# Pain, Sleep, and Mood in Individuals with Spinal Cord Injury

by

Sarah Bradley Feenstra

A Thesis Submitted in Partial Fulfillment of the

Requirements for the Degree of Bachelor of Science

with Honors in Neuroscience from the

University of Michigan

2012

Advisor: Dr. Claire Z. Kalpakjian

Abstract

Individuals with spinal cord injury (SCI) experience a wide range of medical complications after injury, many of which are interrelated. Chronic pain, sleep disturbances, and depression and other mood disturbances that persevere beyond the immediate, acute effects of sustaining an injury are prevalent complications of SCI; evidence suggests that there is a greater prevalence of these problems in the SCI population compared to the general population. The goal of this pilot study was to examine the relationship between these three complications in individuals with SCI. Nineteen participants completed seven continuous days of data collection; daily ratings of mood, pain, and sleep were collected. Results indicate that pain predicts sleep quality, and that pain and sleep quality predict mood. Future studies may investigate underlying mechanisms of these three complications.

Key words: spinal cord injury, sleep, pain, negative mood

## Pain, Sleep, and Mood in Individuals with Spinal Cord Injury

Spinal cord injury (SCI), like many other chronic illnesses or injuries, results in many long-term secondary complications, both physiological and psychological. These can often lead to a detrimental effect on the life and well-being of patients with SCI. Pressure ulcers, autonomic dysreflexia, pneumonia/atelectasis, urinary tract infection, spasticity, and hypotension are a few of the most common long-term secondary medical impairments in SCI patients (McKinley, Jackson, Cardenas, & DeVivo, 1999; Noreau, Proulx, Gagnon, Drolet, & Laramee, 2000), while anxiety and depression are two of the most prevalent mood disorders in SCI patients (North, 1999). These medical and psychological impairments are very often intertwined. Factors such as pain, social isolation, and medication that result from the injury itself and the consequent secondary medical complications affect the psychological state of SCI patients.

Individuals with SCI commonly report difficulty in sleeping due to spasms, restless sleep, snoring, waking early, and difficulty falling asleep. In comparison to a control group, these sleep disturbances in SCI individuals are significantly worse than in the normal population (Biering-Sorensen & Biering-Sorensen, 2001). Sleep cycle recordings taken through electrodes inserted in rats with and without SCI (level T9) showed rats with SCI not only experienced reduced sleep efficiency, but also presented significantly different sleep architecture. More frequent arousals, leading to fragmented sleep and greater total time spent awake, and a relative increase in slow-wave sleep (SWS) accompanied by a relative decrease in rapid eye movement (REM) sleep observed in rats with SCI shows the disruption SCI potentially has on sleep patterns (Esteves et al., 2007). Animal studies such as this can inform clinical understanding through examining aspects of behavior and physiology that may be difficult to examine in clinical trials. Such studies often form a foundation upon which knowledge from clinical trials can be built. One

clinical study regarding sleep disturbances in SCI individuals asked for the top problems that SCI individuals had with their sleep; the single most troublesome factor cited by SCI individuals was pain and paraesthesia (Biering-Sorensen & Biering-Sorensen, 2001). Another study found that quality of sleep is significantly worse in SCI patients with self-reported continuous pain than in SCI patients with intermittent or no pain (Norrbrink Budh, Hultling, & Lundeberg, 2005). There is still some question regarding the relationship between poor sleep quality and pain; a study on patients with chronic pain conditions reported that pain preceded or coincided with the onset of sleep disturbances (Morin, Gibson, & Wade, 1998). However, a study on women with fibromyalgia reported that poor sleep quality precedes the onset of pain (Affleck, Urrows, Tennen, Higgins, & Abeles, 1996). (Fibromyalgia is another chronic condition that causes long-term pain, and thus can be used as a useful comparison with SCI when investigating chronic pain.) This suggests a bidirectional relationship between pain and sleep quality: poor sleep quality leads to increased pain because of disturbances in Stage IV sleep, during which growth hormones that influence pain are produced (Affleck, et al., 1996), while increased pain leads to poor sleep quality.

Depression is highly prevalent in SCI patients as well. Many studies have found higher prevalence of depression in SCI populations than normal populations (Frank et al., 1992; Hoffman, Bombardier, Graves, Kalpakjian, & Krause, 2011); the occurrence of depression is associated with both the occurrence of secondary medical complications and poor self-assessed health status (Elliott & Frank, 1996). Psychomotor changes, sleep disturbances, and other somatic symptoms are predictive of individuals with depression (Bombardier, Richards, Krause, Tulsky, & Tate, 2004) and are commonly occurring secondary outcomes of SCI. Other factors may affect or predict depression in persons with SCI as well. One longitudinal study examined

the prevalence of depression in persons with an SCI over a five year period. The results indicate that while the prevalence of depression appears to be fairly stable over time, demographic factors do play a role in its presence, as well as health behaviors such as exercise and time spend out of the house (Saunders, Krause, & Focht, 2012). One of the strongest predictors of depression in persons with SCI, however, is the level of pain (Craig, Hancock, & Dickson, 1994). A study examining different models of correlation between pain and depression concluded that pain and depression are not independent – a linear causality model best explains the relationship between the two common consequences of SCI. The conclusion was that the presence of pain affects depression to a greater degree than depression affects pain; in other words, pain tends to lead to depression (Cairns, Adkins, & Scott, 1996). However, the two are very closely related, such that the physiological and psychological impacts of one on the other cannot be considered isolated episodes.

