, 2003). The thalamus is involved in both arousal and in the processing of nociceptive stimuli in the cortex (Casey, Morrow, Lorenz, & Minoshima, 2001), and the reticular nucleus of the thalamus is thought to actively regulate the synchronization of the cortex during delta sleep (Steriade & Llinas, 1988). A study by Mountz and colleagues (1995) demonstrated that fibromyalgia patients had reduced regional blood flow to the thalamus and caudate nucleus (Mountz et al., 1995), which may be involved in abnormalities of growth hormone secretion that have been observed in patients with fibromyalgia (Culebras & Miller, 1984). Bennett (1993) reported low levels of somatomedin C, which is a growth hormone responsible for muscle regeneration and homeostasis, in fibromyalgia patients, and further indicated that growth hormone is primarily secreted during stage 4 NREM (Bennett, 1993). Foo and Mason (2003) have argued that persistent pain, unlike acute pain, is associated with functional changes in the raphe magnus (RM) cells, which modulate both pain and arousal (Foo & Mason, 2003). Paulson and colleagues (2002) have also hypothesized that persistent pain may lead to lasting functional changes in the neural systems that regulate both sleep and pain (Paulson, Casey, & Morrow, 2002). Specifically, they present data that suggest that persistent pain might promote changes in the ascending arousal system, which could ultimately lead to disturbance of sleep continuity.

Moldofsky theorizes that the diffuse myalgia, fatigue, and psychological distress experienced by patients with fibromyalgia are not only related to a disorder of their sleep-wake system, but also to circadian alterations of associated biologic systems of the body. Specifically, studies have shown that these systems include, neurotransmitters (e.g. serotonin, substance P), neuroimmune and neuroendocrine (e.g. IL-1, NK cell activity, HPA and thyroid axes), and the

autonomic nervous systems that are altered in patients with fibromyalgia (McAlpine, 1987; Moldofsky, 1994; Paulson et al., 2002; Pillemer, Bradley, Crofford, Moldofsky, & Chrousos, 1997). Several studies have reported that patients with fibromyalgia have decreased levels of serotonin in their cerebrospinal fluid and blood (Russell et al., 1992), and there is evidence for an inverse relationship between pain levels and serotonergic activity in the brain (Bailey, 1997). Furthermore, Moldofsky (1989) reported strong evidence from animal studies demonstrating a relationship between CNS metabolism of serotonin and its role in regulating both pain and NREM sleep. Additionally, Carette and colleagues (1986) reported that low doses of tricyclic antidepressants, which influence the metabolism of serotonin in the central nervous system, have been found to be beneficial for sleep in patients with fibromyalgia (Carette, McCain, Bell, & Fam, 1986). Taken together, findings suggest that low levels of serotonin in fibromyalgia patients' central nervous systems may play a role in their decreased delta (slow wave) sleep, and may predispose these patients to developing the alpha intrusion phenomenon. Unstable serotonin levels have also been proposed as a common factor in both migraine and somnambulism (Barabas, Ferrari, & Matthews, 1983), while Vaeroy and colleagues (1988) reported finding elevated cerebrospinal fluid levels of substance P in patients with fibromyalgia (Vaeroy, Helle, Forre, Kass, & Terenius, 1988). Moreover, sleep and pain are both associated with activation of a number of regions in the central nervous system. Studies have suggested that the supraspinal regions, thalamocortical pathways, or the anterior cingulated cortex may be involved in the interaction between sleep and pain (Chase & Morales, 1994; Jones, 1994; Seigel, 1994).

Sleep Disturbances and Experimental Pain Testing

Onen and colleagues (2001b) reported that REM sleep deprivation in rats led to increased behavioral responses to noxious thermal, mechanical, and electrical stimuli, but not to a noxious

chemical stimulus (Onen, Alloui, Jourdan, Eschalier, & Dubray, 2001). These authors hypothesize that the normal duration of REM sleep may be important for anti-nociceptive activity of endogenous and exogenous opioids. They further suggest that the nociceptive process may be affected by REM sleep deprivation, producing a relative hypersensitivity to noxious electrical stimuli. It is known that both REM sleep and nociception are modulated by the cholinergic system. Additionally, as serotonin is involved in both REM sleep and in pain mechanisms, these authors hypothesize that a possible serotonin depletion, due to increased serotonin metabolism, may partly induce a hyperalgesia in REM sleep deprived animals.

A number of studies have demonstrated that fibromyalgia patients exhibit hyperalgesia in response to various pain stimuli (see (Hurtig et al., 2001), Table 1), compared to healthy controls. In addition, Agargun, et al. (1999) demonstrated a significant negative correlation between pressure pain threshold and an overall measure of sleep quality, as well as measures of subjective sleep quality, sleep efficiency, and sleep disturbance in 16 fibromyalgia patients (Agargun et al., 1999).

Negative Mood, Sleep, and Pain

The associations between pain, depression, and sleep disturbance have been examined in several chronic pain patient samples (Affleck et al., 1996; Atkinson et al., 1988; Morin, Gibson, & Wade, 1998; Nicassio & Wallston, 1992). Some studies have reported that "poor" sleepers reported greater pain, but do not differ from "good" sleepers on measures of depression or anxiety (Moffitt, Kalucy, Kalucy, Baum, & Cooke, 1991; Morin et al., 1998). However, other studies have reported that "poor sleepers" have higher scores on measures of depression and anxiety, in addition to higher pain intensity and more physical disability, compared to "good sleepers" (Atkinson et al., 1988; Pilowsky et al., 1985; Sayar, Arikan, & Yontem, 2002).

Longitudinal analyses have supported pain predicting sleep (Atkinson et al., 1988; Nicassio & Wallston, 1992), although results for sleep predicting pain over time have been less consistent (Nicassio & Wallston, 1992). Additionally, sleep problems and pain have been shown to be predictive of depression over time in chronic pain populations (Nicassio & Wallston, 1992). Conversely, measures of depression have also been found to be predictive of sleep in chronic pain samples (Sayar et al., 2002).

Chiu and colleagues (2005) examined the relationship between psychological factors, sleep disturbances, and pressure pain threshold in a population study, stratifying the sample by presence and extent of current pain (Chiu et al., 2005). Results indicated that those participants who reported the greatest sleep disturbance and highest levels of depression had a 2-fold increased chance of being in the lowest tertile for pain threshold. Importantly, these two variables were found to be independently associated with lower pain threshold, and this relationship remained even after adjusting for participants' initial pain status. Wittig and colleagues (1982) examined polysomnographically-measured sleep patterns in a group of pain patients, and compared these to findings in a group of patients with insomnia secondary to a psychiatric disorder and a group of patients with subjective insomnia complaints, but no objective findings of sleep disturbance. The pain patients were found to have more difficulty initiating and maintaining sleep compared to the group with subjective insomnia complaints; however, the group with insomnia secondary to a psychiatric disorder evidenced poorer sleep efficiency and greater early morning awake time than the pain patients. Additionally, 8 of the 26 pain patients demonstrated alpha rhythm intrusion into NREM stages of sleep.

Current Study

Defining the relationships between particular pain conditions and sleep disturbance may further clarify the shared pathophysiology of sleep and pain. There have not yet been any

comparative studies simultaneously carried out in patients with different types of chronic pain conditions to determine whether there are physiological sleep differences among such patients. Previous investigations have examined specific groups of chronic pain patients, or unspecified "mixed" groups of patients, without examining whether any differences exist among patients with different pain conditions. Although the mechanism is not well studied, pain sensations could interrupt sleep via direct or indirect pathways. If specific relationships between chronic pain conditions and sleep disturbance can be identified, this could clarify the shared physiological underpinnings of sleep and pain, and treatments that target the specific sleep disruptions in a particular chronic pain condition could be developed.

Furthermore, although several investigations have examined sleep patterns in chronic pain patients, these investigations have used a variety of measures which limits the comparison of results across various studies. Similarly, several studies have used measures that were idiosyncratically generated and/or not validated, reducing confidence in the robustness of their findings. Sleep problems appear to be a ubiquitous finding among samples of chronic pain patients. In order to accurately and reliably delineate the nature of this relationship, as well as the influence of negative mood on this relationship, it is essential to use valid measurement instruments when assessing these patients. Previous studies have also indicated varying levels of agreement between different measures of sleep, usually related to the variable being considered (e.g., total sleep time vs. number of awakenings). This suggests that further information is needed to determine the utility and adequacy of different measures of individuals' sleep patterns and sleep problems.

Finally, previous investigations have indicated that individuals' subjective pain reports and their response to experimentally-induced painful stimuli are not perfectly correlated. Both of

these variables are important to examine, as each represents an important target for intervention in chronic pain populations. Additionally, differences among types of experimental pain procedures have been noted. Thermal pain appears to be an appropriate means of measuring pain sensitivity among chronic pain patients.

The present study addressed some of the limitations noted in previous research examining the relationship between sleep disturbance and chronic pain. First, different groups of chronic pain patients were recruited and completed the same procedures. This allows for comparison of results across different pain groups. Second, the self-report instruments used to measure pain, mood, and sleep are all valid and reliable instruments, which permits increased confidence in the findings of this study. Furthermore, sleep was measured using various methodologies (questionnaire, sleep diary, actigraphy) in a portion of the participants, which allows for comparisons across these methods to determine their level of agreement, as well as their utility for measuring different sleep variables within a chronic pain population. Similarly, pain was measured using various methodologies, including self-report (VAS), questionnaires, and psychophysical testing. This again permits examination of the relationships among these various measures and provides a comprehensive picture of participants' pain experience.

