# Sleep, Pain and Daytime Functioning in Patients with Fibromyalgia Syndrome and Osteoarthritis: A Cross-Sectional Comparative Study

By

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# Abstract

Fibromyalgia syndrome (FMS) is a disorder characterised by chronic widespread pain, non-restorative sleep, fatigue and daytime dysfunction. Occurring in 2-5% of the population, the aetiology is largely unknown. Sleep dysfunction occurs in over 90% of FMS patients. While research has shown that both the macrostructure and microstructure of sleep may be altered, there remain inconsistencies in the polysomnographic (PSG) findings, and wide variations in methodological approaches. Few studies have controlled for symptom duration or the time elapsed between diagnosis and PSG sleep assessments. In addition, while psychometric analyses have suggested a distinctive FMS psychological profile (which includes higher levels of depressive symptoms, anxiety and fatigue) few studies have simultaneously, and thoroughly examined sleep and psychological status in the same participants. A frequently reported alteration found in the sleep microstructure of FMS patients is the *alpha-delta sleep anomaly*, characterised by an increase in alpha wave activity during slow wave sleep. Originally considered a possible neurological contribution to FMS, whether the alpha-delta sleep anomaly is fundamental to the development of fibromyalgia syndrome, or results mainly from the pain experience of FMS patients remains unknown. No previous study has directly compared the sleep of FMS and other (non-FMS) patients experiencing similar levels of chronic pain and sleep dysfunction.

The present study was designed to examine sleep macrostructure and microstructure in FMS patients, and evaluate the role of the alpha-delta sleep anomaly as either a possible contributor to fibromyalgia syndrome, or a likely consequence of pain experience. In order to explore these relationships, detailed sleep, activity and psychological profiles were compared in 3 groups: 1) FMS patients ($n$ = 19); 2) osteoarthritis patients with sleep disturbance ($n$ = 17); and non-clinical (normal healthy) adults ($n$ = 10). In order to standardise diagnostic reliability and symptom chronicity, the FMS group was recruited from a single rheumatology facility immediately following diagnosis.

Guided by a series of formal research questions, analyses compared sleep macrostructure (using American Academy of Sleep Medicine criteria), sleep microstructure (using spectral analysis), and a range of psychological variables (including pain experience, sleepiness, fatigue, depression, anxiety, perceived social support, health locus of control, pain catastrophizing and personality). The results indicated that the alpha-delta sleep anomaly is not unique to FMS, but appears to be a feature found in the

sleep of normal healthy adults and (to a greater extent) those with FMS and osteoarthritis. The incidence of the anomaly was statistically similar in both clinical (FMS and osteoarthritis) groups, a pattern consistent of its being a secondary feature of pain, rather than a primary abnormality of FMS. Overall, the psychometric assessments of state and trait anxiety and depression better discriminated between the three groups than did the sleep variables. Nevertheless, on measures of sleep, perceived social support, health locus of control, and pain catastrophizing, FMS and osteoarthritis patients were not significantly different, though both clinical groups differed on these variables from healthy controls.

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# List of Abbreviations

Aδ – Alpha-Delta

BMI – Body Mass Index

FIQ – Fibromyalgia Impact Questionnaire

FMS – Fibromyalgia Syndrome

N1 – Non-REM Stage 1

N2 – Non-REM Stage 2

N3 – Non-REM Stage 3

NHC – Normal Healthy Control

NREM – Non-Rapid Eye Movement

OA – Osteoarthritis

REM – Rapid Eye Movement Sleep

SE – Sleep efficiency

SOL – Sleep onset latency

TIB – Time in bed

TST – Total sleep time

WASO – Wake after sleep onset

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# Outputs Arising from Thesis

### Conference Proceedings

Yeung, W.K., Morgan, K. & McKenna, F. (2015). Objective and subjective sleep comparisons in patients with fibromyalgia syndrome, osteoarthritis and healthy controls. Oral presentation at the 7th World Sleep Federation Congress, November 2015, Istanbul, Turkey.

Yeung, W.K., Morgan, K. & McKenna, F. (2014). Predictors of fatigue in fibromyalgia syndrome and patients with osteoarthritis. Presented at APSS Sleep 2014 Conference, June 2014, Minneapolis, MN, USA.

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Yeung, W.K., Morgan, K. & McKenna, F. (2012). The Loughborough Fibromyalgia Patient Series Study. Presented at APSS Sleep 2012 Conference, June 2012, Boston, MA, USA.

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# 1. Introductory Review

## 1.1. Functions of Pain and Chronic Pain

Pain has been defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage (Merskey & Bogduk, 1994). The majority of what we perceive as pain, amounts to various cortical processes and activations, giving us information which helps localize the pain and inform us as to the intensity of the sensation. Pain is thus a vastly subjective term, and its application to such sensations is learned through previous experiences of injury to the body (Coderre, Mogil, & Bushnell, 2003).

In the infancy of pain research, there had been suggestions that the phenomenon of pain was completely unrelated to the cortex, for example it was found that those who sustained injuries to the cerebral cortex continued to feel pain (Campbell, 1912) leading to conclusions that the cortex played a minimal role. However contemporary investigations have led to speculations that there are specific parts of the cortex which are connected to the processing of pain, and damage to one area of the cortex does not necessarily lead to a complete debilitation in pain perception. The main cortical regions found to be activated during pain sensations include the limbic, paralimbic and sensory areas; these comprise of the anterior cingulate cortex (ACC), insular cortex, prefrontal cortex and primary (SI) and second (SII) somatosensory cortices (Bushnell, 2005; Peyron, Laurent, & Garcia-Larrea, 2000).

Pain can express itself in two forms that can be either ‘acute’ or ‘chronic’. Acute pain is short-lived, chronic pain however is specific to “actual or potential tissue damage” that persists beyond the expected time frame for healing or the occurrence in disease processes where healing may never occur (Ospina & Harstall, 2002). The nociceptive system consists of sensory fibres which help modulate pain sensations throughout the body; these include two types of fibres, namely thinly myelinated Aδ fibres that are rapidly conductive and unmyelinated C fibres that conduct much slower; the latter of which are most associated with chronic pain conditions such as that of ‘fibromyalgia syndrome’ (Williams & Gracely, 2007).

### 1.1.1. Prevalence of Chronic Pain and Healthcare Costs

It has been estimated that more than 1.5 billion people worldwide suffer from varying degrees of chronic pain (*Pain Management: A Global Strategic Business Report*, 2010). The prevalence of chronic pain in the general population ranges from 10-55% (Clark &

Treisman, 2004), and can have far reaching implications for productivity and quality of life. It has been found, for example, that during a two-week period, 13% of the US workforce reported loss in productivity due to common pain conditions such as arthritis or other musculoskeletal pain (Stewart, Ricci, Chee, Morganstein, & Lipton, 2003). A large scale study in 15 European countries and Israel looked at prevalence, severity, treatment and impact of chronic pain. Chronic pain of moderate to severe intensity was found to occur in 19% of the sample, affecting quality of social and working lives (Breivik, Collett, Ventafridda, Cohen, & Gallacher, 2006). Sleep disturbance is one of the most common co-morbid complaints to accompany reports of chronic pain, with sleep dysfunction linked to an increase in pain sensitivity or to an attenuation effect of analgesic medication (Okifuji & Hare, 2011a).

### 1.1.2. Gate Control Theory of Pain

The Gate Control Theory of Pain was formulated to provide a mechanism for coding the nociceptive component of cutaneous sensory input. It was first published in 1965 by Melzack and Wall. The theory suggested that thin (nociceptive) and large (innocuous) nerve fibres transmit information from the site of injury to two destinations (the 'inhibitory' cells and the 'transmission' cells) which are located in the bodies' spinal cord. Signals from both the thin and large nerve fibres excite the transmission cells. When the output of the transmission cells exceeds a critical level (unique to individuals), pain is felt, and it is the brain that makes sense of it. The role of the inhibitory cells is just that- to inhibit activation of the transmission cells. In other words, the transmission cells are the 'gate on pain' and responsible for opening it, and the inhibitory cells have the capacity to 'shut the gate', meaning a reduction/cease in pain experienced. To reiterate, the more the 'gate' is opened, the more pain is felt and vice versa. The two types of fibres are often activated at the same time so they become almost in competition with one another. Melzack & Wall posited that at times, pain signals travelling from the site of injury actually bypass these inhibitory and transmission cells altogether, thereby sending a message directly to the brain. This in turn, could trigger a signal back down the spinal cord to control inhibitory cell activity and therefore reduce pain experience. Importantly, it is the 'status' of the brain itself that is modulated by psychological and behavioural factors, and hence these can help to determine the extent to which the 'gate' is opened, and pain is experienced. As an example, Melzack and Casey (1968) described pain as having three characteristics/dimensions as follows:

- Pain could be viewed in terms of its 'sensory-discriminative' dimension, which refers to an individual's sense of the pain's intensity, location, quality and duration.
- Pain could also be analysed in terms of its 'affective motivational' aspect, which refers to the degree of perceived unpleasantness and the individuals' urge to escape that unpleasantness.
- Finally, the third dimension of pain was seen by the authors as 'cognitive evaluative'. This dimension relates to factors such as how the pain is judged by the individual; how the pain is viewed in terms of cultural values/norms; how much available distraction there is at the time the pain is experienced etc.

