Sleep Problems are associated with Chronic Pain over and above mutual associations with Depression and Catastrophizing

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Abstract

Pain, mood problems and sleeping difficulties are often comorbid and contribute to reduced physical function and quality of life for those suffering from chronic pain. However, the way in which these factors interact is unclear. Until recently it was thought that the effect of sleep on pain and physical function was simply a result of its common association with mood problems. However, a growing body of research suggests that sleep may have a unique contribution.

Objectives: The aim of this study was to determine whether sleep disturbances were associated with pain and poor physical function independent of psychological distress in patients attending a tertiary pain medicine unit.

Method: 101 patients with chronic pain completed a set of questionnaires measuring pain, sleep and mood, and also completed a selection of physical assessments conducted by a physiotherapist.

Results: 75.2% of participants had insomnia and 84.3% reported the presence of at least one sleep problem. Significant positive correlations with pain were detected for depression, catastrophizing, insomnia, short sleep duration and poor sleep quality. Sleep duration had a significant independent association with pain after accounting for depression and catastrophizing. Sleep duration also had an independent association with physical function after accounting for pain and catastrophizing.

Conclusions: Given that sleep has an important and unique contribution to pain and physical function, it is important that sleep disturbances are addressed both in the assessment and treatment of chronic pain.

Introduction

Chronic pain affects mood, cognitive abilities and physical functioning, and thus impacts significantly on quality of life [1]. Sleep problems are also associated with impairments in mood, cognition and physical ability [2]. As people with chronic pain often have sleep problems, it is important to examine the influence that both of these have, not only on each other, but also on mood and the subsequent capacity to perform daily activities. This will, in turn, inform clinical treatments. For example, benefits resulting from treatments that focus on sleep disturbances might spill over to improvements in pain, mood and physical function.

People with chronic pain have problems with their sleep at a rate much higher than in the normal population [3]. In particular, the prevalence of sleep problems among those with chronic pain is as high as 80%, whereas only a minority of pain-free controls suffer from sleep difficulties [4, 5]. Moreover, as sleep deprivation impacts detrimentally on physical function and cognitive performance [2, 6], insomnia and other sleep problems could add significantly to the burden of chronic pain.

A substantial body of research now suggests the existence of a reciprocal relationship between pain and sleep, where pain can result in a reduction both in the quantity and quality of sleep; in turn, poor sleep can result in a subsequent increase in reported pain [3, 7, 8]. One key observation has been that sleep deprivation can decrease both the pain threshold and pain tolerance, even in healthy individuals [9, 10]. This is the case both for total sleep deprivation and deprivation of specific sleep stages, thereby mimicking poor sleep quality [9, 11]. Moreover, sleep problems may act as a risk factor for developing chronic pain [8]; indeed, many patients with chronic pain pinpoint improved sleep as an important goal of treatment for their pain [12, 13]. However, the relationship between

sleep and pain is complex, as depression and catastrophizing correlate highly both with pain and sleep problems [12, 14]. Thus, pain, psychological factors and sleep may all interact.

Approximately 25% to 55% of patients with chronic pain meet the diagnostic criteria for Major Depressive Disorder (MDD) [12, 15-19]. Not only is the prevalence of comorbid depression and chronic pain high, but psychological factors such as depression also contribute significantly to variance in acute and chronic pain [20]. In particular, depression is associated with reduced pain thresholds [21].

Depression is also linked with sleep impairments. In fact, having a chronic sleep problem such as insomnia is one of the defining symptoms of Major Depression [12, 19]. There can also be impairments in cognitive and physical functioning due to psychomotor retardation associated with depression [22]. In addition, through longitudinal research, insomnia has been identifies as a risk factor for developing depression [23, 24].

Along with depression, catastrophizing is a central psychological factor in the experience both of acute and chronic pain [14, 20, 25, 26]. Indeed, pain catastrophizing may serve as a risk factor for the development of chronic pain [27]. Moreover, pre-sleep cognitive ruminations have been found to predict sleep disruption [14, 28, 29]. Pain-related thoughts prior to sleep, and in particular pain catastrophizing, result in poorer sleep continuity after accounting for pain and depression [14, 30]. Thus, catastrophizing may impact pain indirectly via an effect on sleep [14].