Pain is a highly prevalent secondary condition of SCI and is associated with both sleep disturbances and depression. Studies have found pain to be cited as the primary reason for poor sleep quality (Biering-Sorensen & Biering-Sorensen, 2001) and as one of the strongest predictors of depression (Craig, et al., 1994). Yet the appearance of pain in SCI patients is not homogeneous – there is great variation in how individuals respond and adapt to SCI-related pain due to personal characteristics, circumstance, and environment (Widerstrom-Noga, Duncan, & Turk, 2004). The type of pain experienced after an injury can vary as well. A study differentiating between musculoskeletal, visceral, neuropathic at-level, and neuropathic below-level pain found that there are a variety of types of pain experienced and time courses over which that occurs during at least the first five years post-injury (Siddall, McClelland, Rutkowski, & Cousins, 2003). Furthermore, a comprehensive treatment program to effectively counter or

prevent the various types of pain and its effects after injury has yet to be determined. Pain, sleep, and depression are all modulated by the same neuromodulators – monoamines – in the brain, so treatment for pain, sleep, and depression may all incorporate the use of monoamines. Serotonin (a monoamine neurotransmitter) is a precursor for melatonin; melatonin, in turn, is important in sleep, pain, and depression. Melatonin secretion is vital for sleep induction and regulation of diurnal rhythm. Decreased melatonin levels have been proposed to be a marker for depressive disorders, and a recent study has suggested that a melatonin receptor agonist may work as an antidepressant (Hickie & Rogers, 2011). Another study suggested that melatonin may have an antinociceptive effect on rats (Ambriz-Tututi, Rocha-Gonzalez, Cruz, & Granados-Soto, 2009). Therefore, melatonin (an active ingredient in sleeping pills), serotonin, or monoamines more generally may be an important common denominator linking pain, sleep disturbances, and depression in SCI patients (Norrbrink Budh, et al., 2005). To date, no studies have tested this hypothesis in the SCI population to investigate neurochemical differences or similarities to the general population.

The relationships between pain, sleep, and mood are not yet fully understood, and may differ in different populations. A recent study of children with juvenile polyarticular arthritis examined whether sleep quality serves as a predictor of pain in that population, and whether that relationship is moderated at all by mood. The findings suggest that while daily pain does not serve as a predictor of the subsequent night's sleep, sleep quality serves as an important predictor of the pain experienced the next day (Bromberg, Gil, & Schanberg, 2012). In adults with osteoarthritis, pain appears to predict fatigue, which in turn predicts depressed mood; while mood and fatigue exacerbate each other, evidence is only found for fatigue worsening the pain from osteoarthritis (Hawker, et al., 2011). Currently, there is no solid evidence regarding the

relationships between all three – pain, sleep, and mood or depression – in individuals with SCI, so the question of whether there is an underlying mechanism linking pain, sleep disturbances, and mood still lingers. This pilot study addresses this gap in knowledge: it examines some relationships between various measures of sleep, pain intensity and associated consequences of pain, and multiple ratings of mood and depression in SCI patients.

Some studies have been conducted to examine the relationship between two of these three events (pain, sleep disturbance, and depressed mood). This pilot study examines the relationship between pain, sleep disturbances, and depressed mood in individuals with SCI and serves as a clinical start point from which to explore potential treatments. The significance of this pilot study is that these three side effects of SCI (and many other chronic illnesses or injuries) most likely each have effects on the others; the occurrence of one seems to lead to the genesis of another, and these effects are exacerbated in a positive feedback-type mechanism. Therefore, it is likely that there is a common denominator underlying these factors. This study examines the relationships between different pairs of these three frequent consequences of SCI, as well as begins the search for a shared underlying origin of pain, sleep disturbance, and depression in SCI patients. The central hypotheses guiding this study were that pain is significantly associated with sleep problems, and that pain and sleep problems are significantly associated with negative mood above and beyond personal and injury characteristics. The following two aims address these hypotheses. The first aim is to examine the association of pain intensity on sleep quality. Our working hypothesis was that greater pain intensity and higher interference is associated with lower sleep efficiency, longer sleep latency, and greater tiredness upon awakening, controlling for personal and injury characteristics. The second aim is to examine the association of pain and sleep disturbance with mood in persons with chronic SCI. Our working hypothesis was that

higher pain and sleep disturbance is significantly associated with greater levels of negative mood and depression, controlling for personal and injury characteristics.

## Method

### Sample Design and Recruitment

Fifty nine individuals with SCI were screened for eligibility for this study. The basic inclusion and exclusion criteria listed below were used to determine eligibility. Of these, 31 were eligible. Of these, 19 participated in this study. They were recruited from the University of Michigan SCI Research Registry (HUM26981). The SCI Research Registry was designed to provide UM researchers access persons with SCI who are interested in being involved in clinical research. Once a protocol was reviewed and approved by the Registry, individuals meeting study criteria were notified via letter from the Registry that they may be eligible for participating in a study and provided with some information about the study and contact information of the investigators. They were given a two-week window during which they could decline being contacted by the investigators by contacting the Registry directly and withdrawing their name. After the two-week period had passed, the list of names and contact information was forwarded to the investigators, who then took on the responsibility of recruitment.

The inclusion criteria for this study were that participants had to be between the ages of nineteen and sixty years old, must have had an SCI of any level for at least one year, had to be living in the community, and must have been able to read English.

Individuals were excluded from the study if they met any of the following exclusion criteria: presence of a serious psychiatric disorder, such as psychotic disorders (e.g., hallucinations), presence of a cognitive impairment prohibiting them from completing study materials, or presence of sleep apnea, as assessed using the STOP-BANG Questionnaire and scoring method

(Chung et al., 2008). Answering in the affirmative to three or more STOP-BANG questions indicates the presence of, or a significantly increased risk for, sleep apnea, and thus excluded individuals from this study. See Appendix A for the STOP-BANG Questionnaire.

## Measures

Measures were selected based on their ease of use for daily data collection and their use in other populations in wherever possible in the SCI populations.

### Primary outcomes – mood and sleep quality.

***Mood.*** Negative mood descriptors were rated at the end of each day before bedtime: depressed/blue, angry/hostile, worried/anxious, and unhappy. One positive mood descriptor, joyful/happy, was also rated at the same time. Each was rated on 7 point Likert scales ranging from 0 (not at all) to 6 (extreme). The positive mood descriptor was reverse coded and all items were summed to create a continuous score of negative mood. Mood ratings were taken each day before bedtime.

***Subjective sleep quality.*** The University of Michigan Daily Wake/Sleep Diary (Sleep Diary) was used to record factors related to daily sleep patterns. At night, each participant recorded his or her sleepiness rating at bedtime using the Stanford Sleepiness Scale (see below), as well as his or her use of tobacco, alcohol, caffeine, naps, and sleep medications during that day. In the morning, each participant recorded bed time, amount of time it took to fall asleep, number and total duration of awakenings, time of final awakening, and time of rising in the sleep diary. In addition, quality of sleep and tiredness were each rated in the morning after waking using five-point Likert scales ranging from 1 (very poor quality; very tired) to 5 (very good quality; very rested). The Stanford Sleepiness Scale (SSS) is part of the Sleep Diary and is used to rate sleepiness at bedtime (Hoddes et al., 1973). The scale ranges from 1 (wide awake) to 7 (sleep

onset soon) and the number corresponding to the degree of sleepiness of the individual is recorded at night.