These 'components' of the pain experience offered the potential for modern medicine, to treat pain not purely by addressing the sensory output (e.g. via pharmacological therapy) as is the norm, but also methods which positively influenced the motivational-affective and cognitive factors. The theory was therefore a powerful development in pain theory as it viewed the individual as proactive in the pain experience, rather than a passive recipient of medical intervention (Bushnell, 2005; Melzack & Casey, 1968).

### 1.2. Fibromyalgia Syndrome

Fibromyalgia syndrome (FMS) is a chronic condition characterised by widespread musculoskeletal pain. The condition was first noted by Gowers (1904) who described it as numerous vague painful disorders of the locomotor system which he termed 'fibrositis' (Gowers, 1904). The term 'fibrositis' was used due to the assumption that the exhibited musculoskeletal pain is due to inflammation of muscular/connective tissue; further inspection from muscle biopsies of tender points, however, found no consistent inflammation or damage (Pearce, 2004). Smythe & Moldofsky (1977) were the first to set a 'rigorously defined' criteria for fibrositis. They included four symptoms of chronic aching, non-restorative sleep, morning stiffness and fatigue (Smythe & Moldofsky, 1977). FMS is today regarded as a form of non-articular rheumatism (Harth, 1995); and the pain experience in FMS now described as a 'central sensitization', or that which is related to the pathophysiological processes of the central nervous system (Bennett, 2005a).

### 1.2.1. Prevalence and Characteristics

The prevalence of FMS is estimated to range between 0.5 to 5% of the general population (Branco et al., 2010 [*fig. 1.1.*]; White & Harth, 2001) with 90% being female (Yunus, 2001). The diagnosis and treatment options for FMS are associated with significant societal and health care costs (Hughes, Martinez, Myon, Taı, & Wessely, 2006), with it being now more of an accepted clinical entity (Fitzcharles & Boulos, 2003). The prevalence and characteristics of FMS appear greater in older populations. The highest values of occurrence were found to be between the ages of 60 and 79 (Wolfe, Ross, Anderson, Russell, & Hebert, 1995). Similar findings have been observed in a study into the prevalence of FMS in five different European countries, with low prevalence in young adults followed by a rise from the age of 35-44 through to 74-85 (Branco et al., 2010); this appears to be a consistent feature of FMS. FMS considerably impacts the quality of life of sufferers who, around 90% of their time awake, experience pain and fatigue (Henriksson & Burckhardt, 1996). Presently, the disease aetiology is still largely unknown, with differing opinions and attitudes amongst healthcare professionals; for example, a study of knowledge and attitudinal challenges affecting optimal care in FMS found that GPs reported insufficient knowledge and skill in diagnosing FMS, with 23% of GPs and 12% of specialists characterizing patients as malingerers (Hayes et al., 2010). In addition, there has been evidence to suggest that trauma is linked to the manifestation and development of FMS, but this evidence is controversial and not definitive (White, Carette, Harth, & Teasell, 2000).

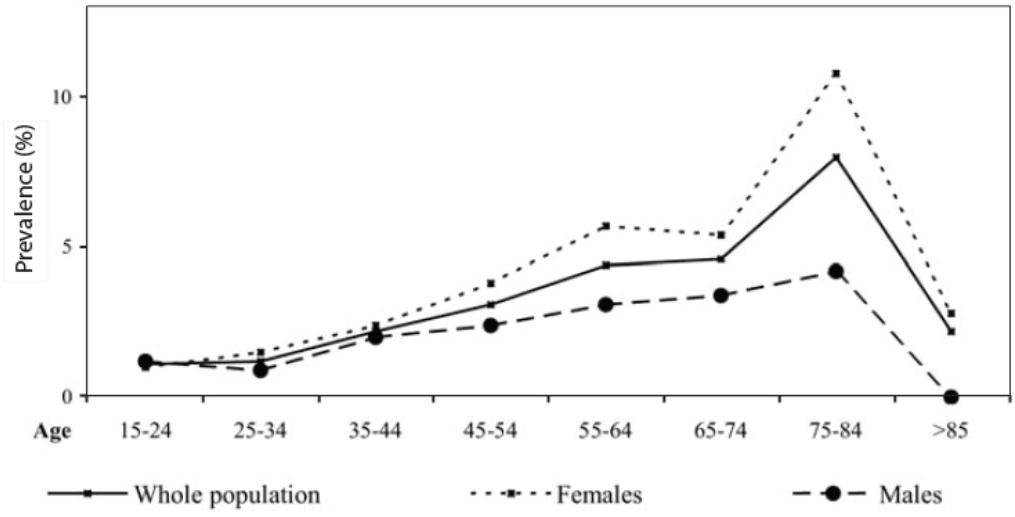



**Figure 1.1.** A graph depicting overall prevalence of FMS per age group in the general population. Image adapted from Branco et al. (2010).

The severity and complexity of the symptomology of FMS can be characterised in roughly three differing dynamics. These are broadly pain, sleep disturbance and psychosocial function. These three dynamics have been shown to relate to each other in various ways (Bigatti, Hernandez, Cronan, & Rand, 2008).

### 1.2.2. Diagnosis of Fibromyalgia Syndrome

One of the most significant issues in FMS is that the symptom manifestation does not seem to have an understandable organic pathology (McBeth, Macfarlane, Benjamin, & Silman, 2001). Indeed prior to the recognition of FMS as a syndrome, there had been no standardized criteria to diagnose such a condition. The development of diagnostic criteria more than twenty years ago has developed an increased interest in the nature and manifestation of the syndrome. The 1990 American College of Rheumatology's criteria (1990 ACR) for the classification of FMS has been the hallmark in such diagnoses; the criteria comprises briefly of widespread pain in the four quadrants of the body (axial plus upper and lower segment plus left- and right- side pain) in combination with tenderness at 11 of the 18 defined tender point sites (Figure 1.2.;Wolfe et al., 1990). The standardized tender-point sites include bilateral points at the occiput, low cervical, trapezius, supraspinatus, second rib, lateral epicondyle, gluteal, greater trochanter and the knee.

Tenderness is determined upon palpation using approximately 4kg of pressure with the pulp of the thumb. For each site to be considered a 'positive' tender point, the patient must rate it as 'painful' rather than 'tender' as 'tender' is not considered painful. Although the combination of the two criteria in diagnosing FMS yields a sensitivity of 88.4% and specificity of 81.1%, it must be taken into account that FMS is usually accompanied by co-morbid debilitating complaints and symptoms; the manifestation of FMS is rarely the same in any two patients (e.g. Thieme, Turk, & Flor, 2004).

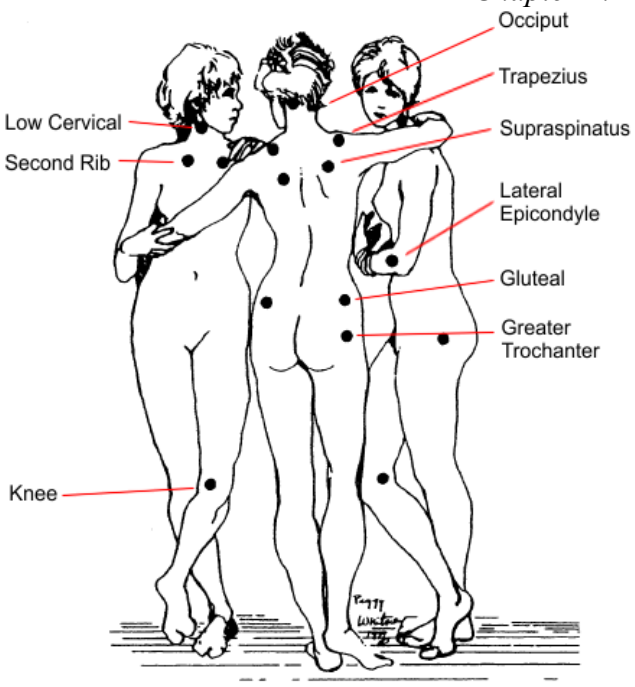



**Figure 1.2.** An image to illustrate the 18 tender point sites as defined in the ACR 1990 Diagnostic Criteria for Fibromyalgia Syndrome. Image adapted from Wolfe et al. (1990; The Three Graces, after Baron Jean-Baptiste Regnault, 1793, Louvre Museum, Paris).

While we have well-established criteria for diagnosis, the process of diagnosis still has its shortcomings. The need for a physical tender point examination is an example of such an issue; the number of tender points can vary within an individual. For example, patients who meet the 11 tender point criteria may have less than 11 tender points on a second examination; secondly the reliability of the tender point exam has been examined frequently (Bédard et al., 1992; Tunks et al., 1995). The ACR recently proposed symptom based practical criteria for a clinical diagnosis of FMS suitable for both primary and specialty care; the aim of the new criteria is not to replace the 1990 ACR, but instead to serve as a complementary instrument, recognizing a wide spectrum of manifestations and symptom severity that is characteristic of primary FMS. A widespread pain index (WPI) of 19 areas of the body and symptom severity score (SS) are considered. For a diagnosis of FMS, a WPI of at least 7 and an SS of at least 5 is required, or alternatively a WPI of 3-6 with an SS of 9. The 2010 revision was found to correctly classify 88.1% of cases previously classified using the 1990 ACR criteria (Wolfe et al., 2010).