It was hypothesized that the prevalence of various types of sleep disturbances would differ between the different groups of chronic pain patients under study, underscoring the importance of implementing targeted treatments for specific sleep problems in these populations instead of assuming that a one-size-fits-all approach is appropriate. The current multimodal approach to nonpharmacological treatment of sleep disturbances has been shown to be effective; however, identifying the active treatment components in these multimodal packages will enable more efficient and cost-effective treatment delivery, which can ultimately target the specific

sleep problem being experienced by patients. There has been some evidence to suggest the differential effectiveness of specific treatment components for particular sleep problems, such as difficulties with sleep onset versus problems with sleep maintenance (Espie, Brooks, & Lindsay, 1989; Harvey, 2000; Waters et al., 2003).

Further, examination of the reported sleep disturbances among these chronic pain populations was undertaken to investigate interactions between the pain condition and the specific sleep disturbance that is being reported, such that the pain condition may be maintaining the sleep problem, the sleep problem may be exacerbating the pain conditions, or some reciprocal influence may be occurring between the sleep problem and the pain condition. It was also deemed important to note whether all 3 groups differed in the sleep disturbances that they presented, or if there was one group (such as fibromyalgia patients) that was distinguishable from the other two groups. If present, the emergence of this pattern of results might have lent support for a greater role of the central nervous system in mediating both the painful symptom presentation, as well as the particular type of sleep problem that is reported, by such a group of patients. Alternatively, if the pattern of results suggested that all 3 groups were distinct from one another, future studies should aim to identify what mechanisms may be underlying both the pain condition and the associated sleep problems in each group of patients.

Along these lines, it was hypothesized that differences in pain sensitivity and sleep patterns would be found among these groups of chronic pain patients, supporting the hypothesis of different mechanisms underlying these painful conditions. For instance, conditions with greater central nervous system involvement may involve both greater pain hypersensitivity and a more pervasive type of sleep disturbance, such as non-restorative sleep. As experimental studies have demonstrated hyperalgesia in healthy participants following sleep deprivation (Moldofsky

& Scarisbrick, 1976; Onen, Alloui, Gross et al., 2001), it was hypothesized that greater hypersensitivity to experimental stimuli in pain patients in the present study would lend further support to the hypothesis of a shared mechanism underlying both the processing of painful stimuli as well as regulation of individuals' sleep.

As described above, the presence of sleep disturbance in chronic pain patients warrants both evaluation and treatment in order to produce the most successful treatment outcome. Improved understanding of the underlying mechanisms of various chronic pain conditions, as well as their involvement in the sleep disturbances presented in these patients, may lead to improved pain management and functional outcome among chronic pain populations.

Specific Aims

- **Specific aim 1:** To measure subjective sleep quality in different populations of chronic pain patients using validated measures, and to identify the types of sleep disturbances present in each population.
- **Specific aim 2:** To examine the relationship between sleep, pain, and negative affect in order to better understand the relationships among these variables.
- **Specific aim 3:** To determine if chronic pain patients who reported concurrent sleep disturbances had greater sensitivity to painful stimuli compared to chronic pain patients who did not report concurrent sleep disturbances.

Hypotheses

- **Hypothesis 1:** Although it was expected that sleep disturbances would be reported by many of the chronic pain patients in this study, it was hypothesized that there would be an unequal distribution of specific types of sleep disturbances across groups. Specifically, it was hypothesized that facial pain patients would report more difficulty initiating sleep (greater sleep latency), back pain patients would report more difficulty maintaining sleep (greater sleep disturbances), and fibromyalgia patients would report a greater prevalence of non-restorative sleep (lower sleep quality), compared to the other groups of pain patients.
- **Hypothesis 2:** It was hypothesized that the relationship between sleep and pain in this sample of chronic pain patients would be partially mediated, when the influence of negative affect was included in the model.

- **Hypothesis 3:** It was predicted that those patients who reported poor sleep (as measured by the PSQI) would show hypersensitivity (higher ratings of pain intensity) during the ramp and hold pain testing procedures, and greater temporal summation compared to those chronic pain patients who reported good sleep (as measured by the PSQI).

- **Hypothesis 4:** It was predicted that participants who reported sleep disturbances would evidence longer sleep latency, more wake time after sleep onset, and lower sleep efficiency, as measured by both actigraphy and sleep diary measures, compared to participants who reported no sleep disturbances.

- **Hypothesis 5:** It was hypothesized that participants who did not report sleep disturbances would demonstrate higher correlations between actigraphy and sleep diary variables than participants who reported sleep disturbances.

CHAPTER2
METHODS

Participants

Participants in this study included 292 individuals with a current chronic pain condition; 116 patients with chronic facial pain, 55 patients with chronic back pain, and 121 patients with fibromyalgia. All participants were between 18 and 65 years of age (*M*=46.67, *SD*=12.05). The sample included 51 males and 241 females; and of those participants who indicated ethnicity, 88.2% were Caucasian. Additionally, a subgroup of participants was recruited that included 22 females (10 good sleepers, 12 poor sleepers) with a current chronic pain condition: 8 with chronic facial pain, 8 with chronic back pain, and 6 with fibromyalgia. Subgroup participants were designated as good or poor sleepers based on their total score from the Pittsburgh Sleep Quality Index (PSQI), using the modified cutoff score suggested by Carpenter and Andrykowski (1998). The average age of the subgroup participants was 43.77 years (*SD*=14.13 years), and 81.8% of subgroup participants identified themselves as Caucasian.

Participants were recruited from three groups of chronic pain patients at the University of Florida. Patients with chronic back pain were recruited from the Spine Care Center, patients with chronic facial pain were recruited from the Facial Pain Clinic, and patients with fibromyalgia were recruited from the Fibromyalgia Clinic. Participants who completed the subgroup procedures were recruited directly from the pain clinics described above, as well as through printed advertisements posted on the University of Florida campus.

Power analyses were conducted to determine the number of participants needed to detect an effect based on findings from previous studies using the PSQI with similar populations of pain patients. Specifically, comparisons were made based on PSQI global scores reported by Agargun and colleagues (1999) for fibromyalgia patients, Yatani and colleagues (2002) for

patients with temporomandibular disorder, and Menefee and colleagues (2000) for patients with back pain (Agargun et al., 1999; Menefee et al., 2000; Yatani et al., 2002). Based on these analyses, effect sizes of 0.53 and 0.62, were obtained in comparisons of PSQI global scores between these groups of chronic pain patients. Therefore, with power set at 0.80, and an alpha value of 0.05, it was determined that approximately 40 participants would be needed in each group of chronic pain patients in order to detect similar effects. Therefore, recruitment efforts attempted to secure at least 40 participants from each of the chronic pain clinics to ensure adequate power in this study.

Procedure

Patients provided demographic information and information related to their health and pain condition. This included the participant's age, sex, ethnicity, duration of pain, education, current medications, and pain ratings. In addition, participants completed a standard questionnaire packet as part of their clinical assessment, including measures of pain, negative affect, coping strategies, somatic focus, and disability. These questionnaires are described below. The first pain measure was either the McGill Pain Questionnaire (MPQ; (Melzack, 1975), a self-report questionnaire that assesses the sensory, affective, and evaluative dimensions of the pain experience, or the Medical College of Virginia Pain Questionnaire (MCV; (Price & Bushnell, 1994), which asks patients to provide visual analogue scale (VAS) ratings on pain intensity, pain unpleasantness, and function dimensions. Participants also completed the Coping Strategies Questionnaire – Revised (CSQ-R; (Riley & Robinson, 1997), a self-report instrument measuring pain coping strategies. The third pain measure that was completed by participants was the Pain Disability Index (PDI; (Pollard, 1984), a brief self-report measure of the degree to which pain interferes in seven life areas. The affective measures that participants completed included the Beck Depression Inventory (BDI; (Beck, Ward, Mendelson, Mock, & Erbaugh,

1961), which assesses the experience of cognitive and affective, and neurovegetative symptoms of depression during the past week; the State-Trait Anger Expression Inventory (STAXI; (Spielberger, 1988), which is used to assess both state anger symptoms and more general constitutional anger symptoms; the Pain-Anxiety Symptom Scale (PASS; (McCracken, Zayfert, & Gross, 1992), which provides an assessment of pain-related anxiety; the Medical College of Virginia Pain Questionnaire (MCV; (Price & Bushnell, 1994), which asks patients to provide visual analogue scale (VAS) ratings on mood, in addition to pain and function dimensions; and the Pennebaker Inventory of Limbic Languidness (PILL; (Pennebaker, 1982), a self-report symptom frequency checklist that assesses nonspecific common physical complaints. In addition to this standard questionnaire packet, participants also completed the Pittsburgh Sleep Quality Index (PSQI; (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), a self-report measure of sleep quality and disturbances over a one-month interval.

A subset of 22 participants (12 reporting sleep disturbances and 10 reporting no sleep disturbances) also underwent psychophysical testing to assess their pain sensitivity. Subgroup participants were Subjects underwent quantitative sensory testing using a contact thermode applied to the volar surface of the forearm. The protocol that was used enabled assessment of both first pain (primarily A-delta function) and second pain (primarily C-fiber input). All thermal stimuli were delivered using a computer-controlled Medoc Thermal Sensory Analyzer (TSA-2001, Ramat Yishai, Israel), which is a peltier-element-based stimulator. Temperature levels were monitored by a contactor-contained thermistor, and returned to a preset baseline of 32 deg C by active cooling at a rate of 10 deg C/Sec. All stimuli were delivered to the ventral left forearm. Alternating stimulation sites were used to prevent carryover effects due to local sensitization.