**Predictors – pain and sleep.**

***Pain*.** Pain intensity was rated on a numeric scale ranging from 0 (no pain at all) to 10 (worst pain). Pain interference was assessed using selected items from the International SCI Basic Pain Dataset (Jensen et al., 2009). All items are rated on 7-point Likert scales ranging from 0 (not at all) to 6 (very much). See Appendix B for the questions used from the International SCI Basic Pain Dataset. Pain intensity and interference ratings (items #1-5) were collected at the end of each day at bedtime; item #6 regarding pain interference with the previous night's sleep was collected in the morning.

***Sleep*.** The sleep variables that were examined as predictors, obtained from the Sleep Diary described above, were: 1) sleep efficiency (calculated as total time asleep divided by total time spent in bed); 2) sleep latency (time to fall asleep); 3) sleep quality; and 4) tiredness in the morning.

**Demographic and Injury Characteristics**

Demographic and injury characteristics were also collected. The demographic characteristics were current age, gender, race, educational level, and occupational status. The injury characteristics were level of injury (e.g., cervical vs. thoracic and below) and years since injury. We also collected information on secondary conditions that may disturb sleep quality such as spasticity, pressure ulcers, and infections. To do this, we used the SCI Secondary Conditions Scale developed by the study's PI Kalpakjian and colleagues (Kalpakjian, Scelza, Forchheimer, & Toussaint, 2007). The SCI-SCS contains 16 items representing problems in the areas of skin, musculoskeletal, pain, bowel, bladder, and cardiovascular and are rated on 4-point

Likert scales ranging from 0 (not experienced/insignificant problem never limiting activity) to 3 (significant/chronic problem).

**Data Collection Procedures and Schedule**

This study used a repeated measures design to collect data across one week (seven days). During the screening and enrollment phase, individuals with SCI who met all study criteria were recruited for this study. After the informed consent document was signed and received by the study team, all measures were mailed to each participant with detailed instructions regarding completion of the documents. On day one, demographic and injury characteristics were documented. Measures were completed just after rising in the morning and just before bedtime in the evening for seven continuous days. On day eight, each participant completed the PHQ-9 and returned all study materials via mail to the study team.

**Statistical Analysis**

We used linear mixed modeling (LMM) with random effects for participant and with repeated effects for day of data collection because our data were repeated measures data. Repeated measures analysis also requires consideration of the correlation of the outcome variables across the study period (i.e., covariance structures); the covariance structure with the largest Swartz's Bayesian Criteria (BIC) was used as the best model fit (Raferty, 1996). Each of the sleep outcomes (sleep efficiency, sleep latency, quality of sleep, and tiredness upon awakening) was modeled with the following predictors and controlling variables (denoted by [ ]): pain intensity + [sleep medication taken before bed] + [day] + [level of injury] + [total nap duration earlier that day] + [secondary conditions].

We used the same analytic approach to test mood outcomes. To do this, we had to lag two of the sleep variables – sleep quality and tiredness in the morning – by one study day within

each participant's seven continuous days of data. This was done because these variables were collected in the morning to describe the previous night's sleep, and each new day of data began after this data collection. However, for these models we wanted to study the effects of these two sleep variables on the subsequent day's mood. Thus, we first investigated pain intensity during the day as a predictor for that night's sleep (as described above), and then we lagged the two sleep variables to use them to investigate the quality of a night's sleep and tiredness in the morning on that subsequent day's mood. We modeled each daily mood descriptor (depressed/blue, worried/anxious, unhappy, and joyful/happy) twice individually: once by the following predictors and controlling variables (denoted by [ ]): pain intensity + quality of previous night's sleep, rated that morning + [level of injury] + [day] + [secondary conditions] and again by the following predictors and controlling variables (denoted by [ ]): pain intensity + tiredness upon awakening that morning + [level of injury] + [day] + [secondary conditions].

## Results

### Description of Sample

Data were collected from 19 individuals. The majority were Caucasian males who had completed at least high school. Slightly less than half were employed full or part-time at the time of the study; slightly more than half had sustained injuries in the thoracic region or below. Average time since injury was 14.53 years. Demographic and injury characteristics are summarized in table 1. Due to the relative gender and age homogeneity of participants (of the nineteen total study participants, fifteen were male and four were female; the average age of all nineteen participants was 46.84 with a standard deviation of 9.685) neither gender nor age had a significant impact on any of the outcome variables initially tested. Therefore, gender and age were removed from the models as controlling variables to make room for other predictors and

controlling variables. In larger studies, it may be necessary to control for gender and age, but in this pilot study it was unnecessary due to their lack of impact on the models.

**Sleep Outcomes**

There were some significant predictors of some of the sleep outcomes measured (see tables 3 through 6). The total duration of naps taken earlier in a day was a significant predictor of sleep efficiency such that on average, sleep efficiency decreased as total nap duration increased. Total nap duration, as well as whether or not sleep medication was taken before bed, both directly predicted sleep latency such that greater napping and taking sleep medication were both associated with longer sleep latency. There were significant inverse effects of sleep medication and of aggregated secondary conditions on quality of sleep, as reported the next morning, such that taking sleep medication and increased presence of secondary conditions both decreased quality of sleep. Quality of sleep was also predicted by the intensity of pain experienced earlier that day, such that sleep quality decreased as intensity of pain increased. Finally, tiredness after awakening (the higher the score, the more restful the sleep) the next morning was significantly influenced by total nap duration the previous day, sleep medication taken before bed, and secondary conditions in an indirect fashion such that increasing each of these three variables led to increased feeling of tiredness (decreased restfulness) after awakening. Intensity of pain experienced throughout the previous day also acted as an inverse predictor of tiredness rating upon awakening the next day: greater pain intensity predicted greater feeling of tiredness in the morning.