The aim of this study was to determine whether sleep is associated with pain and physical function independent of psychological distress in patients who attended an outpatients program for managing chronic pain. As pain experience has previously been shown to be directly impacted by catastrophizing and depression, it was expected that these two factors would explain a large proportion of the variance in pain scores. However, it was also expected that sleep would have its own independent contribution after accounting for catastrophizing and depression. The effect of depression and catastrophizing on physical

function was expected to be tempered by other motivating factors, such as the desire to push through. However, as sleep difficulties also impact on physical function, sleep was expected to have its own independent effect on functional outcomes in patients with chronic pain.

Materials and Methods

Participants

This study involved 44 male and 57 female participants aged between 15 and 83 years (mean = 59.0 S.D. = 14.8). All participants had a prior diagnosis of chronic pain by either a General Practitioner or a Pain Specialist and on average pain had persisted for 6.55 years (range: 3 months to 39 years). 68% of the participants fell within the mild range or greater for depression. Participants were attendees of a 4 week cognitive behaviour therapy (CBT) based pain management course conducted by the Pain Medicine Unit at Fremantle Hospital, Western Australia, and were concurrently being treated pharmacologically for their pain. Prior to participating in the study, potential participants provided their written informed consent for the assessments and procedures, which were approved by the hospital and university ethics committees. Further demographic details are shown in Table 1. This study was part of a larger project that required 80 participants to achieve a power of 0.8 with α at 0.05. Additional participants were recruited into a "treatment as usual" condition, resulting in 101 participants who provided data for this study.

Materials

<u>Berlin Sleep Questionnaire</u>. This instrument consists of 14 items aimed at identifying patients at risk of obstructive sleep apnoea. The items assess the presence and frequency of a) snoring; b) wake time sleepiness or fatigue; and c) obesity or hypertension. Persons with

persistent and frequent symptoms in any two of these three domains are considered to be at risk of sleep apnoea. This questionnaire has moderately high levels of sensitivity and specificity for identifying people with obstructive sleep apnoea [Apnoea-hypopnea index(AHI)>5] [31]. This instrument has good internal consistency with Cronbach's α of .86- .92 [32], Cohen's kappa coefficient of 96.3% and acceptable test-retest reliability [31].

Insomnia Severity Index (ISI) [33]. This instrument is a 7 item scale that covers the DSM-IV insomnia criteria and assesses sleep onset, sleep maintenance, early morning awakening problems, interference with day time functioning, noticeability of impairment, concern about the sleep problem and satisfaction with sleep pattern. The ISI has good internal consistency (Cronbach's α =.74 [34]), appropriate test-retest reliability and good sensitivity to change [34, 35].

Pittsburgh Sleep Quality Index (PSQI) [36]. The PSQI was used to measure sleep quality and sleep duration over the past month. This questionnaire consists of 19 items that are used to assess seven components of sleep: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication and daytime dysfunction. A global score is also obtained by summing the individual components to produce a score ranging from 0-21. High scores indicate poor sleep. Researchers have reported good test-retest reliability as well as adequate sensitivity and specificity to identify those with poor sleep quality in normal sleepers using a cut off score >5; and to identify poor sleep quality among people with insomnia with a cut off score >10 [37, 38]. Cronbach's α ranges between .77 and .85 for the global score [38, 39].

A modified version of the Sleep Disorders Questionnaire (SDQ) [40]. The SDQ consists of 176 items and was developed to evaluate and diagnose the presence of four main sleep

disorders (sleep apnoea, narcolepsy, psychiatric sleep disturbance and restless legs syndrome) [41]. However, as this rather lengthy assessment tool had some overlap with other measures of sleep, only the items concerned with restless legs were used in this study. This tool has been shown to have acceptable test-retest reliability and adequate sensitivity and specificity for identifying restless legs syndrome [40]. Cronbach's α ranges between .70 and .86 for the measure as a whole [42].