### 1.2.3. Current Theories on Fibromyalgia Symptom and Manifestation

The physiological dysfunction in the pain experience has been well researched (Smith, Harris, & Clauw, 2011). FMS patients tend to have a lower threshold for nociceptive processing (Staud, 2002); it is thus implied that they have an alteration in their pain

processing pathways from pain receptors to the cortical processing level, suggestive of central sensitization of the central nervous system (CNS).

Moreover, it has previously been found, that nociception is qualitatively altered in patients with fibromyalgia, suggesting that fibromyalgic pain may be due to abnormal central pain mechanisms (Bendtsen, Nørregaard, Jensen, & Olesen, 1997).

#### 1.2.3.1. Neural Connectivity

Recent studies have found certain abnormalities of neural connectivity in patients with fibromyalgia compared with control subjects. Studies by Napadow and colleagues have found that neural connections between parts of the pain pathways and other networks (default mode network, executive attention network etc.) are highly correlated with pain (Napadow et al., 2010). Other studies have found a range of both positive and negative connectivity in fibromyalgia compared with healthy control participants; some studies for example have found a reduction in connectivity in the brain's pain inhibitory network (Jensen et al., 2012; Napadow, Kim, Clauw, & Harris, 2012).

## 1.3. Sleep

### 1.3.1. Function of Human Sleep

Sleep can be described as a state of immobility, reduced responsiveness with rapid reversibility, so as to differentiate between states of coma or anaesthesia ( Siegel, 2005); The phenomenon of sleep in mammals has perplexed humans for centuries, and even at present, there is no objective evidence to suggest the reasons as to why we sleep. There is, however, a growing importance in sleep research, both in theory and in medicine; after pain, sleep disturbances are the second most frequent indicator of illness (Šušmáková, 2004). Sleep structures differ widely among mammals; it is thus difficult to grasp its function between species, let alone use this information to better understand sleep dysfunction in humans.

Its importance has been underestimated in several early theories of the physiological significance of our sleep. But it is evidently of great significance to our wellbeing. For example, the process of 'sleep rebound' post-deprivation gives us a clue as to the physiological need for sleep. Findings have consistently indicated increases in 'deep' sleep rather than increases in duration (Ferrara, De Gennaro, & Bertini, 1999) that may signify specific aspects of the sleep structure as being more significant than others towards a "recovery" process. There have been multiple theories regarding the function of sleep, for example tissue restoration and growth (Adam & Oswald, 1977),

thermoregulation or consolidation of memory and learning ( Siegel, 2001) just to name a few. However, it is difficult for theories to encompass all aspects of sleep function. Sleep is a complex process regulated by various systems; they in turn interact with different bodily processes.

### 1.3.2. Classification and Definition of Sleep States

Berger (1929) first discovered that the electrical activity of the human brain could be measured by electrodes placed on the scalp, whereby changes in voltage are plotted over time. He found that the frequency and amplitude changes were consistently correlated with vigilance, drowsiness and sleep periods (Berger, 1929). Consequently, modern forms of sleep research are largely connected to the invention and discovery of the electroencephalograph (EEG). Loomis, Harvey, & Hobart (1937) observed the changes in sleep states during the course of a night, and thus described several stages of sleep based on EEG. The sleep stages are divided into two categories of non-rapid eye movement (NREM) and rapid eye movement (REM) sleep; with NREM further divided into four stages from the lightest stage 1 to the deepest stage 4 with each cycling of stages lasting for approximately 90 minutes. An average person will exhibit four to six cycles per night. With a need for standardization for comparability and replication of results Rechtschaffen and Kales (1968) developed a set of rules involving parameters, techniques and wave patterns of three physiological signals to evaluate each stage of sleep; the signals include the electroencephalogram (EEG), electrooculogram (EOG) and the electromyogram (EMG).

As illustrated in figure 1.3 each stage of sleep is characterized by a distinct EEG pattern; with stage 1 characterized by low voltage, mixed frequency (generally in 3-7 cycles per second range) with the highest amplitudes in the 2-7 Hz range called theta waves. A feature of stage 2 involves the anomaly of sleep spindles and K-complexes; sleep spindles being bursts of activity in the 12-16 Hz frequency and K-complexes involving a sharp negative wave followed by a slower positive wave; these anomalies may occur randomly within stage 2. Stages 3 and 4 are what are called ‘Slow Wave Sleep’ involving much slower ‘Delta’ waves in a range of less than 2 Hz, however with amplitudes greater than 75μV (Šušmáková & Krakovská, 2007). Researchers presently do not distinguish between stages 3 and 4 as the attributes they carry are the same with the only difference being the percentage occurrence during each stage; differentiation is thus deemed unnecessary. Figure 1.4 illustrates the electrode placements for evaluating sleep stages with the rules of Rechtschaffen and Kales (1968). The properties of the REM stage show low voltage mixed frequencies, which is comparable to stage 1; sawtooth

wave patterns are often observed, and EMG reaches its lowest level in conjunction with episodic rapid eye movements shown on the EOG.

Presently, the most widely used standard for defining sleep stages is the 'American Academy for Sleep Medicine' criteria (Iber, Ancoli-Israel, Chesson, Quan, & Chesson Jr., 2007; Silber et al., 2007). This involves updated labelling rules for sleep stages as N1, N2, N3 and REM. The main difference is in the elimination separate slow wave sleep stages, rather than having Stages 3 and 4, it is now replaced with stage N3. In addition, the criterion by which sleep stages are classified has also been simplified (Silber et al., 2007).

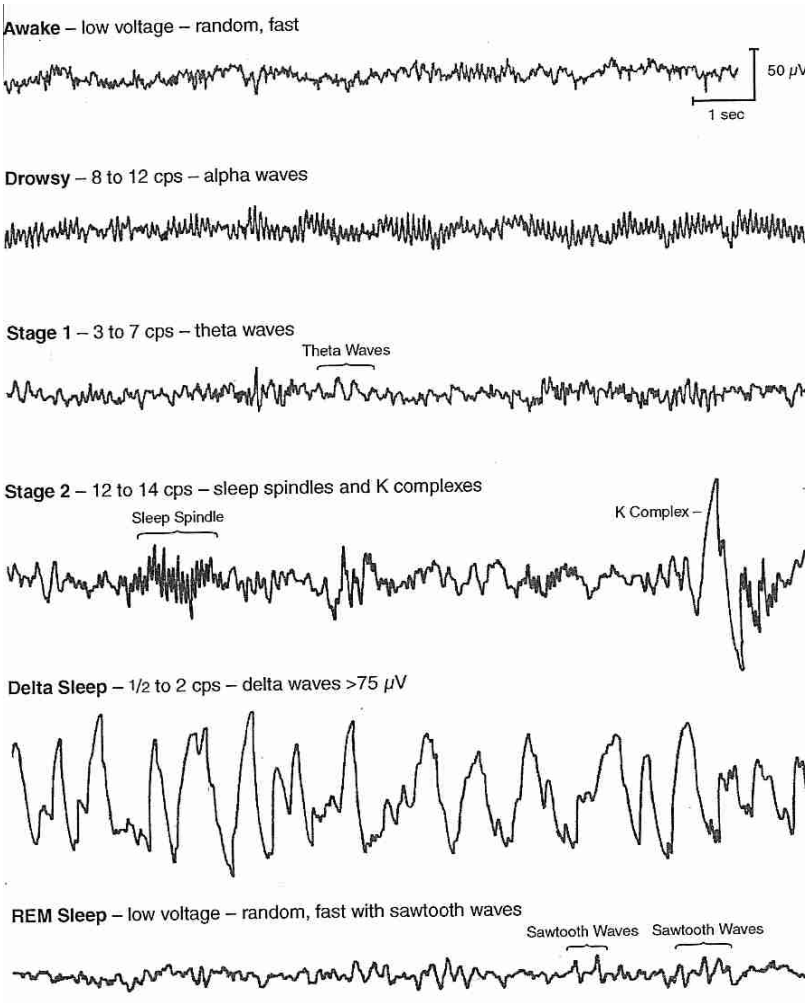



**Figure 1.3.** An illustration depicting the EEG waveforms for sleep, with typically observed waves during awake, drowsy, N1, N2, N3 and REM sleep. CPS depicts cycles per second. Amplitude measurements in microvolts.