Additionally, this subset of 22 participants also completed daily sleep diaries and actigraphy monitoring for two weeks. The actigraphy monitoring was used to provide an objective measure of these individuals' sleep patterns. The sleep diaries were completed twice per day (before participants go to bed, and again in the morning), and provided an additional measure of participants' self-reported sleep patterns. Comparison of these participants' reports provided an indication of the degree to which these measures converge.

Measures

Demographic/patient characteristics information: Patients provided information pertaining to their sex, age, ethnicity, duration of pain, education, current medications, and pain ratings.

Pittsburgh Sleep Quality Index (PSQI; (Buysse et al., 1989): The PSQI is a self-report questionnaire that assesses sleep quality and disturbances over a 1-month time interval, and is designed to be used in clinical populations. This instrument is comprised of 19 items, which generate 7 "component" scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Additionally, the sum of the scores for these 7 components yields one global score. The psychometric properties of this measure have been shown to be sound, suggesting its utility in both clinical practice and research. This measure has been shown to have acceptable internal consistency (Cronbach's alpha = .83; (Buysse et al., 1989), and these authors further demonstrated that this measure has a diagnostic sensitivity of 85.5% and specificity of 86.5% in distinguishing good and poor sleepers. The psychometrics of the PSQI were subsequently evaluated by Carpenter and Andrykowski (1998) in 4 different patient populations, including bone marrow transplant patients, renal transplant patients, women with breast cancer, and women with benign breast problems. Results indicated that the PSQI had good internal

consistency (Cronbach's alpha coefficients = 0.80, across groups) and construct validity, and PSQI scores were found to be moderately to highly correlated with measures of sleep quality and sleep problems in these patients (Carpenter & Andrykowski, 1998).

McGill Pain Questionnaire (MPQ; (Melzack, 1975): The MPQ is a self-report questionnaire of participants' pain experience. This instrument provides both an overall total pain score, as well as evaluations of the sensory, affective, and evaluative dimensions of participants' pain experiences. The McGill Pain Questionnaire (MPQ) has a long history of use in pain research, and it is the most widely used instrument for evaluating pain (Melzack & Katz, 1992). The reliability of the MPQ was investigated by Love and colleagues (1989), and results demonstrated very strong test-retest reliability coefficients of this measure in a group of low back pain patients who were tested on two occasions (Love, Leboeuf, & Crisp, 1989). Additionally, several studies have replicated the factor structure of the MPQ (Lowe, Walker, & McCallum, 1991; Turk, Rudy, & Salovey, 1985), and results from a study by Pearce and Morley (1989) also demonstrated the construct validity of this measure (Pearce & Morley, 1989).

Medical College of Virginia Pain Questionnaire (MCV; (Price & Bushnell, 1994): The MCV questionnaire asks patients to provide visual analogue scale (VAS) ratings on pain, mood and function dimensions. These dimensions include measures of the pain experience itself, specifically pain intensity and pain unpleasantness, rated in reference to current levels, as well as highest, lowest, and usual levels during the preceding week. In addition, negative feelings associated with the pain experience (i.e., depression, anxiety, frustration, fear, and anger) are also rated, in reference to the previous week. Ratings were also provided regarding the extent to which pain prevented an individual from doing what he/she wanted to do, how

difficult an individual found it to endure pain over time, and how concerned an individual is with his/her health.

Beck Depression Inventory (BDI; (Beck et al., 1961): The BDI is a self-report measure of depression consisting of 21 items, which assess cognitive and affective, and neurovegetative symptoms of depression. This measure is designed to determine the extent to which individuals currently exhibit or experience each of these symptoms. Participants are instructed to indicate the statement in each item group that is most descriptive of how they have been feeling during the past week, including the current day. Each item is scored on a scale that ranges from 0 to 3. The use of the BDI has been evaluated in psychiatric and nonpsychiatric populations, and alpha coefficients ranging from .73 to .95 have been reported (Beck, Steer, & Garbin, 1988). The BDI is a well-validated assessment instrument for depression and it is an extensively used measure in experimental pain research.

Pain Anxiety Symptom Scale (PASS; (McCracken et al., 1992): The PASS is a self-report questionnaire consisting of 40 items assessing four dimensions of pain-related anxiety—cognitive anxiety, escape/avoidance, fearful appraisal, and physiological anxiety (McCracken, et al., 1992). Participants indicate to what extent the items are an accurate description of them on a 6-point scale, which ranges from never (0) to always (5). There are five items that are reverse scored. Previous studies have examined the reliability and validity of this measure (McCracken & Dhingra, 2002; Roelofs et al., 2004), and results have shown the PASS to be psychometrically sound. Cronbach's alpha coefficients of 0.94 have been reported in various samples of chronic pain patients (fibromyalgia, low back pain) (Roelofs et al., 2004).

State-Trait Anger Expression Inventory (STAXI; (Spielberger, 1988): The STAXI is used to assess both state anger symptoms and more general trait-like or constitutional anger

symptoms. The factor structure of the STAXI has been supported in analyses with a large sample of college students (D. G. Forgays, Forgays, & Spielberger, 1997) and a sample of middle-aged men and women (D. K. Forgays, Spielberger, Ottaway, & Forgays, 1998). The measurement properties of this assessment instrument have been shown to be acceptable, including good reliability and adequate validity (Kramer & Conoley, 1992).

Pennebaker Inventory of Limbic Languidness (PILL; (Pennebaker, 1982): The PILL is a self-report measure of the occurrence and frequency of non-specific common physical complaints, and is used as a measure of somatic focus. It consists of 54 items, such as upset stomach, sore throat, headache, and nausea. The following response categories are provided: "have never or almost never experienced the symptom", "less than 3 or 4 times per year", "every month or so", "every week or so", and "more than once every week", and responses are indicated by a five-point Likert scale. This measure evaluates commonly experienced symptoms over an unspecified time period in the past and assesses a general tendency to experience and report symptoms instead of the person's specific symptom experience (Gijsbers van Wijk, van Vliet, & Kolk, 1996). Therefore, the PILL is conceptualized as a trait-like symptom scale that evaluates somatization or a general propensity to report physical symptoms (Pennebaker, 1982). When used with healthy subjects, a high score is indicative of somatization. Internal consistency for this measure is high (Cronbach's alpha = 0.91) (Gijsbers van Wijk et al., 1996). The PILL also has sufficient test-retest reliability (r = 0.83) and was shown to correlate moderately with similar symptom scales (Pennebaker, 1982).

Coping Strategies Questionnaire–Revised (CSQ-R; (Riley & Robinson, 1997): The CSQ-R is a reformulation of the original CSQ (Rosenstiel & Keefe, 1983), which was a rationally constructed instrument designed to assess pain coping and was formulated to measure

the extent to which patients used six different cognitive coping strategies and two behavioral coping strategies. The CSQ-R retains 27 of the original 48 items of the CSQ, and proposes a 6-factor solution. The items that were discarded from the original CSQ did not appear to possess good factor discrimination across several studies examining the factor structure of this measure (Riley & Robinson, 1997; Swartzman, Gwadry, Shapiro, & Teasell, 1994; Tuttle, Shutty, & DeGood, 1991). The six-factor solution for the CSQ-R has been replicated, both in samples of chronic pain patients (Riley & Robinson, 1997; Robinson et al., 1997) as well as in an ethnically diverse sample of healthy individuals (Hastie, Riley, & Fillingim, 2004). Additionally, this measure was found to have acceptable internal consistency (Cronbach's alpha = 0.72 to 0.91) across ethnic groups (Hastie et al., 2004).

Pain Disability Inventory (PDI; (Pollard, 1984): The PDI is a 7-item measure of the degree to which chronic pain interferes with patients' functioning in the following areas of life: family/home responsibilities, recreation, social activity, occupation, sexual behavior, self care, and life-support activity (Pollard, 1984). An 11-point scale ranging from 0 (no disability) to 10 (total disability) is used to indicate the amount of disability experienced in each of the domains listed above. The seven ratings are summed to compute a total score (0 - 70). The PDI has adequate psychometric properties with an internal consistency coefficient of .86 (Tait, Pollard, Margolis, Duckro, & Krause, 1987). Additionally, results reported by Tait, Chibnall, and Krause (1990) demonstrated the construct validity of the PDI in a large sample of chronic pain patients, and also indicated that this measure had adequate test-retest reliability with a smaller group of pain patients undergoing inpatient treatment (Tait, Chibnall, & Krause, 1990).