Numerical Pain Rating Scale (NRS). Participants were asked to rate their current pain, lowest pain in the past week, highest pain in the past week and their usual pain in the past week between 0-10 to best describe their pain where 0 = no pain at all and 10 = worst possible imaginable. The NRS is widely used in both clinical practice and pain research and has been demonstrated to have good sensitivity to change in pain levels [43]. Cronbach's α ranges between .84 and .98 in patients with chronic pain, and test-retest reliability is high [44, 45].

Depression, Anxiety and Stress Scale -21 (DASS-21) [46] This self-report scale consists of 7 items in each of the depression, anxiety and stress scales which are rated over the past week. The DASS-21 is a short version of the 36-item DASS. Validity and reliability studies have shown that the DASS-21 is as robust as the DASS in measuring depression, anxiety and stress, and was used in this research as it is considerably shorter than the full DASS [47]. Only the depression score was used in the present study (Cronbach's α = .88) [47].

Coping Strategies Questionnaire [48]. The pain catastrophizing subscale (CSQ-CAT) of this instrument was used to measure participants' tendency to exaggerate the threat value of pain. This subscale consists of 6 items on a 7 point scale; it has adequate test-retest reliability and internal consistency (Cronbach's α = .84) [49, 50].

The following physical assessments were performed by a physiotherapist to objectively measure physical function:

6 Minute Walk Test. This test was used to assess physical function in relation to ambulation and fatigue [51]. The test was originally designed for use with patients with chronic pulmonary disease and has been used extensively in cardiac research [52]. It has very good test-retest reliability (intraclass correlation coefficient [ICC] = 0.90) and correlates moderately with other functional assessments [52].   In this test patients were instructed to walk back and forth along a corridor (30 m long) for 6 minutes with the aim of achieving the longest distance possible. The test began with a 10 minute rest period (sitting in a chair outside the corridor) then the following standard instruction was given:

"You will walk back and forth along this corridor between the brass plate and the exit sign for 6 minutes. You will be given one minute warnings so you know how long you have been walking for. Please walk at your own pace, while attempting to cover the greatest distance possible during the allotted time. If you need to stop and rest, feel free to; however, we encourage you to start again and keep going. We want you to obtain the greatest distance possible for you; however, we do not want you to have a pain flare up afterwards so keep this in mind as you do your walk."

Standard encouragements were given at roughly 30 second intervals in the form of "well done", "keep up the good work", "you are doing well". Participants were given a card at the completion of each lap to ensure the count of laps and thus distance was accurate.

Timed Pen Pick Up. The timed pen pick up task was used as a general test of broad physical functioning. It requires the simultaneous use of balance, lower extremity strength, vision and motion of several joints. It has been used to assess physical function in older

adults and patients with HIV [53, 54]. A pen was placed on the floor and participants were asked to stand in front of it. They were then given the following instruction:

"Stand with your feet comfortably apart at any distance from the pen that you choose. You will be asked to bend down, pick up the pen then straighten. You will do this twice, as quickly as you can, dropping the pen in between and I will time you. So that is two repetitions, your time starts now".

Loaded Forward Reach. This test was used as an assessment of trunk muscle endurance and lifting capacity as well as dynamic balance. The Loaded Forward Reach has previously been used to assess function in patients with chronic back pain and has been found to have good test-retest reliability (ICC=0.74) [55]. Participants were asked to stand straight with their shoulders square to a white board and to hold a 1 kg weight in their right hand with their hand over the top of the weight (i.e., the dorsum of the hand was facing the ceiling). They were then instructed to extend their right arm horizontally in front of them and a mark was placed on the white board to indicate the position of their wrist. The patient was then instructed to "reach forward as far as you can, using whatever technique you wish so long as you do not lose balance or rest on the board". Their heels were required to remain on the ground and their arm to remain horizontal. A mark was again placed on the white board to indicate the position of the wrist. The distance between the starting mark and finishing mark was then measured using a metal tape measure. In the case that a 1 kg weight was too heavy for the participant to hold, a 0.5 kg weight was used.