**Mood Outcomes**

Each mood outcome was modeled twice: once to analyze quality of sleep as a predictor for that subsequent day's mood, and again to analyze tiredness rating in the morning as a

predictor for that day's mood. We opted to model these separately as there was a significant positive correlation between quality of sleep and tiredness rating in the morning ($r = 0.680$; $p \leq 0.000$). In order to analyze both predictors without one undermining the effect of the other, each model was run twice to test the two predictors separately. Worried/anxious mood was the one mood descriptor for which both sleep variables were predictors: tiredness in the morning predicted worried/anxious mood such that greater tiredness predicted increased worried/anxious mood later that day, and increased quality of sleep predicted increased worried/anxious mood. Pain intensity also significantly predicted worried/anxious mood such that increased pain intensity predicted increased worried/anxious mood. Tiredness in the morning was a significant predictor of self-reported depressed/blue mood, as was pain intensity during that day, such that increases in those predictors both increased feelings of depressed/blue mood. Pain intensity and secondary conditions functioned as direct and inverse predictors of unhappy mood, respectively: an increase in pain intensity predicted an increase in unhappy mood, and a decrease in secondary conditions predicted an increase in unhappy mood. Finally, joyful/happy mood was predicted by pain intensity such that a decrease in pain increased joyful/happy mood. Tiredness in the morning also predicted joyful/happy mood such that an increase in restfulness (decrease in tiredness) increased joyful/happy mood. See tables 7 through 14 for a summary of the predictors for the various mood outcomes.

## Discussion

Two main conclusions can be drawn from this study. The first is that various daytime habits regarding sleep, as well as intensity of pain experienced throughout the day, predict multiple measures of sleep quality of individuals with SCI. The second is that mood reported by

individuals with SCI is predicted by sleep the previous night and by the intensity of pain experienced during the day.

The total duration of naps taken earlier in the day significantly predicts sleep such that greater time spent napping led to lower the sleep efficiency, longer the sleep latency, and a lower tiredness rating (i.e. a greater feeling of tiredness) the subsequent morning. It is not surprising these two factors are significantly related, as the increased tiredness experienced in the morning is influenced directly by lower sleep efficiency and longer sleep latency. It may be that naps taken during the day indicate greater pain or inconvenience from secondary conditions – in fact, pain and secondary conditions do predict tiredness rating in the morning. A study of adolescent girls with chronic musculoskeletal pain revealed that girls with more pain may sleep significantly fewer hours during the night, and then nap during the day to attempt to compensate for insufficient nighttime sleep (Tsai et al., 2008). This phenomenon may translate to individuals with chronic pain from an SCI, and thus explain some of these results regarding nap duration, pain intensity, and quality of sleep and tiredness upon awakening in the morning. Longer total nap duration during the day may indicate increased discomfort from pain or secondary conditions, which then predicts poorer nighttime sleep. The duration of a nap also affects an individual's subsequent physiological and psychological state. Naps half an hour in duration or shorter can provide many restorative benefits, while naps longer than 30 minutes in duration (which describes the great majority of the naps taken by individuals in this study – the average naptime was 90 minutes) result in sleep inertia, loss of productivity, deterioration of mood, and are generally associated with higher morbidity and mortality. If slow wave sleep occurs during longer daytime naps, slow wave sleep is often reduced in the subsequent nighttime sleep period, indicating a declined quality of that nocturnal sleep (Dhand & Sohal, 2006). This likely was the

case for many nights in many individuals who napped during the day, further explaining the findings that naps predict lower sleep efficiency, increased sleep latency, and increased tiredness in the morning.

Previous work in a small sample suggests that disruption of normal melatonin rhythms in cervical SCI may, in part, result in lower sleep efficiency (Scheer et al., 2006). However, in our study, we did not find a significant difference in sleep efficiency by injury level which may be due in part to the sample differences or measurement of sleep efficiency. In this sample the average hours asleep per night were consistent with other studies involving persons with SCI as well as the general population (Jensen, Hirsh, Molton, & Bamer, 2009). However, the use of sleep medication by the participants in this study had an unexpected relationship with sleep outcomes. Contrary to expectations, sleep medication was associated with longer sleep latency, decreased sleep quality, and increased tiredness feeling upon awakening. An explanation for this may be that those taking sleep medication may be experiencing severe pain or other chronic conditions that make sleep medication necessary to fall asleep; another explanation may be that those on sleep medication are significantly poorer sleepers and necessitate medication to sleep. Yet sleep medication did not appear to improve any of the sleep measures in this study, thus appearing unhelpful. This is an area for further investigation.

An increased aggregated secondary conditions score was significantly associated with both quality of sleep and tiredness rating such that greater secondary conditions lead to poorer the sleep quality and greater tiredness experienced upon awakening. Studies in various populations have shown that many of the health conditions included in the secondary conditions score in this study may affect sleep quality (Tsujimura et al., 2010), so it is not surprising that, after aggregating many such health conditions into one secondary conditions score per individual,

a higher score is associated with significantly poorer sleep quality and increased tiredness upon awakening.

Finally, increased pain intensity throughout the day predicts poorer sleep quality and greater tiredness upon awakening as well. These findings are in agreement with our first hypothesis, which generally anticipated that greater pain during the day predicts poorer sleep at night. Pain and secondary conditions likely influence the effects of naps and sleep medication on some of the outcomes such that an increase in pain and/or secondary conditions necessitate naps and/or sleep medication, thus leading to poorer sleep outcomes that night. A study of veterans with chronic pain found that, in individuals prescribed sleep medication for the purpose of sleeping despite chronic pain, sleep medication use was associated with poorer sleep quality, shorter sleep duration, and overall poorer sleep quality (Chapman, Lehman, Elliott, & Clark, 2006). Thus it appears that multiple variables – pain, secondary conditions, daytime naps, and sleep medication – may converge in various combinations to negatively impact various measures of sleep.

Each of the four mood outcomes examined have at least a couple of significant predictors. Not surprisingly, the intensity of pain experienced throughout the day predicts depressed/blue mood, worried/anxious mood, and unhappy mood. Those moods are experienced to a greater degree due to increased pain intensity that same day – these appear to be straightforward causal relationships. Pain intensity also functions as a predictor of joyful/happy mood with greater pain intensity associated with decreased joyful/happy mood ratings. These findings are all in tandem with each other and confirm part of our second hypothesis: that pain predicts mood in a negative fashion. Previous studies indicate that various types of pain, including neck, shoulder, back, and general musculoskeletal, are associated with dysphoric and other unpleasant moods (Bru, Svebak,

Mykletun, & Gitlesen, 1997). The increased prevalence of pain after SCI, therefore, likely increases negative mood, as our data suggests.