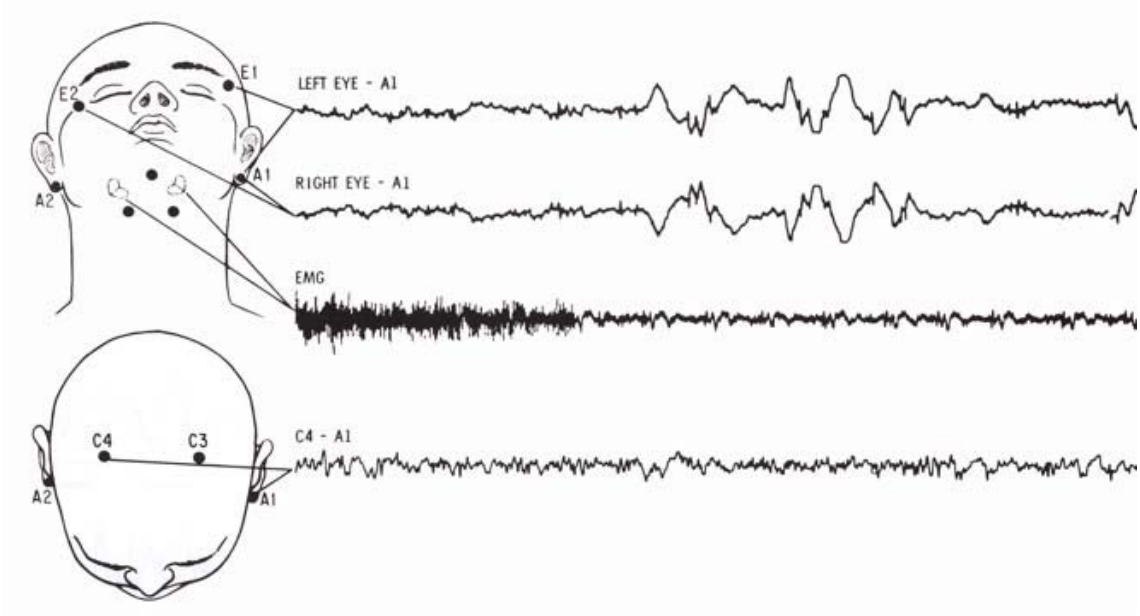



**Figure 1.4.** Illustration of electrode placements for the evaluation of sleep stages as recommended by Rechtschaffen and Kales (1968). *AASM criterion incorporates frontal and occipital channels additional to those shown.

### 1.3.3. Alternative Assessments of Sleep

In addition to the 'Gold Standard' measure of sleep using polysomnography, there are other ways of sleep detection that have their own advantages and disadvantages.

#### 1.3.3.1. Actigraphic Method

Actigraphy is a method used to study sleep-wake patterns and circadian rhythms by assessing wrist motor activity. This is usually packaged into a wristwatch like device with a piezoelectric accelerometer, band pass filters, timers, memory storage, battery and a connective interface such as USB. The movements the actigraph detects are continually recorded, with some units also measuring light exposure. The data allows an indirect assessment of sleep, through the usage of algorithms. These algorithms are automatic scoring methods developed to distinguish sleep from wakefulness (de Souza et al., 2003; Littner et al., 2003; Morgenthaler et al., 2007).

The usage of actigraphy is increasing in clinical research and in practice due to their low cost nature, and possibilities for long term study efficiency. The use of actigraphy has been rising, and is used frequently to study patients with chronic sleep disorders, both to determine circadian rhythm cycles or effects of treatments on sleep. Actigraphic algorithms in detecting sleep-wake status have been consistently shown to be a sensitive method, but in some cases demonstrate low specificity, at times overestimating sleep latency, total sleep time and sleep efficiency and underestimating the number of awakenings (de Souza et al., 2003; Marino et al., 2013).

The usage of PSG has been a gold-standard in determining sleep wake cycles, but also allows an in depth look at sleep stage variations and in some cases allow a more detailed analysis such as through the use of spectral analysis. However, PSG studies are costly to run, and challenging to conduct home studies where the environment is uncontrolled, additionally it is a time consuming process, not just with data collection but also with analysis and scoring of sleep stages. Moreover, long term studies are more difficult to implement and sometimes not viable. Actigraphy on the other hand is low cost, allows long term efficient monitoring of sleep and wake cycles and is simpler to implement and analyze. Both methods have their advantages and disadvantages, it would therefore be useful to implement both where possible; PSG for a more detailed analysis, and actigraphy for a general overview of a participant's sleep and wake cycle/rhythm.

The usage of actigraphy however is under researched in conditions other than sleep disorders. For example, in chronic pain, there are little well validated studies for using actigraphy in these patient populations.

### 1.3.4. Two Process Model of Sleep Regulation

A basic model of sleep regulation is the two-process model, which covers an interaction between the homeostatic (Process S) and circadian (Process C) processes that generate the timing of sleep and wakefulness. Process S is sleep/wake dependent, whereby it increases with increasing time of wakefulness and decreases when you are asleep; the level of Process S at sleep onset is thus a function of prior wake time. Process C on the other hand is independent of sleep and waking; it is governed by the biological clock regulating the timing in periods of sleep and wakefulness over a 24 hour period, thus sleep propensity is rhythmically varied during the circadian cycle (Borbély, 1982).

### 1.3.5. Sleep Dysfunction

#### 1.3.5.1. Insomnia

Insomnia is one of the most prevalent sleep and health complaint in the general population. Approximately 9% of people regularly suffer from insomnia, with 30% suffering occasionally (LeBlanc et al., 2009). In a review of epidemiology of sleep quality, it was concluded that insomnia can be defined in four ways (Ohayon, 2002).

1. Insomnia symptoms: subjective complaints of sleep onset or sleep maintenance difficulties, or early morning awakening (prevalence rates were highest when this definition was used, ranging from 30-48%)

2. Insomnia symptoms accompanied with daytime consequences (e.g. daytime fatigue, lack of concentration, memory lapses, decreased quality of life, decreased job performance and greater absenteeism from work). When using this definition, prevalence rates ranged from 9-15%.

3. Dissatisfaction (based on subjective reports) with sleep quality or quantity (prevalence rates ranged from 8-18%).

4. Insomnia diagnoses based on formal clinical diagnostic criteria such as that seen in the 1994 APA fourth edition of the 'Diagnostic and Statistical Manual of Mental Disorders' (DSM-IV) and the second edition of the 'International Classification of Sleep Disorders' (ICSD-2) published by the AASM in 2005. Prevalence rates were found to be much lower when such criteria was used – typically 6%.

There have been an abundant of research studies investigating the co-morbidity of chronic pain conditions with insomnia, and it appears to be a common occurrence in the general adult population; this has mainly been due to sleep dysfunction/disturbance as a result of chronic pain, and a large number of chronic pain sufferers are able to meet the diagnostic criterion for insomnia including FMS (e.g. Benca, Ancoli-Israel, & Moldofsky, 2004; Siu, Chan, Wong, & Wong, 2012; Wong & Fielding, 2012).

#### 1.3.5.2. Non Restorative Sleep

There has been a recent rise in interest in to the pathology of non-restorative sleep (NRS). NRS was first recognised as an insomnia symptom in the DSM-III-R in 1987 and describes sleep as being restless, light, or of poor quality regardless of the duration (Ohayon, 2005). NRS indeed lacks a standard, operational definition; a more refined definition explains it as reports of persistently feeling unrefreshed upon awakening in the presence of normal sleep duration, occurring in the absence of a sleep disorder (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008). Although not specific to FMS, it has been proposed that NRS has led to the aetiologies of chronic fatigue syndrome and fibromyalgia; this stems from the fact that NRS is common to these conditions (Gotts et al., 2013).

Due to individuals perceiving sleep as insufficiently refreshing, despite an appearance of normal sleep according to standard sleep assessment parameters, researchers have pursued alternative physiological markers of non-restorative sleep with inconclusive and sometimes controversial results (Wilkinson & Shapiro, 2012). The prevalence of NRS as a symptom varies between countries, however it is quite frequently

observed in the general population. Ohayon (2005) found 10.8% prevalence in seven European countries. In addition, a 1991 general social survey of approximately 12,000 Canadians found a high prevalence of insomnia (24%), with a high proportion reporting unrefreshing and non-restorative sleep (Sutton, Moldofsky, & Badley, 2001).

### 1.4. Medication and its Effects on Sleep Physiology

One of the key methodological challenges of studying sleep structure in chronic conditions like FMS is the likelihood that patients will be prescribed drugs which not only impact their condition, but also impact sleep. Various medications affect an individual's sleep physiology. Population groups such as those with chronic pain conditions (e.g. FMS or OA) are usually prescribed a myriad of medications for their primary symptoms or co-morbid disorders. Typical types of drugs prescribed for such individuals include anti-depressant medication of the serotonin reuptake inhibitor variety (SSRIs) and non-steroidal anti-inflammatory drugs (NSAIDS). Many SSRIs have been shown to affect sleep physiology. The SSRI 'citalopram' for example has been shown to alter several polysomnographic variables; these include a significant decrease in REM sleep, an increase in REM sleep latency and an increase in the percentage of Stage 2 sleep (Van Bemmel, Van Den Hoofdakker, Beersma, & Bouhuys, 1993). All types of anti-depressant drug therapies will affect sleep architecture which can be positive or negative. It is thus necessary to have wash-out periods of anti-depressants where possible.

In addition to SSRIs, non-steroidal anti-inflammatory drugs (NSAIDS) are primarily used for analgesic affects and in higher doses anti-inflammatory uses and so are relatively prevalent in patients with FMS or OA. Studies on the effects of NSAIDS on sleep have shown mixed results. Gengo (2006) looked at the use of Ibuprofen, on healthy adults. Polysomnographic and subjective measures were taken. It was found that a total daily dose of 1200mg did not produce clinically or statistically significant alterations in night time sleep in comparison to a control group who received a placebo (Gengo, 2006). In contrast, a similar study conducted looked at the effect of prostaglandin-inhibiting drugs on sleep. These included aspirin, acetaminophen or ibuprofen. In this case, in comparison to a placebo, both aspirin and ibuprofen were found to increase the number of awakenings, increase percentage time in wake, and decrease sleep efficiency. Ibuprofen also appeared to delay the onset of SWS. The NSAID acetaminophen however, did not differ significantly from the placebo (Murphy, Badia, Myers, Boecker, & Wright, 1994).