Procedure:

After the initial screening to determine acceptance into the study, participants completed the questionnaire package over roughly half an hour, in the morning just prior to the commencement of their pain management program.

The physical assessments were performed at the same time on two consecutive days and the results averaged to account for any variation due to either over or under performing on the first day as participants attempted to gauge what they were capable of achieving without risking a pain flare up. Physical assessment took roughly half an hour with the first one directly following the completion of the questionnaire package.

The raw scores from the three physical measures were converted to standard z scores. After inverting the z score for the 6 Minute Walk Test and Loaded Forward Reach, all three z-scores were summed to provide an overall physical function score for each participant with high scores indicating reduced physical function.

Data analysis:

Data were analysed using hierarchical linear regression. Pearson correlations were examined to identify potential covariates and to assess whether necessary preconditions for testing relationships through regression were present. For the regression analyses, missing data were replaced with the mean for that variable to maintain adequate sample size (3.96% of the full data set).

Results

Prevalence of Sleep Problems

Of the 101 participants 75.2% met the criteria for clinical insomnia as outlined by Morin, Belleville, Belanger and Ivers [56]. 41.7% were assessed as having a high risk of sleep apnoea as indicated by the Berlin Sleep Questionnaire and 52% indicated that they experienced symptoms of restless legs syndrome. Overall, 84.3% reported the presence of at least one sleep problem.

Correlations between Pain, Depression, Physical Function and Sleep

Pearson correlations were examined to identify possible covariates of sleep and pain. Current pain was examined specifically because it was most likely to correlate with physical function on that day and also with several other measures of current functioning. As shown in Table 2, the strongest correlations with current pain were catastrophizing and depression; however, these correlated highly with each other. Next was insomnia, poor physical function, sleep duration and sleep quality. Low physical function correlated significantly with pain, insomnia, poor sleep quality, short sleep duration and catastrophizing, but not with depression. There was no association between age or pain duration and any of the variables listed in Table 2.

Selection of Predictor Variables for Regression Analysis

Current pain and physical function were chosen as indices of chronic pain. To adequately examine the relationship between sleep, psychological distress and chronic pain, it was necessary first to identify measures that should be included as predictor variables in regression analyses. Acceptance was based both on the statistical significance of the relationship and the distinctiveness of the construct being measured. The Holm-Bonferroni adjustment was used to reduce potential type I errors due to multiple comparisons [57].

Predictors of current pain included catastrophizing, depression, insomnia, short sleep duration and poor sleep quality (Table 2). Insomnia correlated highly with sleep duration and quality and, in terms of face validity, essentially measured the same construct. Thus, sleep duration and quality were included in the regression analyses rather than insomnia as this provided more information about the separate aspects of sleep than insomnia alone. Although depression and catastrophizing also correlated highly with each other, they were considered to measure different constructs, as it is possible to have catastrophizing thoughts

without being depressed [58]. Thus, both variables were retained as predictor variables in regression analyses.

Predictors of low physical function included insomnia, sleep duration, sleep quality, pain and catastrophizing (Table 2). However, insomnia was not included in the subsequent regression analysis for the reasons outlined above.

Regression Analyses to Assess the Relationship between Sleep, Mood, Pain and Physical Function

A regression analysis was performed to examine the role of sleep in explaining variation in current pain scores after accounting for depression and catastrophizing. Sleep duration initially was entered into the regression model before sleep quality as it had the stronger relationship with current pain.

Short sleep duration contributed significantly to the variance in current pain scores, independent of depression and catastrophizing (R square change=.043, p=.019). However, sleep quality did not account for further variation in current pain scores (Table 3). Conversely, when sleep quality was entered prior to sleep duration, only sleep duration predicted pain (R square change =0.030, p=.048). Thus, in the final regression model, sleep duration and catastrophizing each separately predicted current pain intensity independently of depression and sleep quality (Table 3).

A second regression analysis was performed to examine the role of sleep in explaining variance in physical function, after accounting for current pain and catastrophizing. Short sleep duration contributed significantly to poor physical function (R square change=.039, p=.038) after controlling for the effects of current pain levels and catastrophizing. However, sleep quality did not further contribute to variation in physical function after sleep duration had been taken into account (Table 4).