Graded Thermal Stimulation or RAMP and HOLD (RH)

All thermal stimuli were delivered using a computer-controlled Medoc Thermal Sensory Analyzer (TSA-2001, Ramat Yishai, Israel), which is a peltier-element-based stimulator. The

temperature of the probe was calibrated immediately prior to each session. Visual Analog Scale (VAS) ratings of 4 graded intensities (45, 47, 49, 51^{o} C) of 3 second temperature stimuli were obtained in the following fashion. Stimuli were applied in random order to the forearm by a contact thermode and were 3 seconds in duration. Several sites located on the forearms of both arms were employed. Stimulus presentation was timed such that no site was stimulated with less than a 3-minute interval to avoid sensitization of the site. Participants rated 8 stimuli (2 at each intensity) using a VAS for pain intensity anchored at the right end by "the most intense pain imaginable." A second random sequence of 8 stimuli (2 at each intensity) was rated by VAS for pain unpleasantness (anchored at the right end by "the most unpleasant sensation imaginable.") This method of pain assessment has been shown to yield ratio scale measurement of clinical pain that is both internally consistent and provides independent sensory intensity and affective dimensions of experimentally induced pain (Price, Harkins, & Baker, 1987).

Temporal Summation (Wind-up)

Another method of eliciting second pain was employed that mimics natural conditions of nociceptive thermal stimulation such as when one touches a hot object. Trains of 8 stimuli with an inter-stimulus interval of 3 seconds were used. The stimuli were pulsed from a baseline temperature of 45 C^{o} to 52 C^{o}. When rating sensory magnitude, the participants were instructed to attend to the peak of late sensations that occur approximately 1.5 to 2 seconds after the probe leaves the skin on each presentation. This type of stimulus presentation results in a temporal summation believed to be primarily C-fiber determined.

Sleep Diary and Actigraphy

Although actigraphy does not correlate perfectly with polysomnographic measurement of sleep, the use of actigraphy provided an objective measure of certain sleep parameters, which enhanced the methodology of the present research study. As described previously, sleep can be

measured in various ways, and current recommendations involve using a multi-modal assessment of sleep patterns (meaning a combination of subjective, behavioral, and physiological measures of sleep). Actigraphy data provided an objective measure of participants' sleep without the burden inherent in polysomnography, while the sleep diary captured participants' subjective perception of certain sleep parameters. Both types of information are important and can provide useful information during both assessment and treatment activities. Furthermore, assessment of the degree of agreement between these measures can illustrate the parameters for which these methodologies overlap, and the parameters about which each provided unique, and potentially important, information.

Actigraphy assessment used a high-sensitivity algorithm. Variables obtained from actigraphy included: time in bed, total sleep time (TST), wake after sleep onset (WASO), number of awakenings, sleep efficiency, and sleep onset latency.

For the sleep diary, participants were asked to complete the diary before they went to bed at night, and then again the following morning. The variables that were included in the morning sleep diary are listed below:

- Time participant got into bed
- Approximate time participant fell asleep (SOL)
- Wake time
- Time participant got out of bed
- Number and duration of any awakenings during the night (number of awakenings and WASO)
- Rating of overall sleep quality using a visual analogue scale
- Participants were also asked to list any other factors that interfered with their sleep, such as pain or worries
- Visual analogue scale (VAS) for pain intensity and pain unpleasantness upon waking

The portion of the sleep diary that participants completed in the evening (i.e., before bed) contained a different set of variables, including:

- Number and amount of caffeinated beverages consumed during the day

- Number and amount of alcoholic beverages consumed during the day
- Any medications taken during the day
- Amount and type of physical activity
- Number and duration of naps taken during the daytime or early evening
- Visual analogue scale (VAS) for pain intensity and pain unpleasantness at bedtime

Statistical Analyses

Analysis 1: To determine if there were differences in sleep quality variables across type of chronic pain group, Kruskal-Wallis nonparametric tests for 3 independent samples were conducted for the following component scores from the PSQI across each of the three pain groups: sleep quality, sleep latency, and sleep disturbances. This nonparametric test was used due to the ordinal scale of the dependent variables in these analyses.

Analysis 2: Structural Equation Modeling (SEM) was used to examine the role of negative affect in the relationship between sleep and pain. Mediation was indicated if there was a lower or non-significant path coefficient between the latent factor of sleep and the latent factor of pain, after the latent factor of negative affect was entered into the model.

Analysis 3: A General Linear Model approach was used to conduct a mixed model analysis of variance to assess group (good sleeper vs. poor sleeper), heat pulse number, and group by heat pulse number interactions on pain report in the temporal summation/windup protocol.

Analysis 4: A General Linear Model approach was used to conduct a mixed model analysis of variance to assess group (good sleeper vs. poor sleeper), temperature level, and group by temperature level interactions on pain report in the ramp and hold procedure.

Analysis 5: A General Linear Model approach was used to conduct a mixed model analysis of variance to assess chronic pain group, heat pulse number, and chronic pain group by heat pulse number interactions on pain report in the temporal summation/windup protocol.

Analysis 6: A General Linear Model approach was used to conduct a mixed model analysis of variance to assess chronic pain group, heat pulse number, and chronic pain group by heat pulse number interactions on pain report in the ramp and hold procedure

Analysis 7: To determine if there were differences in actigraphy and sleep diary variables for participants with and without complaints of sleep disturbances, 2 multivariate analyses of variance (MANOVA) were conducted. One MANOVA examined SOL, WASO, sleep efficiency, as measured by actigraphy, between participants who did and did not report sleep disturbances. The second MANOVA examined SOL, WASO, sleep efficiency, as measured by sleep diary, between participants who did and did not report sleep disturbances.

Analysis 8: Pearson correlations were computed for SOL, WASO, TST, and sleep efficiency, as measured by actigraphy and sleep diary, for participants who did and did not report sleep disturbances. Differences between groups were then tested using z-tests.

CHAPTER 3
RESULTS

Sample characteristics were examined to determine whether there were any significant demographic differences among the three groups of chronic pain patients. Significant differences were found across groups in years of education, ($F(2,157)=5.57$, $p<.01$), with post hoc analyses indicating that facial pain (FP) patients had significantly more years of education than back pain (BP) patients. Significant differences in sex ($\chi^2(2)=36.96$, $p<.001$) and use of narcotic medications ($\chi^2(2)=37.35$, $p<.001$) were also found across the three chronic pain groups. No other significant differences in sample characteristics were found. Demographic characteristics of the sample and results of these analyses are provided in Table 3-1.

Differences in Subjective Sleep Across the Three Pain Groups

To examine whether there were differences in subjective sleep quality variables across the three chronic pain groups, Kruskal-Wallis nonparametric tests for 3 independent samples were performed. The dependent variables in this analysis were the sleep quality, sleep latency, and sleep disturbance component scores from the PSQI; the Kruskal-Wallis nonparametric test was used due to the ordinal scale of these variables. Results revealed significant differences among the three groups on PSQI sleep quality, $\chi^2(2) = 33.74$, $p<.001$; PSQI sleep latency, $\chi^2(2) = 16.63$, $p<.001$; and PSQI sleep disturbances, $\chi^2(2) = 44.28$, $p<.001$. For each of the three PSQI components, post hoc analyses were conducted using Mann-Whitney U tests in order to determine which groups were significantly different from one another. For sleep quality component scores, facial pain patients had significantly lower scores (indicating better sleep quality) compared to back pain patients, $z = 3.89$, $p<.001$; and fibromyalgia patients, $z = 5.53$, $p<.001$. For sleep latency component scores, facial pain patients had significantly lower scores (indicating shorter sleep latency) compared to back pain patients, $z = 2.87$, $p<.01$; and

fibromyalgia patients, $z = 3.83$, $p<.001$. For sleep disturbances component scores, facial pain patients had significantly lower scores (indicating fewer sleep disturbances) compared to back pain patients, $z = 3.68$, $p<.001$; and fibromyalgia patients, $z = 6.33$, $p<.001$; there was also a trend for back pain patients to have lower scores compared to fibromyalgia patients, $z = 1.73$, $p<.10$. These results are shown in Figure 3-1. These findings are consistent with results from a one-way ANOVA comparing PSQI global scores for each of the three pain groups, $F(2,262) = 25.86$, $p<.001$, $\eta^2 = 0.17$; post hoc Tukey tests indicated the same pattern of results (FP<BP,FMS; $p<.001$).

Sleep onset latency (SOL), wake after sleep onset (WASO), and sleep efficiency (SE), as measured by diary and actigraphy, and average sleep quality VAS ratings from the diaries, were also compared across subgroup participants from the three pain groups. The omnibus test revealed no significant differences across group. However, when mean values for each variable were examined across each group, the pattern of results that emerged was broadly consistent with the findings revealed by examining PSQI component score across groups. The effect size of this analysis was large ($\eta^2 = 0.28$), suggesting that the sample size of the subgroup could have played a role in the non-significant findings. These results are presented in Table 3-2.

Role of Negative Mood in the Sleep-Pain Relationship

Structural Equation Modeling (SEM) was used to examine the relationships among sleep, pain and negative mood in this sample of chronic pain patients. Specifically, the relationships between the latent factors of sleep and pain, the latent factors of sleep and negative mood, and the latent factors of negative mood and pain were examined to investigate whether direct causal paths existed between these factors. Additionally, in the final model including all three latent factors, the potential mediating influence of the negative mood factor was considered in terms of

its influence on the sleep-pain relationship. Following the procedures of Baron and Kenny (1986), mediation was indicated if there was a reduced or non-significant path coefficient between the latent factor of sleep and the latent factor of pain, after the latent factor of negative mood entered into the model (Baron & Kenny, 1986).

The sleep factor was indicated by three observed variables: PSQI global score, sleep quantity (raw score) from the PSQI, and the sleep quality component score from the PSQI. The negative mood factor was indicated by four observed variables, BDI total score, depression score from the MCV, PASS total score, and anxiety score from the MCV. The pain factor was indicated by three observed variables, MPQ total score, VAS for average pain intensity, and usual pain intensity from the MCV.