The mixed results from the use of NSAIDS in sleep disruption cause some concern. Caution should always be used when studying clinical populations such as these

and certain types of drugs must be taken into account when looking at outcomes of sleep pathology.

## 1.5. Chronic Pain and Sleep

There have been numerous studies into the effect chronic pain has on sleep physiology, daytime functioning and psychosocial variables. It has been well documented that sleep dysfunction is a highly prevalent symptom in differing chronic pain conditions, but how it actually affects sleep should be investigated further. Research that has looked into this area utilizes both subjective and physiological metrics (e.g. Smith & Haythornthwaite, 2004; Tang, Goodchild, Hester, & Salkovskis, 2012; Tang, Wright, & Salkovskis, 2007).

### 1.5.1. Fibromyalgia and Sleep Dysfunction

Sleep plays an important role in our lives and its interaction with chronic pain conditions is well documented; sleep disturbance is one of the most common complaints in patients suffering from chronic pain (Smith & Haythornthwaite, 2004). A major symptom reported by FMS sufferers is a dysfunctional sleep characterised by symptoms of insomnia (i.e. problems getting to sleep, problems staying asleep, unrefreshing sleep, and early morning awakening). These reports suggest that increases in sleep symptom severity can negatively impact pain experience in FMS (Bigatti et al., 2008). This novel approach to FMS has led to suggestions as to a reciprocal relationship between sleep disturbance and pain; pain disturbs sleep quality and poor sleep further exacerbates pain (Smith & Haythornthwaite, 2004). Sleep disturbance has recently been viewed as a more cardinal symptom of FMS than was previously thought with more than 90% of patients describing some form of impaired sleep quality (Moldofsky, 2008). A major and common sleep complaint in FMS is the apparent unrefreshing and fragmented sleep that patients experience which has been coined ‘non-restorative’ sleep (NRS). The consequences of NRS can lead to more debilitating daytime symptoms, such as an increase in the number of tender points, increased pain, fatigue (both mental and physical), sleepiness and negative mood (Wilkinson & Shapiro, 2012).

### 1.5.2. Non Restorative Sleep in FMS

It is not known whether non-restorative sleep in fibromyalgia is a primary or secondary phenomenon. One problem that has been highlighted numerous times in terms of FMS is whether the poor sleep they experience is a contributing factor to FMS or a consequence of the illness. A recent longitudinal study investigated the association between self-reported sleeping problems and the risk of FMS among adult women. 12, 350 adult

women from Norway were assessed at baseline (1984-1986) and again at follow-up (1995-1997). Incident FMS was reported by 327 (2.65%) women at follow up and a strong dose-dependent association was discovered between sleep problems and the risk of FMS; the association was found to be stronger (albeit not significant) in middle-aged and older women as opposed to younger women. Sleeping problems at baseline appeared to predict an increased risk of FMS in comparison to those that had never experienced sleeping problems (Mork & Nilsen, 2011). Although it cannot infer a cause and effect relationship, it does suggest sleeping problems early on, are fundamental to the development of FMS and not a consequence of the illness.

Many studies have investigated the nature and pathology of NRS using traditional sleep assessment parameters including polysomnography and actigraphy. Such measures have also been used to investigate sleep in FMS patients. Moldofsky and colleagues investigated the NREM sleep disturbances in FMS patients in relation to healthy subjects. They found a significant overnight increase in dolorimeter (pain threshold) scores of those with FMS with a coincidental NREM sleep disturbance. Moreover, a study of healthy subjects who underwent Stage 4 sleep deprivation was found to lead to temporary development of musculoskeletal and mood symptoms (Moldofsky, Scarisbrick, England, & Smythe, 1975). This highlights a possible link between NRS and daytime symptoms in FMS, in this case, of an increase in tenderness in the morning. In addition to this finding, a decrease in pain and fatigue has also been observed from mid-morning to mid-afternoon, during which time patients were described as hitting a cognitive 'brick wall' that is, reaching a point in the day where patients expressed an inability to think or concentrate properly (C-oté & Moldofsky, 1997). This shows NRS not only affects patients physically in terms of pain and tenderness, but there also appears to be an additional decline in cognition.

The general consensus is that a physiological sleep disturbance leads to complaints of NRS which in turn moderates/mediates daytime and cognitive impairment. For example, what is described as 'periodic limb movements in sleep' (PLMS), a phenomenon found most frequently in association with 'restless legs syndrome' (Hornyak, Feige, Riemann, & Voderholzer, 2006) is one of many comorbid disorders related to FMS. The wakeful symptoms of experiencing NRS include a sense of physical and mental fatigue, variable nonspecific bodily pain, and increased sensitivity to noxious stimuli, dysphoria and autonomic disturbances (Moldofsky, 2006). A study into cognitive performance in relation to daytime symptoms and sleep found that in comparison to asymptomatic controls, FMS patients had lower accuracy in cognitive tasks, greater sleepiness, fatigue, pain and negative mood. However on more complex tasks, they were

significantly slower in speed rather than impaired accuracy (C-oté & Moldofsky, 1997). This could possibly branch from a distraction due to the pain, but its findings are found to be inconclusive.

Rather than psychological distress, NRS has been found to correlate with the number of tender points and myalgia in FMS patients ( Yunus, Ahles, Aldag, & Masi, 1991); and on occasions when a patient achieved a restful night's sleep, there are significant improvements in daytime symptoms. This may emphasize the importance of focussing on improved management of sleep in order to better improve FMS symptoms including comorbid disorders.

### 1.5.3. Evidence from a Polysomnography Perspective

As discussed, there have been many attempts at observing NRS using various standard sleep measurement tools. Evidence in this area is contentious, however there have been several significant features observed using polysomnography.

The fundamental structure of sleep has been shown to be altered in FMS patients. Typically, FMS patients show an increase in Stage 1 sleep, a reduction in delta sleep (Slow-wave-sleep; Stage N3) and an increase in the number of arousals (Harding, 1998). A prominent feature that has evoked controversy is the alpha (α) EEG sleep anomaly; first described by Moldofsky *et al* (1975) and has been a recurrent finding, not just in FMS patients, but in those with other chronic pain or sleep disorders as well (e.g. Wittig, Zorick, Blumer, Heilbronn, & Roth, 1982). The alpha anomaly is found to occur in NREM sleep and has been described as large amplitude alpha waves in the frequency of 8-13 Hz superimposed onto delta (δ) waves. This type of alpha 'intrusion' is known as 'alpha-delta' (α-δ) sleep, a term first coined by Hauri and Hawkins (1973). The alpha wave anomaly was presumed to be a product of an internal arousal mechanism which in turn, disrupted the restorative functions of NREM sleep, leading to symptom manifestation and development (Moldofsky et al., 1975). Figure 1.5 illustrates an example of α-δ sleep in a 28 year old with FMS from C4-A1 and C3-A2 EEG derivations (Dauvilliers & Touchon, 2001).

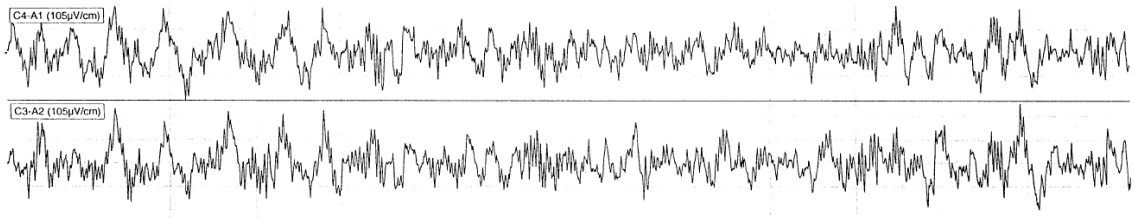



**Figure 1.5.** Example of alpha-delta sleep in a 28-year-old patient with FMS from C4-A1 and C3-A2 EEG derivations. Adapted from Dauvilliers & Touchon (2001).

Scrutinising the alpha EEG anomaly further, three distinct patterns were ascertained to be associated with it. These were described as phasic, tonic and low alpha. The phasic pattern was predominant in those with FMS, being found in 50% of FMS patients in comparison to only 7% of normal controls. The tonic pattern was found in 20% of FMS patients compared to 9% of controls, and low alpha in 30% of FMS patients compared to 84% of controls. The phasic pattern is expressed as alpha waves occurring simultaneously with delta waves; The tonic patterns are alpha waves occurring continuously throughout NREM stages of sleep; The low alpha patterns are generally low levels of alpha activity throughout NREM sleep. The phasic pattern of the alpha anomaly appears to be the strongest correlate of an increase in symptomology; these include the worsening of pain, increase in number of tender points and longer durations of pain post-sleep;

FMS patients generally exhibit less total sleep time, lower sleep efficiency and less slow-wave sleep (Roizenblatt, Moldofsky, Benedito-Silva, & Tufik, 2001). This study by Roizenblatt and colleagues, suggests that there are distinct patterns of the alpha anomaly in all FMS patients. However there appears to be a specific (phasic) type that predominates, which is linked to the most severe of clinical symptoms; it is interesting to note that this typing of alpha pattern as an 'intrusion' of alpha into delta wave sleep may have implications for NRS, as delta waves have been associated with restorative functions during sleep (e.g. Peigneux et al., 2004; Shapiro, Bortz, Mitchell, Bartel, & Jooste, 1981).