Discussion

In this study, the association between chronic pain and sleep problems was investigated in patients attending a 4-week pain management course at a pain medicine unit within an Australian tertiary health care institution. Sleep problems were found to predict pain levels and poor physical function after accounting for psychological distress.

Prevalence of sleep problems:

Within this group the predominant sleep problem was insomnia, as over 75% met the criteria for this disorder. This is substantially higher than the reported prevalence of 5.6% in the general population of Australia [59], but similar to rates found in chronic pain populations elsewhere [4, 5]. This disparity highlights the need to further investigate the relationship between sleep and pain.

The next most common sleep problem in this sample was restless legs syndrome, with 52% reporting interference with sleep as a result of this condition. In addition, 41% were at high risk of sleep apnoea. This again is in contrast to the much lower rates of 9.4% for restless legs and 4.9% for sleep apnoea in the general Australian population [60]. Overall, 84.3% of our patients reported having at least one sleep problem. This is comparable to findings from other specialist chronic pain treatment centers [5].

Correlates with Pain and Low Physical Function:

Strong correlations were found between pain and the following variables in order of significance: catastrophizing, depression, insomnia, low physical function, short sleep duration and poor sleep quality. This was largely in line with expectations and previous

research showing the separate relationships between these factors and pain [12, 14, 61]. Of note is the lack of significant correlation between pain and sleep apnoea or restless legs syndrome after applying the Holm-Bonferroni adjustment. Both restless legs and sleep apnoea primarily affect the quality of sleep as they produce micro arousals, and this may be a factor in their interaction with pain. ~~Thus, our results suggest that these microarousals have little impact on pain during waking periods.~~

Low physical function correlated significantly with pain, insomnia, poor sleep quality, short sleep duration and catastrophizing. Contrary to expectations and previous findings [22] was the absence of an association with depression, particularly as psychomotor retardation is an important feature of depression [19]. Perhaps depression is associated more strongly with performance of fine motor tasks than with the gross motor exercises utilised in this study.

These findings indicate that impaired sleep is highly related to high pain levels and low physical function. However, the direction of this relationship cannot be determined without further research.

Associations among Pain, Mood and Sleep:

Short sleep duration was associated with current pain scores, independent of depression and catastrophizing. This is in line with expectations based on research in healthy non-depressed individuals, where sleep deprivation resulted in heightened sensitivity to pain [9-11]. Our findings do not support the view that constructs such as catastrophizing impact pain indirectly via their effect on sleep [14], as catastrophizing provided an independent contribution to variance in current pain scores when sleep factors were accounted for. However, catastrophizing might have indirect effects on pain mediated by other unmeasured factors (e.g., avoidance of potentially painful but therapeutic activities).

Our findings show that the relationship between sleep and pain cannot simply be explained by their common associations with depression and catastrophizing. It can thus be theorised that sleep and pain have a direct relationship where either an increase in pain impedes sleep, or sustained poor sleep increases pain sensitivity. It seems plausible that an increase in pain results in an increase in arousal which would subsequently result in difficulty both initiating and maintaining sleep [10]. However, research conducted by Edwards et al. [7] showed that poor sleep is more predictive of pain the following day than pain predicting poor sleep the subsequent night. One possibility is that the regulation of sleep and the modulation of pain share common neurobiological systems [10]. Thus, it is possible that a dysregulation in either factor would have an effect on both; alternatively, dysfunction in the underlying neurobiological systems may result in an effect both on sleep and pain.

The finding that sleep duration had a stronger independent association with pain than sleep quality is also of note. Although this is in line with laboratory studies artificially restricting sleep, resulting in increased pain sensitivity regardless of the subjective quality of that sleep [9, 11], the picture is not so clear in temporal sleep/pain relationship studies in natural settings. Findings vary in different age groups and may also depend on the nature of the pain condition [62, 63]. Thus, it is possible that the mechanism that underlies the interaction between pain and sleep varies according to the pain aetiology involved.