Furthermore, some sleep factors appear to impact mood outcomes as well. Self-reported tiredness rating in the morning (such that a lower rating indicates a greater feeling of tiredness) was associated with greater worried/anxious feelings and less joyful/happy feelings. Both pain and some sleep measures predict mood, and the fact that pain acts as a predictor of sleep as well likely exacerbates the effects of pain on mood, since it directly impacts mood and very likely indirectly impacts mood simply by negatively impacting sleep, as revealed above. There were a few sleep measures that statistically significantly predicted mood in a direction contrary to expectations. For example, an increased tiredness rating appeared to increase depressed/blue mood, increased quality of sleep appeared to directly predict worried/anxious mood, and increased secondary conditions appeared to decrease unhappy mood. One explanation for these findings is that they may result from the relatively small number of participants in the study. Although we collected seven consecutive days of data from each participant, thus creating in effect 133 data points for each predictor or outcome, a major limitation of this study is the fact that it was a pilot study with nineteen participants. Findings of studies regarding the associations between sleep and mood are varied. Some studies conclude that sleep and mood are associated in younger (adolescent) subjects but otherwise are relatively independent (Oginska & Pokorski, 2006), while other studies find that negative mood may mediate the relationship between chronic pain and sleep disturbances (O'Brien et al., 2010). Knowledge of the relationship between sleep and mood in persons with SCI is varied and often targeted toward individuals with obstructive sleep apnea, which we excluded from this study for the purposes of studying general sleep measures rather than a specific sleep disorder. These unexpected results regarding sleep and

mood are areas for further investigation in the future. From here, the next step is to replicate and expand this study on a larger scale to generate more power. Subsequent proposed studies should use more objective measures – such as actigraphy to measure sleep – to supplement the predominantly subjective measures used in this study.

In conclusion, the previously proposed hypotheses regarding the effects of pain on sleep and the effects of pain and sleep on mood were supported through the findings of this study. As demonstrated, a variety of factors interact and affect the four sleep and four mood outcomes examined. This pilot study is an introduction to the examination of the complex relationships between three long-term complications of SCI that can direct future studies and treatment. Further work may examine physiological aspects of sleep, pain, and mood such neurotransmitters or dopaminergic neurons associated with depressed mood and sleep. More broadly, results from this proposed study could extend to individuals with other chronic illnesses or disabilities with similar long-term complications.

References

Affleck, G., Urrows, S., Tennen, H., Higgins, P., & Abeles, M. (1996). Sequential daily relations of sleep, pain intensity, and attention to pain among women with fibromyalgia. *Pain, 68*(2-3), 363-368.

Ambriz-Tututi, M., Rocha-Gonzalez, H. I., Cruz, S. L., & Granados-Soto, V. (2009). Melatonin: A hormone that modulates pain. *Life Sciences, 84*(15-16), 489-498. doi: DOI 10.1016/j.lfs.2009.01.024

Biering-Sorensen, F., & Biering-Sorensen, M. (2001). Sleep disturbances in the spinal cord injured: an epidemiological questionnaire investigation, including a normal population. *Spinal Cord, 39*(10), 505-513.

Bombardier, C. H., Richards, J. S., Krause, J. S., Tulsky, D., & Tate, D. G. (2004). Symptoms of major depression in people with spinal cord injury: Implications for screening. *Archives of Physical Medicine and Rehabilitation, 85*(11), 1749-1756. doi: 10.1016/j.apmr.2004.07.348

Bromberg, M. H., Gil, K. M., & Schanberg, L. E. (2012). Daily sleep quality and mood as predictors of pain in children with juvenile polyarticular arthritis. *Health Psychology, 31*(2), 202-209.

Bru, E., Svebak, S., Mykletun, R. J., & Gitlesen, J. P. (1997). Back pain, dysphoric versus euphoric moods and the experience of stress and effort in female hospital staff. *Personality and Individual Differences, 22*(4), 565-573.

Cairns, D. M., Adkins, R. H., & Scott, M. D. (1996). Pain and depression in acute traumatic spinal cord injury: Origins of chronic problematic pain? *Archives of Physical Medicine and Rehabilitation, 77*(4), 329-335.

Chapman, J. B., Lehman, C. L., Elliott, J., & Clark, J. D. (2006). Sleep quality and the role of sleep medications for veterans with chronic pain. *Pain Medicine, 7*(2), 105-114.

Chung, F., Yegneswaran, B., Liao, P., Chung, S. A., Vairavanathan, S., Islam, S., . . . Shapiro, C. M. (2008). STOP questionnaire - A tool to screen patients for obstructive sleep apnea. *Anesthesiology, 108*(5), 812-821.

Craig, A. R., Hancock, K. M., & Dickson, H. G. (1994). Spinal cord injury: A search for determinants of depression 2 years after the event. *British Journal of Clinical Psychology, 33*, 221-230.

Dhand, R. & Sohal, H. (2006). Good sleep, bad sleep! The role of daytime naps in healthy adults. *Current Opinion in Pulmonary Medicine, 12*(6), 379-382.

Elliott, T. R., & Frank, R. G. (1996). Depression following spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 77*(8), 816-823.

Esteves, A. M., Mello, M. T., Squarcini, C. F. R., Lancellotti, C. L. P., Comparoni, A., & Tufik, S. (2007). Sleep patterns over 15-day period in rats with spinal cord injury. *Spinal Cord, 45*(5), 360-366. doi: DOI 10.1038/sj.sc.3101971

Frank, R. G., Chaney, J. M., Clay, D. L., Shutty, M. S., Beck, N. C., Kay, D. R., . . . Grambling, S. (1992). Dysphoria - a Major Symptom Factor in Persons with Disability or Chronic Illness. *Psychiatry Research, 43*(3), 231-241.