The relationships between the latent factors were tested sequentially, in accordance with the procedures outlined by Baron and Kenny (1986), and path coefficients were examined to determine whether significant causal relationships existed. The first step involved testing the relationship between the sleep factor and the pain factor. A significant relationship was found, path coefficient = -0.46, t = -3.72, indicating that poorer sleep predicts greater pain; the model was also found to provide a good fit for the data, $\chi^2(8)=3.85$, p=0.87, RMSEA=0.00. Next, the relationship between the sleep factor and the negative mood factor was tested. A significant relationship was found, path coefficient = -0.57, t = -7.66, such that poorer sleep also predicts higher levels of negative affect; the model was also found to provide a good fit for the data, $\chi^2(13)=18.74$, p=0.13, RMSEA=0.04. Third, the relationship between the negative mood factor and the pain factor was tested. A significant relationship was found, path coefficient = 0.69, t = 3.63, indicating that higher levels of negative affect predict greater pain; however, the fit of this model did not provide an excellent fit for the data, $\chi^2(12)=40.59$, p=0.00, RMSEA=0.09.

Finally, the full model involving all 3 latent factors was tested. Examination of the path coefficients in this final model, revealed a non-significant path between the sleep factor and the pain factor, path coefficient = -0.02, t = -0.18; a significant path between the sleep factor and the negative mood factor, path coefficient = -0.57, t = -7.72; and significant path between the negative mood factor and the pain factor, path coefficient = 0.99, t = 4.34. Results indicated that the full model fit the data well, $\chi^2(32)=41.77$, p=0.12, RMSEA=0.03. This final model indicates that negative affect mediates the effect of sleep on pain in this sample of chronic pain patients. Poorer sleep also continued to predict higher levels of negative affect, and increased levels of negative affect continued to predict increased pain in the final model.

The final structural equation model is shown in Figure 3-2. As stated above, mediation of the relationship between sleep and pain by negative mood was indicated by this final model. Specifically, the path coefficient between the sleep factor and the pain factor was reduced when negative mood was entered into the model (-0.02), compared to the path coefficient between the sleep factor and the pain factor without negative mood in the model (-0.46). This indicates that the direct relationship between sleep and pain was significantly reduced when negative affect was also included in the analysis, indicating that negative mood mediates the role of sleep on pain.

Psychophysical Testing–Temporal Summation/"Wind up" and Ramp and Hold

A General Linear Model approach was used to conduct a series of mixed model analyses of variance. For the temporal summation procedures, these analyses examined group (either: good sleeper vs. poor sleeper, or chronic pain group), heat pulse number, and group by heat pulse number interactions on pain report among facial pain, back pain, and fibromyalgia subgroup participants. For the ramp and hold procedures, these analyses examined group (either: good

sleeper vs. poor sleeper, or chronic pain group), temperature level, and group by temperature level interactions on pain intensity ratings and pain unpleasantness ratings among facial pain, back pain, and fibromyalgia subgroup participants.

Omnibus multivariate tests for the temporal summation procedures indicated no significant differences in pain report across either good vs. poor sleepers, or across chronic pain groups. Omnibus multivariate tests for the ramp and hold procedures indicated no significant differences in pain intensity ratings or pain unpleasantness ratings across either good vs. poor sleepers, or across chronic pain groups. Significantly higher pain intensity ratings and significantly higher pain unpleasantness ratings were found at higher temperatures, in all ramp and hold analyses. Results of these mixed model analyses of variance are provided in Table 3-3.

Actigraphy Data and Sleep Diary Data

A MANOVA examined sleep onset latency (SOL), wake after sleep onset (WASO), sleep efficiency, and total sleep time (TST), as measured by actigraphy, between subgroup participants who did and did not report sleep disturbances. The overall omnibus test was non-significant, $F(4,17) = 0.79$, $p>.05$, $\eta^2 = 0.16$. A second MANOVA examined sleep onset latency (SOL), wake after sleep onset (WASO), sleep efficiency, and total sleep time (TST), as measured by participants' sleep diaries, between subgroup participants who did and did not report sleep disturbances. The overall omnibus test for this analysis was also non-significant, $F(4,17) = 1.47$, $p>.05$, $\eta^2 = 0.26$.

Finally, separate Pearson correlations were computed between actigraphy and diary measurement of SOL, WASO, sleep efficiency (SE), and total sleep time (TST) for good and poor sleepers in the subgroup (Table 3-4). The correlations for each variable (SOL, WASO, SE, TST) were compared between good and poor sleepers. Results revealed significantly stronger

correlations between diary and actigraphy measurements of WASO for good sleepers. Correlations between diary and actigraphy measurement of SOL, SE, and TST were also higher among good sleepers; however, the difference in the magnitude of the correlations between good and poor sleepers for each of these variables did not reach significance (Table 3-4).

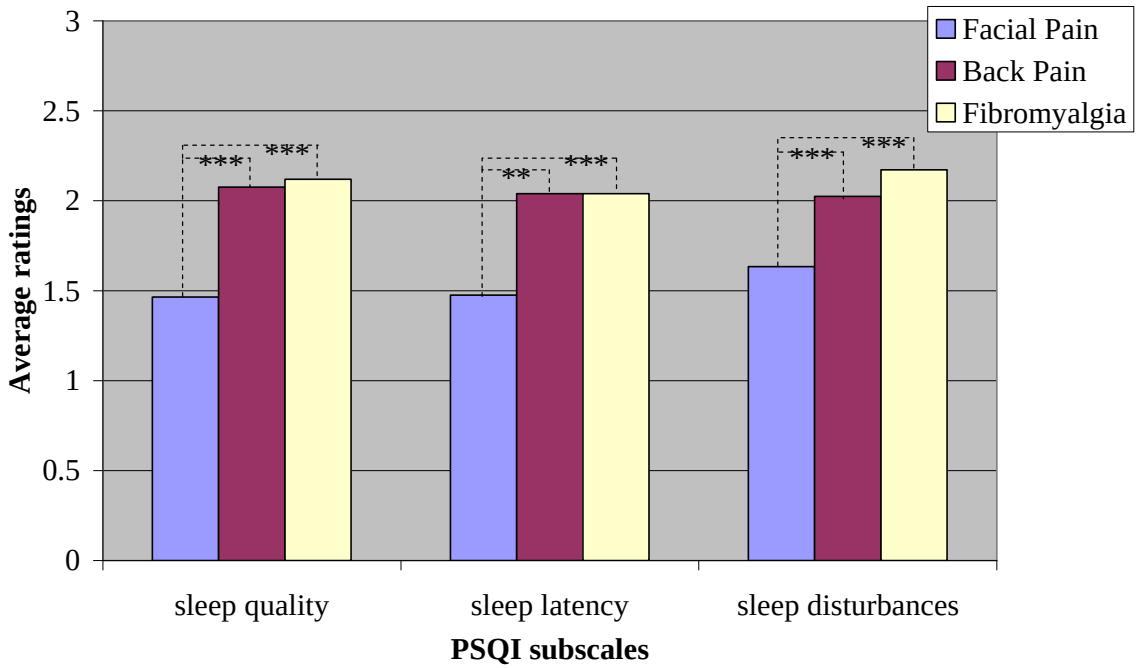

Figure 3-1. Self-reported sleep (as reported by PSQI) for 3 chronic pain groups. **p<.01; ***p<.001.

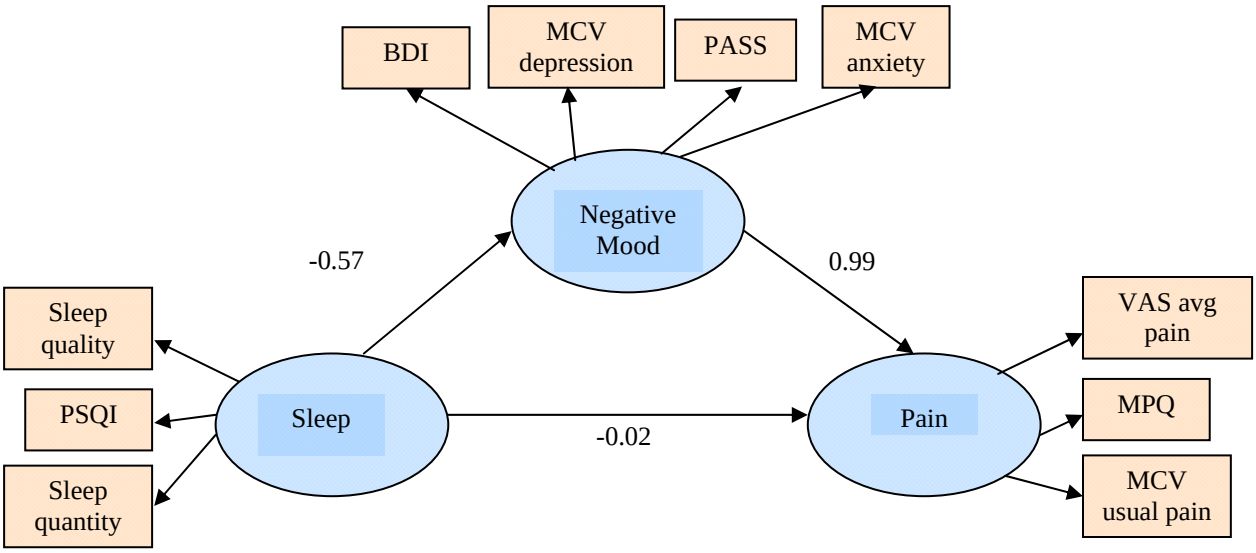

Figure 3-2. Structural equation model for the relationship among sleep, pain, and negative mood. $\chi 2(32)=41.77$, $p=0.12$, RMSEA=0.03.