Given the strong association between sleep problems and pain levels, it is important that sleep is assessed in patients with chronic pain. A further practical implication of this research is that it may be helpful for chronic pain management programs to include a component aimed at improving sleep as part of their treatment protocol to reduce pain.

Associations among Low Physical Function, Pain, Mood and Sleep:

Short sleep duration was associated with low physical function, after controlling for the effects of current pain levels and catastrophizing. This is congruent with previous findings by

Banks and Dinges [2] and Van Helder and Radomski [6] who demonstrated the detrimental effect of sleep deprivation on physical performance. Building from this, our findings show that the relationship between sleep disturbances and low physical functioning cannot simply be explained by their common association with pain or psychological distress. In fact, sleep had a larger part to play than catastrophizing or current pain levels in explaining the variation in physical functioning. Thus, sleep disturbances may impact far more severely on physical functioning in patients with chronic pain than previously thought.

Many pain management programs aim to improve physical function as one of the primary outcomes. As sleep has such an important influence on physical function, it may be helpful to address sleep problems as part of multidisciplinary pain management courses.

Limitations

The findings of this research need to be interpreted within the study limitations. This research was conducted with a heterogeneous group of patients with chronic pain; however, the majority had lower back pain. Our adoption of broad inclusion criteria could increase the clinical relevance of the findings as the sample may be representative of attendance at other tertiary pain management centres. However, sleep may interact differently with pain in different diagnostic categories. For example, sleep problems associated with a widespread pain condition such as fibromyalgia may have a different etiology than the insomnia commonly comorbid with lower back pain.

The large age range in this sample may also have impacted on the findings as both sleep and physical functioning vary across the life span. Whether effects of these variables on pain differ between adolescent and older adult age groups will need to be addressed in further studies.

In addition, this sample came from a clinical population attending a 4 week program and, as such, participants may have been less physically active than other patients who worked full time and were unable to attend. Potentially, sleep problems may not be as prevalent in higher functioning groups and hence might have less influence on pain and physical function.

Conclusions

As comorbidity between sleep problems and chronic pain is extremely high, it is important to explore potential mediators of this relationship such as psychological distress. However, our findings suggest that sleep also has a significant and independent association with pain and physical function, over and above any mutual association with depression and catastrophizing. Thus, it may be helpful to address sleep problems as part of the treatment of chronic pain as improvements in sleep could result in improvements in pain, mood and function.

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Table 1: Demographic characteristics of the sample

Gender		Work Status		Pain locations		Depression[a]	
Male	43.56%	Full time	6.06%	Head	10.53%	Normal	31.96%
Female	56.44%	Part time	12.12%	Cervical	5.26%	Mild	20.62%
Marital Status		Voluntary work	4.04%	Upper Limbs	28.42%	Moderate	20.62%
Married	32.95%	Home duties	13.13%	Thoracic	9.47%	Severe	10.31%
Defacto	7.95%	Retired	14.14%	Abdominal	8.42%	Extremely Severe	16.49%
Divorced	13.64%	Student	3.03%	Lower back	52.63%		
Separated	6.82%	Unemployed	46.46%	Lower limbs	16.84%		
Single	37.50%	Retraining	1.01%	> 3 major sites	15.79%		
Widowed	1.14%						

[a]Depression categories were determined by ratings on the Depression, Anxiety and Stress Scale -21 [46].

Table 2: Association among indices of pain, physical function, depression and sleep

	Mean ± S.D.	Pearson's correlation coefficient							
		Current pain	Insomnia	Restless legs	Sleep apnoea	Short sleep duration	Poor sleep quality	Depression	Catastrophizing
Current pain	5.2 ± 2.3	1							
Insomnia	14.4 ± 7.1	.350***#	1						
Restless legs	5.5 ± 2.7	.208*	.361***	1					
Sleep apnoea	0.4 ± 0.5	.185	.243*	.092	1				
Short sleep duration	1.4 ± 1.2	.319**#	.572***	.377***	.062	1			
Poor sleep quality	1.8 ± 0.9	.284**#	.717***	.318***	.343***	.419***	1		
Depression	15.0 ± 10.7	.379***#	.533***	.303**	.324**	.258*	.387***	1	
Catastrophizing	14.1 ± 8.8	.474***#	.434***	.264*	.273*	.224*	.332***	.657***	1
Low physical function	0.1 ± 2.3	.303**#	.356***#	.115	.182	.305**#	.337***#	.145	.282**#