Hawker, G. A., Gignac, M. A. M., Badley, E., Davis, A. M., French, M. R., Li, Y., Perruccio, A. V., Power, J. D., Sale, J., & Lou, W. (2011). A longitudinal study to explain the pain-depression link in older adults with osteoarthritis. *Arthritis Care & Research, 63*(10), 1382-1390. doi: DOI 10.1002/acr.20298

Hickie, I. B., & Rogers, N. L. (2011). Novel melatonin-based therapies: potential advances in the treatment of major depression. *Lancet, 378*(9791), 621-631. doi: Doi 10.1016/S0140-6736(11)60095-0

Hoddes, E., Zarcone, V., Smythe, H., Phillips, R., & Dement, W. C. (1973). Quantification of Sleepiness - New Approach. *Psychophysiology, 10*(4), 431-436.

Hoffman, J. M., Bombardier, C. H., Graves, D. E., Kalpakjian, C. Z., & Krause, J. S. (2011). A Longitudinal Study of Depression From 1 to 5 Years After Spinal Cord Injury. *Archives of Physical Medicine and Rehabilitation, 92*(3), 411-418. doi: DOI 10.1016/j.apmr.2010.10.036

Jensen, M. P., Hirsh, A. T., Molton, I. R., & Bamer, A. M. (2009). Sleep Problems in Individuals With Spinal Cord Injury: Frequency and Age Effects. *Rehabilitation Psychology, 54*(3), 323-331. doi: 10.1037/a0016345

Jensen, M. P., Widerstrom-Noga, E., Richards, J. S., Finnerup, N. B., Biering-Sorensen, F., & Cardenas, D. D. (2009). Reliability and validity of the International Spinal Cord Injury Basic Pain Data Set items as self-report measures. *Spinal Cord, 48*(3), 230-238.

Kalpakjian, C. Z., Scelza, W. M., Forchheimer, M. B., & Toussaint, L. L. (2007). Preliminary reliability and validity of a spinal cord injury secondary conditions scale. *Journal of Spinal Cord Medicine, 30*(2), 131-139.

McKinley, W. O., Jackson, A. B., Cardenas, D. D., & DeVivo, M. J. (1999). Long-term medical complications after traumatic spinal cord injury: A regional model systems analysis. *Archives of Physical Medicine and Rehabilitation, 80*(11), 1402-1410.

Morin, C. M., Gibson, D., & Wade, J. (1998). Self-reported sleep and mood disturbance in chronic pain patients. *Clinical Journal of Pain, 14*(4), 311-314.

Noreau, L., Proulx, P., Gagnon, L., Drolet, M., & Laramee, M. T. (2000). Secondary impairments after spinal cord injury - A population-based study. *American Journal of Physical Medicine & Rehabilitation, 79*(6), 526-535.

Norrbrink Budh, C., Hultling, C., & Lundeberg, T. (2005). Quality of sleep in individuals with spinal cord injury: a comparison between patients with and without pain. *Spinal Cord, 43*(2), 85-95.

North, N. T. (1999). The psychological effects of spinal cord injury: a review. *Spinal Cord, 37*(10), 671-679.

O'Brien, E. M., Waxenberg, L. B., Atchison, J. W., Gremillion, H. A., Staud, R. M., McCrae, C. S., & Robinson, M. E. (2010). Negative mood mediates the effect of poor sleep on pain among chronic pain patients. *Clinical Journal of Pain, 26*(4), 310-319.

Oginska, H. & Pokorski, J. (2006). Fatigue and mood correlates of sleep length in three age-social groups: School children, students, and employees. *Chronobiology International, 23*(6), 1317-1328.

Raferty, AE. (1996). Bayesian Model Selection in Social Research. In PV Marsden (Ed.), *Sociological Methodology* (pp. 111-163). Oxford, UK: Basil Blackwell.

Saunders, L. L., Krause, J. S., & Focht, K. L. (2012). A longitudinal study of depression in survivors of spinal cord injury. *Spinal Cord, 50*(1), 72-77. doi: Doi 10.1038/Sc.2011.83

Scheer, Fajl, Zeitzer, J. M., Ayas, N. T., Brown, R., Czeisler, C. A., & Shea, S. A. (2006). Reduced sleep efficiency in cervical spinal cord injury; association with abolished night time melatonin secretion. *Spinal Cord, 44*(2), 78-81. doi: 10.1038/sj.sc.3101784

Siddall, P. J., McClelland, J. M., Rutkowski, S. B., & Cousins, M. J. (2003). A longitudinal study of the prevalence and characteristics of pain in the first 5 years following spinal cord injury. *Pain, 103*(3), 249-257.

Tsai, S. Y., Labyak, S. E., Richardson, L. P., Lentz, M. J., Brandt, P. A., Ward, T. M., & Landis, C. A. (2008). Brief report: Actigraphic sleep and daytime naps in adolescent girls with chronic musculoskeletal pain. *Journal of Pediatric Psychology, 33*(3), 307-311.

Tsujimura, A., Takao, T., Miyagawa, Y., Yamamoto, K., Fukuhara, S., Nakayama, J., Kiuchi, H., Suganuma, N., Nakamura, T., Kumano-go, T., Sugita, Y., Nonomura, N., & Okuyama, A. (2010). Urgency is an independent factor for sleep disturbance in men with obstructive sleep apnea. *Urology, 76*(4), 967-970.

Widerstrom-Noga, E. G., Duncan, R., & Turk, D. C. (2004). Psychosocial profiles of people with pain associated with spinal cord injury - Identification and comparison with other chronic pain syndromes. *Clinical Journal of Pain, 20*(4), 261-271.

## Author Note

Sarah Bradley Feenstra, Department of Neuroscience, University of Michigan, Ann Arbor.

First and foremost, I would like to express my deepest gratitude to Dr. Claire Z. Kalpakjian for her guidance throughout this project and the time I spent in her lab. Her advice and mentorship were invaluable, and I feel extremely lucky to have been introduced to clinical research by such an extraordinary mentor. I would also like to thank CSCAR's Kathy Welch for her statistical guidance throughout this project, and Mary Burton for her assistance in the lab. I greatly appreciate the financial support provided to me during part of this project by the LSA Honor Program's 2011 Honors Summer Fellowship. Finally, I would like to thank my friends and family for their support and encouragement throughout this project.