Table 3-1. Demographic information for the 3 chronic pain patient groups

	Facial pain $N = 116$		Back pain $N = 55$		Fibromyalgia $N = 121$				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*df*	*p*
Age	46.28	14.12	46.44	10.28	47.53	10.82	0.35	2,291	0.706
Pain duration	91.32	109.91	128.70	111.57	130.29	70.80	2.37	2,175	0.097
Years of education	14.20	2.76	12.89	2.32	15.86	4.71	5.57	2,157	0.005

		Facial pain *N* (%)	Back pain *N* (%)	Fibromyalgia *N* (%)	χ^2	*p*
Sex						
	Female	95 (80.5)	34 (61.8)	147 (95.5)	36.96	0.000
	Male	23 (19.5)	21 (38.2)	7 (4.5)		
Race						
	Caucasian	107 (90.7)	46 (83.6)	6 (85.7)	9.30	0.318
	Black/African-American	4 (3.4)	8 (14.5)	1 (14.3)		
	Asian	1 (0.8)	0 (0.0)	0 (0.0)		
	Hispanic	4 (3.4)	1 (1.8)	0 (0.0)		
	Other	2 (1.7)	0 (0.0)	0 (0.0)		
Work status						
	Full-time	23 (19.5)	8 (15.1)	0 (0.0)	15.32	0.053
	Part-time	8 (6.8)	2 (3.8)	0 (0.0)		
	Working, unspecified	25 (21.2)	7 (13.2)	0 (0.0)		
	Student	13 (11.0)	1 (1.9)	1 (14.3)		
	Not employed	49 (41.5)	35 (66.0)	6 (85.7)		
Narcotic med use						
	Yes	29 (26.1)	41 (75.9)	4 (57.1)	37.35	0.000
	No	82 (73.9)	13 (24.1)	3 (42.9)		
Antidepressant med use						
	Yes	41 (36.9)	22 (42.3)	4 (66.7)	2.33	0.313
	No	70 (63.1)	30 (57.7)	2 (33.3)		
Sleep med use						
	Yes	47 (41.2)	20 (45.5)	3 (100.0)	4.51	0.341
	No	62 (54.4)	23 (52.3)	0 (0.0)		

Table 3-2. Comparison of diary- and actigraphy-measured sleep variables across 3 pain groups

	Facial pain		Back pain		Fibromyalgia				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	η^2
Sleep diary variables							*df(2,19)*		
SOL	21.74	13.24	42.42	24.91	32.73	19.08	2.20	0.138	0.19
WASO	13.17	12.35	47.54	79.53	54.40	39.83	1.29	0.298	0.12
SE	91.12	3.89	86.87	7.23	85.22	5.77	2.00	0.163	0.17
VAS sleep quality	5.46	1.22	5.04	1.31	4.49	1.24	1.02	0.380	0.10
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	η^2
Actigraphy variables							*df(2,19)*		
SOL	16.93	13.37	29.68	23.47	23.46	16.67	0.95	0.404	0.09
WASO	47.26	13.06	57.58	14.77	67.25	27.92	1.99	0.164	0.17
SE	83.66	3.56	78.48	9.26	79.05	6.00	1.37	0.278	0.13

Note. SOL=Sleep onset latency; WASO=Wake after sleep onset; SE=Sleep efficiency; VAS=Visual analogue scale.

Table 3-3. Multivariate mixed model MANOVA results for pain ratings in temporal summation and ramp and hold procedures

Temporal summation					
Source	Hypothesis df	Error df	*F*	*p*	η^2
Pulse number	3	18	1.24	0.326	0.17
Pulse number x type of sleeper	3	18	1.24	0.325	0.17
Pulse number	3	17	1.28	0.312	0.19
Pulse number x chronic pain group	6	36	0.90	0.509	0.13

Ramp and hold – *pain intensity ratings*					
Source	Hypothesis df	Error df	*F*	*p*	η^2
Temperature	3	18	24.70	0.000	0.81
Temperature x type of sleeper	3	18	0.26	0.855	0.04
Temperature	3	17	24.10	0.000	0.81
Temperature x chronic pain group	6	36	0.99	0.448	0.14

Ramp and hold – *pain unpleasantness ratings*					
Source	Hypothesis df	Error df	*F*	*p*	η^2
Temperature	3	18	18.82	0.000	0.76
Temperature x type of Sleeper	3	18	0.26	0.852	0.04
Temperature	3	17	20.14	0.000	0.78
Temperature x chronic pain group	6	36	1.08	0.392	0.15

Table 3-4. Correlation between actigraphy- and diary-measured sleep variables for good and poor sleepers

	SE actigraphy	WASO actigraphy	SOL actigraphy	TST actigraphy
Good sleepers (*N*=9)				
SE diary	0.47			
WASO diary		0.91**		
SOL diary			0.77*	
TST diary				0.92***
Poor sleepers (*N*=13)				
SE diary	0.34			
WASO diary		0.19		
SOL diary			0.47	
TST diary				0.82**
Difference z-score	0.30	2.59**	0.99	0.84

Note. SOL=Sleep onset latency; WASO=Wake after sleep onset; SE=Sleep efficiency; TST=Total sleep time. *p<.05; **p<.01; ***p<.001.

CHAPTER 4
DISCUSSION

Results revealed significant differences in subjective sleep reports across the three chronic pain populations in the current sample. Most notably, the facial pain patients reported better sleep quality, shorter latency to sleep onset, and fewer sleep disturbances, compared to the patients in the back pain and fibromyalgia groups. This suggests that the facial pain patients were experiencing less disturbed sleep overall, compared to the other two groups. The back pain patients and the fibromyalgia patients endorsed similar reports regarding sleep quality, latency to sleep onset, and sleep disturbances overall. They reported higher levels of subjective sleep problems on a validated self-report measure of sleep quality, compared to the facial pain patients.

Descriptive analyses indicated significant differences in sex, education, and narcotic medication use across chronic pain groups. No significant differences on any of the three sleep variables were found across sex. Significant differences were found for sleep quality and sleep latency across years of education, with poorer sleep being related to fewer years of education. Facial pain patients also had significantly higher education compared to back pain patients. Finally, significant differences in narcotic medication use was found across all three sleep variables, with users having higher scores on each of the three sleep variables (indicating poorer sleep) compared to non-users.

The highest rates of narcotic use were found among back pain patients, followed by fibromyalgia patients, with facial pain patients endorsing the lowest rates of narcotic medication use. As narcotic medications are known to affect sleep continuity and sleep architecture (reduced sleep quantity, suppression of REM and stage 3-4 sleep) (Kay, Eisenstein, & Jasinski, 1969), it is possible that higher rates of use of these medications among the back pain and fibromyalgia patients is related to the poorer sleep reported by these patients. However,

fibromyalgia patients reported the most impaired sleep across subscales, and back pain patients had the greatest rates of narcotic medication use. Further, studies have demonstrated that individuals typically develop a tolerance to the sleep effects of these medications within a few weeks after initiating use (Kay et al., 1969). Additionally, average pain levels were compared across pain groups, and fibromyalgia patients were found to have higher levels of average pain compared to facial pain patients; back pain patients did not differ from either of the other two groups. It is possible that higher levels of average pain among fibromyalgia patients were related to the increased subjective sleep problems reported by these patients; however, back pain patients also reported similar levels of sleep problems and similar levels of pain, so it is unclear how important of a role average pain ratings played in the subjective sleep reports of these patients.

Thus, while some support was found for the hypothesis that there would be differences in the distribution of sleep problems across the three chronic pain groups, it was not the case that each group of chronic pain patients exhibited increased levels of specific types of sleep problems. The differences in sleep that emerged between the three chronic pain groups were in quantity rather than type of sleep disturbance. Within each of the three chronic pain groups, multiple types of sleep problems (difficulties with initiation of sleep, frequent disturbances during sleep, and poor subjective sleep quality) were reported. However, it appears that patients with back pain and fibromyalgia endorse greater levels of sleep problems when compared to patients suffering from chronic facial pain. Back pain and fibromyalgia groups reported significantly greater problems within all three areas: initiation of sleep, frequency of sleep disturbances, and subjective sleep quality, compared to the group of facial pain patients in this study.

It may be that the sleep problems of chronic pain patients are similar overall, or it is possible that the component scores from the Pittsburgh Sleep Quality Index (PSQI) were not sensitive enough to differentiate each of the specific sleep problems being investigated. Therefore, the sleep onset latency (SOL), wake after sleep onset (WASO), and sleep quality VAS ratings from subgroup participants' diaries (or actigraphy and diaries for SOL and WASO) were also examined to determine whether any differences existed between the three chronic pain groups on any of these characteristics. No significant differences emerged in these analyses; this may be due in part to the small sample size of the subgroup as large effect sizes were seen in these analyses. The overall pattern of results that emerged from analysis of the diary and actigraphy variables in the subgroup is generally consistent with the findings from the self-report measures in the larger sample of participants.