The localisation of alpha sleep generation has also been investigated using multichannel EEG or brain imaging techniques; the most prominent alpha during sleep is normally observed in the occipital region, however there has been documented alpha activity typings which differ in site generation, scalp distribution and behavioural correlates (Pivik & Harman, 1995). For example, a study looking specifically at the alpha rhythm used simultaneous EEG and fMRI to map MRI changes in the cortex in relation to a modulation of alpha activity. They found an increased alpha power in the thalamus and insula regions. The group were drawn toward the conclusion that the increased alpha power was related to an index of cortical inactivity (Goldman, Stern, Engel, & Cohen, 2002). An earlier study observed a frontal prevalence of 'alpha-like activity' in people with FMS; it was postulated that it may relate to a typing of 'kappa' activity (Horne & Shackell, 1991). Kappa type activity is usually observed in the 'theta' (4-7 Hz) or 'alpha' (8-13 Hz) range; it was previously thought to be an eyelid fluttering artefact usually observed in prefrontal leads that sit above the eye; it is now regarded as a form of mental activity e.g. (Glanzer, Chapman, Clark, & Bragdon, 1964). The 'alpha-like' activity in

the frontal regions of those with FMS could suggest a manner of mentation or rumination during sleep, which may lead or contribute to disturbed sleep;

Although the alpha-delta EEG anomaly is reported in several studies, the literature at present is still inconsistent in its findings and conclusions. There are some researchers who find alpha-delta occurrence in all the FMS patients they examined ( Branco, Atalaia, & Paiva, 1994), and some who found no difference between FMS and control subjects in terms of the alpha-delta anomaly (González et al., 2011). These differences can be explained via differing methodological employments, equipment and EEG or statistical analysis methods used; these factors also make comparisons across studies difficult. In addition, there is no standardization in the detection of the alpha-delta rhythm; various studies utilize different electrode montages, machinery, analysis methods and even in patient selection criteria.

Even though alpha-delta sleep is a highly likely contributor to sleep fragmentation and NRS in FMS, there are other features of the sleep EEG which may be related to sleep disturbance in FMS. Those with FMS may exhibit alterations in a variation of periodic arousal disturbance in their sleep EEG. The 'cyclic alternating pattern' (CAP; [Figure 1.6.]) is a periodic EEG activity of NREM sleep. CAP is characterized by "transient electro-cortical events distinct from background EEG activity and can recur up to 1 minute intervals" (Terzano et al., 2001); it may signify sleep instability, sleep disturbances or both. There are many documented varieties of CAP; the type that is found to be most associated with arousal disturbances in FMS is the periodic K-alpha Complex, figure 1.7. The periodic K-alpha occurs in two phases, the first phase (phase A) is a K-complex observed in stage N2, followed immediately by a burst of alpha activity lasting for less than five seconds; phase A is followed by a quiescent period of NREM sleep, the cycle is then repeated after 20-30 seconds (Terzano et al., 2001).

CAP sequences can be found to occur in all stages of NREM sleep, the CAP sequences commence typically at sleep-onset and at sleep recovery post-nocturnal-awakening. It has been found that almost 50% of all NREM sleep stage changes are accompanied by a CAP sequence; the CAP rate (CAP time/Total REM) in young adults was found to be around 23% with increases in age (Terzano, Parrino, & Spaggiari, 1988). A high prevalence of the periodic K-alpha CAP was found in FMS patients, with correlations to symptom severity (tender points) and decreases in sleep efficiency; in comparison to controls, FMS patients were found to be significantly less sleep efficient, had greater increase in N1 sleep and more than twice the number of arousals per hour (Rizzi et al., 2004). This may point to a new marker for sleep alteration in FMS patients.

Another interesting aspect of sleep EEG in FMS patients is in their spindle morphology. FMS patients tend to have a decrease in spindle activity, a marker for stage N2 onset; one study found women with FM pain have fewer sleep spindles and reduced EEG power in spindle activity in comparison to healthy sleepers (Landis, Lentz, Rothermel, Buchwald, & Shaver, 2004). This may be linked to the greater CAP rate observed in FMS patients, due in part to K-complexes not being followed by normal spindles, but rather by a burst of alpha activity; consequently, the spindle rate will decrease; however, this reported phenomenon should be scrutinised further.

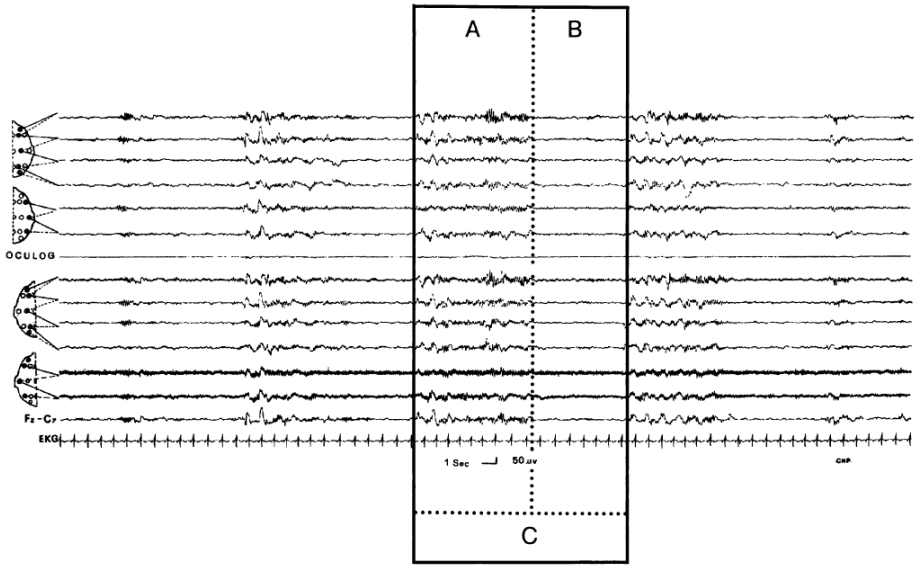



**Figure 1.6.** Example of cyclic alternating pattern in sleep stage 2. The box outlines the CAP, with phase A and phase B. Adapted from Terzano et al. (2001).

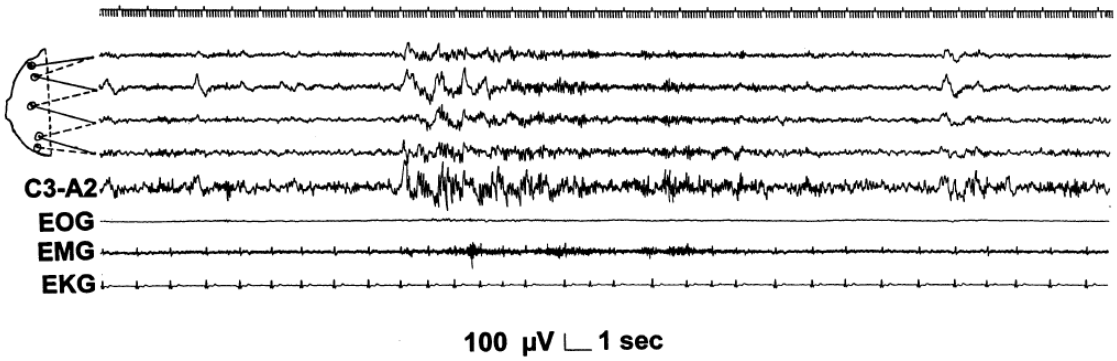



**Figure 1.7.** Example of K-alpha complex in stage 2 of sleep. Adapted from Terzano et al. (2001).

There has been some evidence to suggest a genetic link in FMS manifestation. Although FMS is most prevalent in adult populations, there are a portion of cases that occur in young people who are diagnosed with 'juvenile FMS' [JF] (Yunus & Masi, 1985). One investigation found a greater proportion of children who had JF had mothers who also had a diagnosis of FMS. In addition, they both exhibited alpha prominence

during SWS in comparison to asymptomatic controls, an example of the phasic pattern of alpha. However, the mothers had a greater level of subjective sleep complaints and a more noticeable polysomnographic anomaly than their child counterpart (Roizenblatt et al., 1997). This implies a familial link to FMS; this could be described via a genetic influence, environmental or psychological effects or even an interaction between these factors e.g. (Kashikar-Zuck et al., 2008).