Table 1

*Demographic and Injury Characteristics*

| | N = 19 |
|---|---|
| Age (SD), range | 46.84 (9.685), 29 to 60 |
| Years post injury (SD), range | 14.53 (8.030), 1 to 31 |
| Male gender N (%) | 15 (78.9) |
| Race N (%) | |
| Caucasian | 14 (73.7) |
| African American | 1 (5.3) |
| Unknown | 4 (21.0) |
| Education N (%) | |
| Did not complete high school | 1 (5.3) |
| Completed high school/GED | 5 (26.3) |
| Some college | 4 (21.0) |
| Bachelor's Degree | 6 (31.6) |
| Graduate Degree | 3 (15.8) |
| Occupational status at injury N (%) | |
| Working full-time | 7 (36.8) |
| Working part-time | 0 (0.0) |
| Unemployed | 12 (63.2) |
| Level of injury N (%) | |
| Cervical | 8 (42.1) |
| Thoracic and below | 11 (57.9) |

Table 2

*Descriptives of Outcomes and Predictor Variables*

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Sleep Efficiency | 115 | 0.26 | 0.97 | 0.7814 | 0.13985 |
| Hours asleep | 120 | 2 | 12 | 6.86 | 1.68 |
| Sleep Latency (min) | 133 | 5 | 255 | 35.92 | 42.314 |
| Nap duration (hours) | 36 | 0.25 | 3.75 | 1.54 | 0.911 |
| Quality of Sleep | 133 | 1 | 5 | 3.39 | 0.787 |
| Tiredness in morning | 133 | 1 | 5 | 3.27 | 0.863 |
| Depressed/Blue | 133 | 0 | 4 | 1.16 | 1.218 |
| Worried/Anxious | 133 | 0 | 6 | 1.00 | 1.219 |
| Unhappy | 133 | 0 | 6 | 1.08 | 1.197 |
| Joyful/Happy | 133 | 0 | 6 | 2.48 | 1.374 |
| Pain Intensity | 133 | 0 | 8 | 2.70 | 2.136 |

Note: N refers to the number of measurements across the study period, across all study participants

Table 3

*Linear Mixed Model Results for Sleep Efficiency*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | .819 | .064 | 15.189 | 12.807 | .000 | .683 | .955 |
| Injury level | .028 | .051 | 11.327 | .550 | .593 | -.085 | .141 |
| Day | .002 | .005 | 93.973 | .347 | .729 | -.008 | .011 |
| *Total nap duration* | *-.039* | *.016* | *105.507* | *-2.481* | *.015* | *-.071* | *-.008* |
| Sleep medication | -.096 | .047 | 11.633 | -2.050 | .064 | -.199 | .006 |
| Pain intensity | .011 | .007 | 103.515 | 1.624 | .108 | -.002 | .024 |
| Secondary conditions | -.004 | .004 | 11.335 | -1.028 | .325 | -.014 | .005 |

Table 4

*Linear Mixed Model Results for Sleep Latency*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | 26.315 | 14.367 | 23.094 | 1.832 | .080 | -3.399 | 56.030 |
| Injury level | -12.087 | 10.023 | 17.494 | -1.206 | .244 | -33.188 | 9.014 |
| Day | -.038 | 1.065 | 75.625 | -.036 | .971 | -2.159 | 2.082 |
| *Total nap duration* | *15.416* | *3.459* | *79.933* | *4.457* | *.000* | *8.533* | *22.299* |
| *Sleep medication* | *41.717* | *9.527* | *17.950* | *4.379* | *.000* | *21.697* | *61.737* |
| Pain intensity | .965 | 1.505 | 103.398 | .641 | .523 | -2.020 | 3.950 |
| Secondary conditions | -.353 | .864 | 17.586 | -.408 | .688 | -2.171 | 1.466 |

Table 5

*Linear Mixed Model Results for Sleep Quality*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | 4.436 | .224 | 38.465 | 19.809 | .000 | 3.983 | 4.890 |
| Injury level | .084 | .140 | 35.908 | .604 | .550 | -.199 | .368 |
| Day | -.043 | .029 | 42.639 | -1.485 | .145 | -.102 | .015 |
| Total nap duration | -.144 | .074 | 71.275 | -1.955 | .054 | -.291 | .003 |
| *Sleep medication* | *-.275* | *.135* | *36.944* | *-2.043* | *.048* | *-.548* | *-.002* |
| *Pain intensity* | *-.074* | *.031* | *78.488* | *-2.395* | *.019* | *-.136* | *-.013* |
| *Secondary conditions* | *-.044* | *.012* | *37.249* | *-3.624* | *.001* | *-.069* | *-.020* |

Table 6

*Linear Mixed Model Results for Tiredness in the morning*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | 4.316 | .241 | 45.318 | 17.878 | .000 | 3.829 | 4.802 |
| *Injury level* | *.308* | *.148* | *40.249* | *2.083* | *.044* | *.009* | *.608* |
| *Day* | *-.078* | *.033* | *42.972* | *-2.405* | *.021* | *-.143* | *-.013* |
| *Total nap duration* | *-.194* | *.082* | *71.665* | *-2.372* | *.020* | *-.358* | *-.031* |
| *Sleep medication* | *-.432* | *.146* | *41.125* | *-2.949* | *.005* | *-.727* | *-.136* |
| *Pain intensity* | *-.070* | *.034* | *78.729* | *-2.014* | *.047* | *-.139* | *-.001* |
| *Secondary conditions* | *-.040* | *.013* | *41.552* | *-3.088* | *.004* | *-.067* | *-.014* |

Table 7

*Linear Mixed Model Results for Depressed/blue mood #1*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | -.090 | .619 | 29.820 | -.147 | .884 | -1.355 | 1.174 |
| Injury level | .139 | .380 | 15.795 | .366 | .719 | -.667 | .946 |
| Day | .056 | .057 | 50.620 | .993 | .326 | -.057 | .170 |
| *Pain intensity* | *.355* | *.043* | *89.823* | *8.365* | *.000* | *.271* | *.440* |
| Secondary conditions | -.043 | .032 | 13.930 | -1.344 | .201 | -.112 | .026 |
| Sleep quality (lag) | .046 | .093 | 76.785 | .494 | .623 | -.140 | .232 |