The structural equation modeling analysis sought to increase understanding of the relationship between sleep, pain, and negative mood. In particular, the role of sleep in predicting pain was of interest, as was the potential mediating effect of negative mood on this relationship. Results from this analysis supported a direct relationship between sleep and pain, when negative mood was not considered in the model. This supports and extends previous research by demonstrating that increased sleep problems predict greater pain, using validated and reliable measures in a large group of chronic pain patients. Poorer sleep was also shown to be predictive of higher levels of negative mood, which again supports previous research and highlights the importance of addressing sleep problems when present in chronic pain patients. Additionally, when negative mood was included in the model, it was shown to mediate the relationship between sleep and pain in this sample. Thus, the importance of assessing and treating both sleep problems and negative mood in chronic pain patients cannot be underestimated.

While the relationship between sleep and pain is complex, these results suggest that there are multiple pathways by which sleep is related to pain. First, sleep disturbance may lead directly to increased pain among chronic pain patients. Second, sleep disturbance may lead to increased pain in chronic pain patients through sleep's influence on negative mood. While higher levels of negative mood are found among chronic pain patients, not all patients with chronic pain have increased levels of negative mood. This model demonstrates that the influence of sleep on pain may take multiple routes, and is also related to whether increased levels of negative mood are present. This suggests that assessment of both sleep and negative mood should routinely be undertaken in chronic pain populations. This model also suggests that treatment efforts can take multiple routes, although research is needed to determine whether interventions that improve sleep also lead to improvements in mood and/or pain as well.

No differences were found across the three chronic pain groups in their response to the psychophysical testing. All participants noted higher ratings of pain intensity and pain unpleasantness at higher temperatures in the ramp and hold procedure, but no other significant results were found between pain groups in either the ramp and hold or the temporal summation procedures. Additionally, the results of the psychophysical testing in the subgroup of participants did not support the hypothesis of greater sensitivity to painful stimuli among those patients with concurrent sleep disturbance. However, it should be noted that these analyses were exploratory in nature, and a general pattern of large effect sizes was demonstrated across analyses.

The results of this study demonstrated the high prevalence of subjective sleep problems in chronic pain patients. By including different groups of chronic pain patients, and examining differences in sleep reports across these different groups of patients, this study allows for a

greater understanding of the similarities and differences in the sleep problems reported by different populations of chronic pain patients. Contrary to the hypothesis that different types of sleep problems would be more prevalent in specific chronic pain groups, results suggested the emergence of similar subjective sleep reports across all three chronic pain groups. One significant difference noted across groups, was that the facial pain patients reported fewer sleep disturbances overall compared to the other two groups. This pattern of results suggests that a broad-based sleep treatment, within interventions for chronic pain, may be the most appropriate approach given the current evidence. Since no specific sleep problems emerged within each of the chronic pain groups, there is no evidence to suggest targeting sleep treatments for specific sleep problems within any chronic pain populations.

Examination of the relationships among sleep, pain, and negative mood revealed several important findings, and underscored the role of both sleep and negative mood in the clinical picture of chronic pain. First, poor sleep was found to directly predict both negative mood and pain in this sample of chronic pain patients. This highlights the importance of thoroughly assessing for and treating sleep problems within chronic pain populations. The direct relationship between sleep and pain suggests that addressing sleep problems in pain patients will likely have a beneficial impact on these patients' pain experience. However, since negative mood mediated the relationship between sleep and pain in this sample of chronic pain patients, addressing negative mood may have a greater impact on patients' pain experience among those chronic pain patients who are experiencing both sleep disturbance and negative mood.

Within the subgroup of participants who completed the psychophysical testing, no significant differences emerged across the three chronic pain groups on either the ramp and hold or temporal summation protocols. Participants from all three groups responded similarly to the

thermal pain stimuli in each protocol. Additionally, no significant differences were noted between subgroup participants with and without concurrent sleep disturbances. These results did not support the hypothesis that chronic pain patients with concurrent sleep problems would experience greater sensitivity to the painful thermal stimuli, and fail to support previous findings of increased pain sensitivity among individuals who experienced reduced or disrupted sleep (Kundermann et al., 2004; Moldofsky & Scarisbrick, 1976; Onen, Alloui, Gross et al., 2001).

Comparison of Study Results to Previous Findings

Similar to previous studies, the current results support the ubiquitous nature of sleep problems in chronic pain populations. Overall, 63.5% of participants reported subjectively poor sleep using a modified cut-off score on the PSQI, within this sample of back pain, facial pain, and fibromyalgia patients. This supports the hypothesis of sleep problems as a pervasive condition among chronic pain patients, and suggests that sleep problems should be routinely assessed for and treated in this population. This study adds to the existing knowledge by examining the relative distribution of specific sleep complaints reported by patients with different chronic pain conditions, allowing for a comparison of findings across different chronic pain patient samples. In particular, while similarly disrupted sleep was noted across the entire sample, results indicated that reported sleep problems were more severe among back pain and fibromyalgia patients, as compared to the facial pain patients. The back pain and facial pain patients did not appear to differ from one another in the type or severity of sleep problems reported. Further study employing polysomnography would be useful in identifying whether objective sleep differences emerged among different groups of patients, but the present findings suggest that subjective experience of sleep is similar for back pain and fibromyalgia patients.

While it was hypothesized that the three chronic pain groups would differ in their subjective sleep reports, results supported the presence of a more generalized pattern of sleep

disturbance across groups. Specifically, all three chronic pain groups reported difficulties with both sleep onset and frequent sleep disturbances, as well as subjectively poor quality sleep. Differences among groups emerged in the severity of these sleep problems, with fibromyalgia patients endorsing significantly greater levels of these problems compared to the facial pain patients, and back pain patients endorsing sleep problems that fell intermediate of these other two groups. Thus, it appears that sleep is more broadly disturbed within chronic pain conditions than initially hypothesized, and no specific differences regarding the sleep problems reported by various chronic pain populations were evident in this sample. The experience of chronic pain, either alone or in conjunction with negative mood, may simply serve as a gross disruptive factor for sleep among these patients.

No significant relationships were found between subjective reports of good vs. poor sleep and sensitivity to painful thermal stimuli in the current study. Previous studies have reported increased sensitivity to painful stimuli following conditions of interrupted or restricted sleep (Kundermann et al., 2004; Moldofsky & Scarisbrick, 1976; Onen, Alloui, Gross et al., 2001). Thus, the present findings are somewhat inconsistent with these previous reports from the literature. Interestingly, the effect sizes found in the subgroup analyses for the temporal summation procedure were large, suggesting that the presence or absence of sleep disturbance may be an important predictor of experimental pain response in chronic pain populations. Prior studies have demonstrated that chronic pain patients have an increased likelihood of sensitization to painful stimuli (Staud et al., 2003), and it may be that this is further compounded by the experience of disturbed sleep. However, this cannot be determined based on the findings from the present analyses and needs to be examined in future studies.

Role for Negative Mood in the Sleep-Pain Relationship

Higher levels of negative mood are commonly reported, both among chronic pain populations and among individuals with sleep problems (Breivik et al., 2005; Breslau, Roth, Rosenthal, & Andreski, 1996; Buysse et al., 1994; Duquesnoy et al., 1998; Ford & Kamerow, 1989; Ohayon, 1997; Verhaak et al., 1998). However, the interrelationships among sleep, pain, and negative mood have been inconsistent in the existing literature (Atkinson et al., 1988; Moffitt et al., 1991; Morin et al., 1998; Pilowsky et al., 1985; Sayar et al., 2002). Some studies have reported higher levels of depression and/or anxiety among chronic pain patients with sleep disturbances; other studies have not found these relationships. The current results support a mediating role for negative mood in the relationship between sleep and pain. In other words, while significant relationships have been reported between sleep and pain, these relationships must take into account the presence of negative mood. In particular, among chronic pain patients endorsing high levels of negative mood, pain is more strongly predicted by negative mood than by sleep. However, it is not difficult to see how negative mood, sleep disturbances, and pain can each act to increase the other two, leading to a cycle that perpetuates itself if there is no intervening action to disrupt it. Addressing negative mood will likely have a beneficial effect on patients' pain experience or perceptions regarding their ability to cope with their pain, and may also improve sleep as well. Further, among patients with low levels of negative mood, intervening to improve sleep disturbances will likely have a positive impact on patients' pain experience as well. As effective interventions have been developed for both negative mood and sleep, implementing these treatment will be important as it is likely to improve patients' pain experience and lead to significant improvements in functioning.

Implications for Conceptualization and Treatment of Chronic Pain

The comorbidity between chronic pain and sleep disturbances has been widely reported in the literature (Atkinson et al., 1988; Pilowsky et al., 1985; M. T. Smith & Haythornthwaite, 2004). Similarly, numerous studies have reported increased reports of negative mood among both chronic pain patients (Breivik et al., 2005; Duquesnoy et al., 1998; Robinson & Riley III, 1999; Verhaak et al., 1998), and patients with sleep problems, particularly those reporting insomnia complaints (Breslau et al., 1996; Chang, Ford, Mead, Cooper-Patrick, & Klag, 1997; Ford & Kamerow, 1989; Katz & McHorney, 2002). The model investigated in this study examined the role of sleep and negative mood in predicting pain among chronic pain patients, and revealed that negative mood mediated the relationship between sleep disturbance and pain. Thus, previous findings suggesting a causal link between sleep disturbances and pain in chronic pain patients may be due, in part, to the effects of negative mood. High levels of negative mood may increase or perpetuate the impact of sleep disturbances on patients' pain experiences, possibly through the interruption of sleep, which is a common report in the clinical pictures of both depression and anxiety.