Note: The above variables were measured with the following tools: current pain – Numerical Rating Scale (0-10) ; insomnia – Insomnia Severity Index; restless legs – Sleep Disorders Questionnaire; sleep apnoea – Berlin Sleep Questionnaire; sleep duration and sleep quality – Pittsburgh Sleep Quality Index; depression – Depression Anxiety and Stress Scale short form (DASS-21), catastrophizing – pain catastrophizing subscale of the Coping Strategies Questionnaire; Reduced physical function – Timed Pen Pick Up, Loaded Forward Reach and Six Minute Walk.

*Correlation is significant at the .05 level (2-tailed). ** Correlation is significant at the .01 level (2-tailed). *** Correlation is significant at the .001 level (2-tailed).

For predictors of current pain and physical functioning - Correlation is significant after applying the Holm-Bonferroni adjustment.

Table 3: The role of sleep variables in predicting current pain after accounting for depression and catastrophizing

Current Pain (predicted variable)		B	Std. Error	Beta	t	$R^2\Delta$
Model 1	(Constant)	3.306	.411		8.0487***	.227***
	Depression	.023	.024	.107	.958	
	Catastrophizing	.110	.030	.404	3.6337***	
Model 2	(Constant)	2.982	.424		7.0337***	.043*
	Depression	.014	.024	.066	.596	
	Catastrophizing	.105	.030	.385	3.5317**	
	Sleep duration	.394	.166	.213	2.3757*	
Model 3	(Constant)	2.816	.502		5.6167***	.003
	Depression	.011	.025	.052	.460	
	Catastrophizing	.103	.030	.377	3.4277**	
	Sleep duration	.355	.178	.192	1.9997*	
	Sleep quality	.163	.261	.063	.623	

Note: 1. The above variables were measured with the following tools: current pain – Numerical Rating Scale; sleep duration and sleep quality – Pittsburgh Sleep Quality Index; depression – Depression Anxiety and Stress Scale short form (DASS-21); catastrophizing – pain catastrophizing subscale of the Coping Strategies Questionnaire;

2. Physical functioning was not included in this analysis as it did not correlated significantly with current pain after applying the Holm-Bonferroni adjustment.

3. * significant at the .05 level (2-tailed)

   ** significant at the .01 level (2-tailed).

   *** significant at the .001 level (2-tailed).

Table 4: The role of sleep variables in predicting physical function after accounting for current pain levels and catastrophizing

Physical Function (predicted variable)		B	Std. Error	Beta	t	$R^2\Delta$
Model 1	(Constant)	1.629	.531		3.069**	.088**
	Current pain	.289	.093	.297	3.093***	
Model 2	(Constant)	1.844	.548		3.366**	.019
	Current pain	.217	.105	.223	2.063*	
	Catastrophizing	.042	.029	.158	1.461	
Model 3	(Constant)	2.001	.544		3.680***	.039*
	Current pain	.162	.107	.166	1.518	
	Catastrophizing	.038	.028	.141	1.329	
	Sleep duration	.373	.178	.208	2.102*	
Model 4	(Constant)	2.513	.597		4.206***	.032
	Current pain	.147	.105	.151	1.391	
	Catastrophizing	.026	.028	.097	.901	
	Sleep duration	.246	.187	.137	1.317	
	Sleep quality	.515	.265	.205	1.942	

Note: The above variables were measured with the following tools: physical function – Timed Pen Pick Up, Loaded Forward Reach and Six Minute Walk; current pain – Numerical Rating Scale; catastrophizing – pain catastrophizing subscale of the Coping Strategies Questionnaire; sleep duration and sleep quality – Pittsburgh Sleep Quality Index.

* significant at the .05 level (2-tailed)

** significant at the .01 level (2-tailed).

*** significant at the .001 level (2-tailed).