Table 8

*Linear Mixed Model Results for Depressed/blue mood #2*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | -.872 | .580 | 28.719 | -1.503 | .144 | -2.060 | .315 |
| Injury level | .055 | .374 | 17.045 | .148 | .884 | -.734 | .845 |
| Day | .058 | .055 | 52.103 | 1.044 | .301 | -.053 | .169 |
| *Pain intensity* | *.363* | *.040* | *88.477* | *8.998* | *.000* | *.283* | *.443* |
| Secondary conditions | -.032 | .031 | 15.073 | -1.037 | .316 | -.099 | .034 |
| *Tiredness (lag)* | *.238* | *.085* | *86.405* | *2.801* | *.006* | *.069* | *.407* |

Table 9

*Linear Mixed Model Results for Worried/anxious mood #1*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | 2.050 | .746 | 95.124 | 2.750 | .007 | .570 | 3.530 |
| Injury level | .438 | .270 | 31.676 | 1.625 | .114 | -.111 | .988 |
| Day | -.008 | .064 | 66.758 | -.128 | .898 | -.136 | .120 |
| *Pain intensity* | *.133* | *.058* | *88.899* | *2.313* | *.023* | *.019* | *.248* |
| Secondary conditions | -.013 | .025 | 33.763 | -.522 | .605 | -.064 | .038 |
| *Sleep quality (lag)* | *-.412* | *.148* | *107.762* | *-2.795* | *.006* | *-.705* | *-.120* |

Table 10

*Linear Mixed Model Results for Worried/anxious mood #2*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | 1.990 | .664 | 83.472 | 2.995 | .004 | .669 | 3.311 |
| *Injury level* | *.510* | *.251* | *31.565* | *2.036* | *.050* | *-.000* | *1.021* |
| Day | -.002 | .061 | 63.937 | -.039 | .969 | -.125 | .120 |
| *Pain intensity* | *.141* | *.056* | *79.826* | *2.528* | *.013* | *.030* | *.252* |
| Secondary conditions | -.017 | .023 | 33.376 | -.742 | .463 | -.065 | .030 |
| *Tiredness (lag)* | *-.421* | *.134* | *105.143* | *-3.148* | *.002* | *-.686* | *-.156* |

Table 11

*Linear Mixed Model Results for Unhappy mood #1*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | 1.715 | .725 | 61.363 | 2.366 | .021 | .266 | 3.165 |
| Injury level | .139 | .374 | 24.674 | .372 | .713 | -.632 | .911 |
| Day | -.049 | .036 | 64.897 | -1.373 | .174 | -.121 | .022 |
| *Pain intensity* | *.195* | *.052* | *91.077* | *3.785* | *.000* | *.093* | *.297* |
| *Secondary conditions* | *-.078* | *.034* | *24.420* | *-2.307* | *.030* | *-.148* | *-.008* |
| Sleep quality (lag) | -.067 | .125 | 89.422 | -.537 | .592 | -.316 | .182 |

Table 12

*Linear Mixed Model Results for Unhappy mood #2*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | 1.803 | .670 | 51.600 | 2.693 | .010 | .459 | 3.147 |
| Injury level | .149 | .372 | 24.429 | .401 | .692 | -.618 | .916 |
| Day | -.051 | .036 | 64.267 | -1.412 | .163 | -.123 | .021 |
| *Pain intensity* | *.196* | *.051* | *92.482* | *3.823* | *.000* | *.094* | *.298* |
| *Secondary conditions* | *-.079* | *.034* | *24.550* | *-2.345* | *.027* | *-.148* | *-.010* |
| Tiredness (lag) | -.087 | .106 | 87.019 | -.822 | .413 | -.299 | .124 |

Table 13

*Linear Mixed Model Results for Joyful/happy mood #1*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | 2.831 | .893 | 51.969 | 3.169 | .003 | 1.038 | 4.623 |
| Injury level | .092 | .486 | 19.398 | .190 | .852 | -.923 | 1.107 |
| Day | -.103 | .081 | 52.347 | -1.260 | .213 | -.266 | .061 |
| *Pain intensity* | *-.158* | *.057* | *82.490* | *-2.778* | *.007* | *-.271* | *-.045* |
| Secondary conditions | -.015 | .044 | 19.691 | -.350 | .730 | -.107 | .077 |
| Sleep quality (lag) | .191 | .128 | 71.751 | 1.490 | .141 | -.065 | .447 |

Table 14

*Linear Mixed Model Results for Joyful/happy mood #2*

| | | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Std. Error | df | t | Sig. | Lower Bound | Upper Bound |
| Intercept | 2.230 | .842 | 44.415 | 2.647 | .011 | .533 | 3.927 |
| Injury level | .093 | .478 | 20.073 | .194 | .848 | -.904 | 1.089 |
| Day | -.094 | .079 | 52.238 | -1.196 | .237 | -.252 | .064 |
| *Pain intensity* | *-.157* | *.055* | *80.869* | *-2.837* | *.006* | *-.266* | *-.047* |
| Secondary conditions | -.001 | .044 | 20.378 | -.021 | .983 | -.092 | .090 |
| *Tiredness (lag)* | *.324* | *.119* | *82.853* | *2.729* | *.008* | *.088* | *.561* |

*Appendix A*

STOP-BANG Questionnaire

*S*noring: Do you snore loudly (louder than talking or loud enough to be heard through closed doors)?

*T*ired: Do you often feel tired, fatigued, or sleepy during daytime?

*O*bserved: Has anyone observed you stop breathing during your sleep?

Blood *p*ressure: Do you have or are you being treated for high blood pressure?

*B*MI: Is your Body Mass Index over 35 $kg/m^2$?

*A*ge: Are you over 50 yrs old?

*N*eck circumference: Is your neck circumference greater than 40 cm?

*G*ender: Are you male?

*Appendix B*

International SCI Basic Pain Dataset

1. How much did you limit your activities in order to keep your pain from getting worse TODAY? (0 = not at all; 6 = very much)
2. How much did your pain change your ability to take part in recreational and other social activities TODAY? (0 = no change; 6 = extreme change)
3. How much did your pain change the amount of satisfaction or enjoyment you got from family-related activities TODAY? (0 = no change; 6 = extreme change)
4. In general, how much has pain interfered with your day-to-day activities TODAY? (0 = no interference; 6 = extreme interference)
5. In general, how much has pain interfered with your overall mood TODAY? (0 = no interference; 6 = extreme interference)
6. In general, how much did pain interfere with your ability to get a good night's sleep LAST NIGHT? (0 = no interference; 6 = extreme interference)