Additionally, certain areas in the central nervous system have been implicated in both pain perception/regulation, as well as the regulation/facilitation of sleep, such as the hypothalamus (Montagna, 2006). Abnormalities of the hypothalamic-pituitary-adrenal (HPA) axis functioning have been noted among 30-70% of individuals suffering from major depression, and good treatment response has been demonstrated for individuals who evidence normalization of HPA functioning with use of antidepressant medications (Takahashi, 2002). This lends further supports to the importance of this pathway in mood regulation, and given the overlap with functions related to both sleep and pain, this pathway may be a common physiological link between these oft related conditions. Taken together, these findings support the argument for the

involvement of common pathophysiological pathways in sleep disturbance, mood disorders, and chronic pain.

Interestingly, no clear relationship was found between sleep disturbance and sensitivity to painful stimuli in the present study. This is somewhat contradictory to findings from previous studies, which have reported increased sensitivity to painful stimuli or increased pain reports among healthy individuals following conditions of sleep restriction or interrupted sleep (Kundermann et al., 2004; Moldofsky & Scarisbrick, 1976; Onen, Alloui, Gross et al., 2001). Similarly, studies examining pain sensitivity among chronic pain patients have also suggested an inverse relationship between pain response to experimental stimuli and sleep (Agargun et al., 1999). The present results are inconsistent with these findings.

It should be noted that these analyses utilized participants' self-reports about their subjective sleep to determine good and poor sleepers, rather than experimentally manipulating participants' sleep. When sleep has been manipulated experimentally among healthy participants, increased pain sensitivity has been reported (Kundermann et al., 2004; Moldofsky & Scarisbrick, 1976; Onen, Alloui, Gross et al., 2001). Additionally, a recent study by Smith and colleagues demonstrated differential effects on pain inhibition for restricting total sleep time to a shorter duration compared to repeatedly disrupting sleep using forced awakenings to produce a similar shorter total duration of sleep, within a sample of healthy participants (M. T. Smith, Edwards, McCann, & Haythornthwaite, 2007). These results suggest that differential effects on pain processing may be produced by disruptions in sleep continuity as compared to reduced sleep quantity produced by a shortened schedule. The pattern of more generalized sleep disturbances reported by the subgroup of chronic pain patients in the present study may be qualitatively different than the sleep deprivation produced by restricting total sleep time in

healthy participants. Thus, the increased pain sensitivity related to sleep disturbances reported by previous studies may vary as a function of the type of sleep disturbance, as well as the type of population (healthy volunteers versus chronic pain patients). In other words, differential effects on pain sensitivity may be seen following experimentally-produced sleep restriction in healthy volunteers as compared to the effect of more chronic or cumulative sleep interruptions on pain response in chronic pain patients. If this hypothesis is true, it could help to explain the lack of significant findings regarding pain sensitivity in the present analyses.

Current evidence supports cognitive-behavioral approaches to the treatment of chronic pain as having the most consistent empirical support (Robinson & O'Brien, in press), with improvements seen in pain, mood, and coping, as well as reductions in interference and improved functional outcomes (such as fewer absences from work, reduced medication use and health care visits) (Linton, Boersma, Jansson, Svard, & Botvalde, 2005; Nash, Park, Walker, Gordon, & Nicholson, 2004; Turner, Mancl, & Aaron, 2006). Within CBT approaches for chronic pain, negative mood is often addressed either directly or indirectly, and the results of this study suggest that addressing negative mood within chronic pain treatments is important and should continue to be a central part of these treatments. However, the assessment and treatment of sleep is a less standard component in CBT treatments for chronic pain, and most often consists of education about sleep hygiene when it is included. While this may be useful information, sleep hygiene alone has not been demonstrated to be effective as a means of implementing changes to improve sleep (Engle-Friedman, Bootzin, Hazlewood, & Tsao, 1992; Guilleminault et al., 1995).

Given the high comorbidity of sleep disturbance and chronic pain, it would appear prudent to include a formal assessment of patients' sleep within chronic pain assessments.

Additionally, incorporating established techniques (stimulus control, sleep restriction) from CBT for Insomnia (CBT-I) treatments for addressing sleep disturbances into existing CBT treatments for chronic pain would likely be more effective for addressing sleep problems being experienced by chronic pain patients. The skill-based, behavioral nature of these techniques allows for their inclusion within existing cognitive-behavioral treatments for chronic pain. Incorporating these sleep treatment components with existing techniques for addressing mood and activity, as well as increasing patients' knowledge regarding chronic pain, will likely lead to better outcomes and more fully address the full spectrum of impairment experienced by chronic pain patients.

Limitations

Some limitations to the above findings should be noted. Analyses involving the subgroup of participants completing sleep diaries, actigraphy monitoring, and the psychophysical testing procedures were intended to be exploratory, in order to identify the presence of potentially provocative findings that could subsequently be explored in a larger and more representative sample. As such, the sample size of this subgroup of participants was small and may have made it difficult to detect significant findings using traditional statistical criteria.

Results from the analyses of participants' response to psychophysical testing revealed large effect sizes between good and poor sleepers (temporal summation), and across chronic pain groups (temporal summation and ramp and hold), in these analyses. This suggests that sleep disturbances may be an important of determinant of chronic pain patients' responses to painful stimuli and that type of pain condition may also be an important influence on individuals' response to painful stimuli. However, the present analyses may not have been able to demonstrate these relationships at traditional statistical significance levels, due to the small sample size of the subgroup reducing the power of the analyses. There was no pain-free sample

of participants in the present study, so results are not available to examine the role of sleep disturbance on psychophysical pain response among individuals without chronic pain.

Similarly, when sleep diary and actigraphy measurement of several sleep parameters across good and poor sleepers were examined, no significant differences emerged. The large effect sizes of these analyses again suggested that the sample size of the subgroup may have impacted the ability for significant findings to emerge. Thus, consistent with the general pattern of correlations found between sleep diary and actigraphy measures found among good and poor sleepers, it appears that these measures may be more strongly associated in good sleepers compared to poor sleepers. Examination of these relationships in a larger sample will increase the power of the analyses and improve the ability to detect such relationships, if they are present. The large effect sizes found across subgroup analyses suggests avenues for additional studies using larger numbers of participants, in order to elucidate the nature of the relationships among sleep disturbance, type of chronic pain, and psychophysical response.

Additionally, the number of female participants was much greater than the number of male participants in the sample. This is consistent with the literature on chronic pain, where females tend to be over-represented in most chronic pain populations (Moulin et al., 2002; Verhaak et al., 1998). While the unequal distribution of males and females makes it difficult to directly examine sex differences in these findings, the preponderance of data has demonstrated a lack of sex differences in clinical pain (Robinson, Wise, Riley III, & Atchison, 1998). This allows for increased confidence in the applicability of the current findings to both male and female chronic pain populations.

Future Directions

It would be interesting to examine whether incorporating CBT-I techniques into existing CBT treatments for chronic pain affords any benefit for chronic pain patients. Specifically,

examination of patients' mood, sleep, and pain reports following standard CBT treatment for pain, CBT for pain plus sleep hygiene information alone, and CBT for pain plus sleep hygiene information and CBT-I techniques, would provide information about the additive benefits of the addition of sleep treatment to existing CBT treatments for chronic pain. While it is likely that the addition of the sleep techniques would confer added utility to chronic pain treatments, it would also increase the duration and thus, the cost, of these treatments. Thus, it would be important to provide a justification for the additional time and cost of adding these techniques into existing treatment paradigms, by demonstrating improved patient outcomes when these components are part of the treatment package. Additionally, longitudinal evaluations would be useful to examine any improvement in outcomes that patients experience following treatment.

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BIOGRAPHICAL SKETCH

Erin Maureen O'Brien was born in 1978 in Piscataway, New Jersey. The oldest of three daughters, she grew up in Marlton, New Jersey and graduated from Cherokee High School in 1996. She attended Saint Joseph's University in Philadelphia, Pennsylvania, and was accepted into a 5-year B.S./M.S. program, where she earned a B.S. in psychology and an M.S. in experimental psychology in 2000 and 2001, respectively. Her master's thesis was titled, "Sleep and Risk-Taking Behavior in Adolescents" and this work was published in 2005.

Upon graduating in 2001 with her M.S. in experimental psychology, Erin obtained a position as a clinical research coordinator in the Center for Sleep and Respiratory Neurobiology at the University of Pennsylvania. Here she coordinated the progression of several large NIH-funded clinical research protocols under the direction of Dr. Allan Pack. This experience solidified Erin's interest in pursuing additional study in the field of psychology and resulted in her application and acceptance into the doctoral program at the University of Florida so that she could earn her Ph.D. in clinical psychology. Here she pursued her dual interests in the study of sleep disturbances and chronic pain, which culminated in her dissertation research.

As part of her doctoral program, Erin completed a year-long clinical internship at the Warren Alpert Medical School at Brown University where she pursued additional training in the area of behavioral medicine. Upon completion of her Ph.D. program, Erin will be continuing her research and clinical work as a post-doctoral fellow in the Methods to Improve Diagnostic Assessment and Services (MIDAS) clinical-research program at Brown University, with a focus on working with patients presenting with insomnia and other sleep disorders.