### 1.6. Psychosocial Characteristics, Symptoms & Manifestations in FMS

Research has demonstrated that there are distinct psychosocial differences between those with FMS and normal healthy individuals. This distinct 'profile' may be a contributing factor to the manifestation or maintenance of FMS. For example, many cases of FMS have documented onset of symptoms after a traumatic event such as a non-injurious motor accident (Moldofsky et al., 1975). It has also been shown that FMS patients' psychological profile is somewhat distinct from those with other chronic conditions (Shuster, McCormack, Riddell, & Toplak, 2009). For example they may exhibit greater depression and anxiety and a greater external locus of control (Gustafsson & Gaston-Johansson, 1996; Kurtze, Gundersen, & Svebak, 1998). It must then be speculated that there are certain 'types' of individuals who are more at risk or prone to developing FMS than others. It is thus necessary when observing FMS patients that this is controlled and accounted for. In order to greater understand FMS pathology, it is essential to build a psychosocial profile of FMS patients in order to understand the effect differing dimensions of psychology may have on their symptom and syndrome development.

Depression and anxiety are two major comorbid disorders exhibited in FMS patients (Thieme et al., 2004). However, it must be noted that the cause and effect relationship between these factors and major FMS symptomology is unknown. These factors were found to be highly elevated in a study into psychiatric disorders in those with FMS (Epstein et al., 1999). In addition, those that took part in the study were found to have a high lifetime and current prevalence of major depression and panic disorders. Moreover, current anxiety was found to predict a proportion of variance in physical functioning (Epstein et al., 1999). The prevalence of depression comorbidity in FMS is found to be in the range of 28.6% and 70% across studies (Shuster et al., 2009). In addition, 30-40% of FMS patients have been found to suffer from depression, stress and anxiety. Moreover, both depression and anxiety have been found to be strongly related to the severity of FMS symptoms (Kurtze et al., 1998). In a study comparing FMS with pain controls, they looked into psychological distress and observed several measures including anxiety and depression; FMS patients were found to be more symptomatic on all

measures of psychological distress; those who scored above cut-off points for anxiety and depression had more physical symptoms and poorer function that those who scored below (White, Nielson, Harth, Ostbye, & Speechley, 2002). These findings highlight the importance of taking into account affective distress as an intervention consideration.

Aside from anxiety and depression, there are other psychological aspects of FMS to take into consideration. These include perceived social support, health locus of control, pain catastrophizing and personality dimensions. A study by Shuster and colleagues looked at the psychological profile of women with FMS. Their results showed that women with FMS had a higher external locus of control, lower levels of adaptive cognitive bias, less perceived family social support and lower mood in comparison to a control group (Shuster et al., 2009). In addition, many of these psychological dimensions appear to be linked to depression and anxiety. For example external health locus of control was significantly associated with ratings of both anxiety and depressed mood (Shuster et al., 2009). It was hypothesised in a study by Walteros and colleagues (2011) that chronic pain conditions such as FMS, were associated with deficits in decision making and associated learning. Those with FMS compared to a healthy control group had a poorer performance in both an emotional decision making task (Iowa Gambling Task) and a conditional associative learning task (CALT). In addition associated learning was shown to be mediated by depression, indicating that pain and depressive symptoms in FMS may lead to deficits in certain emotional cognitive tasks (Walteros et al., 2011).

Looking at social support, findings from a recent study of FMS patients found significant reductions in pain sensitivity and subjective pain ratings in the presence of their significant other compared to when they were alone (Montoya, Larbig, Braun, Preissl, & Birbaumer, 2004). In addition, comparative studies into those with FMS and those with other chronic rheumatic diseases found that FMS patients are more externally oriented in terms of health locus of control. Patients believed their symptoms depended on uncontrollable events and the disease could not be influenced by the individual (Gustafsson & Gaston-Johansson, 1996; Pastor et al., 1993). This indicates an aspect of cognition that is distinct in FMS patients rather than those with other rheumatic diseases. It may serve as a further contributing factor in FMS development and maintenance and should be observed with care.

Pain catastrophizing has also been found to be highly associated with increased pain and depression and greater disability (Carol S Burckhardt, Clark, O'Reilly, & Bennett, 1997). This finding was also found to be true once compared to a control group exhibiting similar symptoms to those with FMS, namely rheumatoid arthritis (Hassett,

Cone, Patella, & Sigal, 2000). Looking at factors of personality, FMS patients have been shown to score highly on the dimension of 'neuroticism' (Epstein et al., 1999), a term for 'emotional instability'. It has been suggested that FMS may be a manifestation of neuroticism, as high subjective pain sensitivity and low thresholds of pain perception are common features in both highly neurotic controls and highly neurotic FMS patients. The aspect of neuroticism is seemingly related to higher depression, anxiety and experience of stress in FMS and other pain conditions (Netter & Hennig, 1998).

Further to this, the processes of sleep disturbance may also be more intricately related to various psychological processes than first thought. A study by Hamilton et al. (2012), looked to test their 'Sleep and Pain Diathesis Model' (SPDM), the model predicts that sleep quality is related to fibromyalgia outcomes such as disability and depression and these relationships are mediated by both pain and emotional dysregulation. They administered a battery of questionnaires to 35 patients with FMS and found a greater report of sleep disruption that coincides with a greater report of 'psychological disability', which in turn was mediated by certain cognitive processes (Hamilton et al., 2012). This study has provided insight and links into how the effect of sleep disturbance, non-restorative sleep even, can affect psychological outcomes via mediation through cognitive processes such as pain helplessness and therefore pain itself. The various psychological factors (i.e. social support, health locus of control etc.) may thus be linked in more intricate ways than first thought and should be observed in more detail. Of course the study into the SPDM utilized a questionnaire based approach, so a possible limitation concerns the accuracy or objectivity of the sleep measures used.

In addition, there have been investigations into the potential associations between various types of trauma (emotional, physical and sexual) and fibromyalgia. A recent meta-analysis investigated this association and found significant associations between FMS and self-reported physical abuse in childhood and adulthood, and sexual abuse in childhood and adulthood (Häuser, Kosseva, Üceyler, Klose, & Sommer, 2011). However, these findings are inconclusive, with a meta-analysis the authors reported a poorer study quality, which were associated with higher effect sizes for sexual abuse in childhood. Additional exploration in this area of FMS should be explored further.

## 1.7. Summary

### 1.7.1. Present Study Aims and Hypotheses

After careful consideration of the literature, the review has detailed some unexplored areas in which an investigation is needed. Firstly, it is evident that those with FMS have

disturbed sleep, research has proposed a number of areas in which to explain their sleep disturbance. However, the EEG evidence is inconsistent in what it finds, especially with regards to the alpha wave anomaly. The main question that should be posed is whether disturbed sleep in terms of varying EEG phenomena, (alpha-delta sleep, periodic K-alpha, the amount of SWS and frontal alpha-like activity), is a result of the symptomology of FMS or whether it is fundamental to the development of the syndrome. Recent evidence has suggested the latter (i.e. Mork *et al*. in press), but the exact pathology of the sleep disturbance is still largely unknown. Secondly, FMS patients have been found to have psychological dimensions in certain extremes, it is wise thus to build a more robust psychological profile of such individuals, and control for such variables when looking at their sleep architecture. It is also important to investigate the significance of these factors in terms of mediation and moderation and how they relate to each other. It is therefore necessary to compare variables within FMS with a control group which does not have a diagnosis of FMS, but which does experience similar levels of musculoskeletal pain. Such a group could be selected from those with osteoarthritis, a patient population which also experiences sleep disruption/disturbance due to their chronic pain condition.

The present study will therefore utilize an observational comparative design, comparing FMS patients with those who have osteoarthritis (OA). In order to provide age and gender specific normative data for comparison, a third group of normal healthy controls (NHC) recruited locally from the general population will also be included. Because OA experience similar levels of chronic pain to those with FMS, and their sleep disturbance is largely due to chronic pain, the sleep disturbance, especially of non-restorative sleep, is less clear-cut in FMS and therefore utilizing OAs as a control group would be appropriate. As yet no study has both compared FMS patients with a comparator group experiencing similar levels of pain and explored or controlled for the influence of psychological attributes in FMS sleep studies.

### 1.7.2. Research Aims and Objectives

The aim is thus to combine actigraphy (as an objective measure), PSG and psychometric variables in a series of controlled analyses addressing the following key research questions:

1. When scored according to AASM criteria, does the polysomnographic sleep of FMS, OA, and healthy control participants show significant differences on measures of: total sleep time; sleep onset latency; sleep efficiency; wake after sleep onset; and the percentage of time spent in each stage of sleep?

2. Through spectral analysis, do FMS patients exhibit a significantly greater frequency and power of alpha-delta sleep than OA patients or healthy controls?

3. Through spectral analysis, do FMS patients exhibit significant differences in the microstructure of sleep across the standard frequency range for sleep PSG than OA patients or healthy controls?

4. Do FMS, OA, or healthy control participants show significant differences on objective (PSG and Actigraphy) and subjective (PSQI, ESS and FSS) measures of sleep disturbance and quality?

5. Do measures of total sleep time, sleep onset latency, wake after sleep onset and sleep efficiency correlate between polysomnography and actigraphy across the groups?

6. In comparisons of mean values, do FMS, OA and healthy control participants show differences on psychometric assessments of: pain, depression, anxiety, 'perceived social support', 'health locus of control', 'pain catastrophizing' and personality?

# 2. Methodology

In order to address the research objectives, set out in *Chapter 1*, a cross-sectional observational sleep study was designed to include polysomnography, actigraphy and self-assessment. The study comprised of three parallel groups:

1. A Fibromyalgia Syndrome (FMS) group, meeting diagnostic criteria for FMS and reporting significant sleep disturbance
2. An Osteoarthritis (OA) group, which was age-matched with the FMS group, and included participants who did not meet FMS criteria, but who experienced night-time chronic pain and significant sleep disturbance; and
3. An age-matched healthy control group which included participants who were generally healthy, and free of any chronic pain

Ethical approval for the study was provided by the NHS Research Ethics Service. The recruitment process and study procedures are fully described below. (Appendix A, NRES Committee North West – Greater Manchester East, REC 05/Q1402/50, 22-06-2011)

## 2.1. Participants

### 2.1.1. Power Calculation

Power for the study was calculated using the G*Power software (Faul, Erdfelder, Buchner, & Lang, 2009). The main outcome of the study is alpha power prevalence during slow wave sleep. Alpha power band dominance in FMS patients was obtained from the literature (Moldofsky et al., 1975), the within group standard deviation of alpha activity was 8.3%. If the difference between the FMS and OA control group means is 7.5%, a sample size of twenty participants per group will achieve 80% power confidence, at 5% significance level, in rejecting the null hypothesis.

### 2.1.2. Eligibility

Adult women aged 18 to 65 years of age were included in the study. All participants were female due to the high proportion (9:1) of females suffering from FMS. The full inclusion/exclusion criteria are presented below.

### 2.1.3. Participant Criteria

***Table 2.1. Inclusion criteria into the study for participants with Fibromyalgia (FMS), Osteoarthritis (OA) and Normal Healthy Controls (NHC)***

| Group | Inclusion Criteria |
|---|---|
| **FMS** | • Women aged between 18 and 65 years<br>• Newly diagnosed with at least six-month symptom prevalence<br>• Meeting the 1990 American College of Rheumatology criteria for FMS at the time of the study<br>• Experience sleep disturbance |
| **OA** | • Women aged between 18 and 65 years<br>• Current localized non-inflammatory joint pain with symptom prevalence of at least six-months<br>• Not meeting the 1990 American College of Rheumatology criteria for FMS at the time of the study<br>• Experiencing sleep disturbance due to pain as measured by the PSQI (score of >5) and a pain questionnaire |
| **NHC** | • Women aged between 18 and 65 years<br>• In current general good health |

***Table 2.2. Exclusion criteria for recruitment into the study with Fibromyalgia, Osteoarthritis and Normal Healthy Controls***

| Group | Exclusion Criteria |
|---|---|
| **FMS** | • Currently receiving hormone replacement therapy (HRT)<br>• Currently being prescribed psychotropic drugs, including:<br>  o Hypnotics<br>  o Tricyclic antidepressants<br>  o Other antidepressant drug therapy<br>• History of any form of severe psychiatric illness (schizophrenia, depression etc.)<br>• Currently/recently pregnant (12 months)<br>• History of medical conditions which could mimic FMS symptoms, including:<br>  o Morbid obesity<br>  o Autoimmune/inflammatory diseases<br>  o Cardiopulmonary disorders |
| **OA** | • Currently receiving hormone replacement therapy (HRT)<br>• Currently being prescribed psychotropic drugs, including:<br>  o Hypnotics<br>  o Tricyclic antidepressants<br>  o Other antidepressant drug therapy<br>• History of any form of severe psychiatric illness (schizophrenia, depression etc.)<br>• Currently/recently pregnant (12 months)<br>• History of medical conditions which could mimic FMS symptoms, including:<br>  o Morbid obesity<br>  o Autoimmune/inflammatory diseases<br>  o Cardiopulmonary disorders |
| **NHC** | • Currently suffer from conditions or disorders that could affect their sleep<br>• Currently exhibit chronic or acute pain.<br>• Currently on medication that could affect their sleep<br>• Currently receiving hormone replacement therapy (HRT) |

- Currently being prescribed psychotropic drugs, including:
  - Hypnotics
  - Tricyclic antidepressants
  - Other antidepressant drug therapy
- History of any form of severe psychiatric illness (schizophrenia, depression etc.)
- Currently/recently pregnant (12 months)

Participants who wished to take part in the study, but were taking hypnotic drugs were given the option of undertaking a wash-out period two weeks prior to the study; their condition was monitored closely by a consultant rheumatologist. If they were taking non-steroidal anti-inflammatory drugs, a three-day washout period prior to the study was offered, again with clinical monitoring provided by a consultant rheumatologist.

All participants completed a health screening questionnaire (Appendix B) prior to taking part in the study.

### 2.1.4. Participants

Nineteen newly diagnosed FMS patients ($M$=40.74, $SD$=11.45), seventeen patients exhibiting OA symptoms ($M$=46.47, $SD$=11.61), including localized joint pain and sleep disturbance, and ten healthy normal controls (HNC; $M$=38.40, $SD$=13.79) from the local population were recruited for the study. All participants were female. The purpose of recruiting a HNC group was to obtain a baseline measure for EEG, actigraphy and psychometric data; this allows for a better comparison of results across the clinical sample. Age was matched at a group level rather than at an individual level. The groups were broadly matched by looking at the means and standard deviations during the recruitment process. No participants were excluded due to age mismatch.

### 2.1.5. Recruitment

The clinical participants in the FMS and OA groups were recruited from a single *rheumatology facility* based at Trafford General Hospital, Trafford, UK. They were recruited from August 2011 to April 2014. FMS patients were recruited through regular outpatient clinics. OA patients were selected and recruited through orthopaedic waiting lists, these included those on the list for hip, knee, and shoulder related surgeries. Participants in the healthy control group were recruited by advertising (Appendix C) through local community organisations and local employers within the East Midlands and

Greater Manchester areas. The healthy control group were recruited from February 2012 to June 2014.

### 2.2. Use of NSAIDS (Non-Steroidal Anti-inflammatory Drugs)

There are many medications which are known to affect sleep pathology and these need to be taken into account when recruiting participants from clinical populations. Non-steroidal anti-inflammatory drugs (NSAIDS) such as Ibuprofen are primarily used for their analgesic effects and, in higher doses, for their anti-inflammatory effects. Since both effects are beneficial for those with painful inflammatory conditions, NSAIDS are widely used by patients with FMS or OA (Wolfe, Zhao, & Lane, 2000).

Studies on the effects of NSAIDS on sleep structure and quality report mixed results. Gengo (2006) looked at the use of ibuprofen on healthy adults. Polysomnographic and subjective measures were taken. It was found that a total daily dose of 1200mg did not produce clinically or statistically significant alterations in night time sleep in comparison to a control group who received a placebo (Gengo, 2006).

In contrast, a similar study on the effects of prostaglandin-inhibiting drugs on sleep including aspirin, acetaminophen and ibuprofen increased the number of awakenings, increased the percentage time in wake, and decreased sleep efficiency. Ibuprofen also appeared to delay the onset of SWS, though the effects of the NSAID acetaminophen on sleep did not differ significantly from the placebo group (Murphy et al., 1994).

Given that the FMS and OA groups in the present study were all diagnosed patients receiving medical care for their conditions, it would have been impractical to exclude patients prescribed NSAIDS. However, two factors supported the sometimes unavoidable use of NSAIDS. First, the available evidence is insufficient to suggest a robust detrimental effect on our sleep structure and quality; and second, the use of NSAID drugs was considered a random (possible) effect which, in the event, would still allow meaningful comparisons between the FMS, OA and NHC groups.

### 2.3. Materials

#### 2.3.1. Monitoring Equipment

##### 2.3.1.1. Polysomnography (PSG)

Digital PSG was conducted using the *Embla A10* (Figure 2.1.) unit ambulatory recorder and *Somnologica* software (Flaga-Medcare Somnologica 5.1®, Flaga hf medical devices, Reykjavik, Iceland). The device converts analogue electrophysiological signals into

machine readable digital formats; these are transmitted and recorded onto a PCMCIA memory card.

The recording montage consisted of a maximum of seven electrophysiological derivations for both nights of recordings. The basic montage included two electro-oculographic (EOG) channels referenced to the single mastoid (LOC/A1 & ROC/A1), two electroencephalographic (EEG) channels referenced to each mastoid (C3/A2 & C4/A1), a bipolar-mentalis electromyogram (EMG), a bipolar prefrontal EEG channel (Pf1/F3) and a bipolar occipital EEG channel (O1/P3). EEG and EMG channels were sampled at 200 Hz, EOG channels were sampled at 100 Hz. Electrodes were attached in accordance with the 10:20 system (Figure 2.2.) of electrode placement (Jasper, 1958);

In order to maintain amplifier inputs within a small voltage range relative to the amplifier's zero voltage level, a *ground* (pgnd) electrode was placed on the Fpz electrode site, 10% above the Nasion. The electrodes used for EEG recordings were AgAgCl (Silver-silver chloride) cup electrodes with a 10mm diameter and 1.5m leads. EOG, EMG and mastoid placements used disposable *wet-gel* electrodes with a 1m lead and standardized plug (Biosense Medical, UK).

The PSG system and montage outputs eight digital files in total that are loaded onto the *Somnologica* software for sleep scoring. Variables derived from PSG and their definitions are displayed in table 2.3. Variables were also derived from spectral analysis for the C3 channel that included the logarithmic average spectral power of sleep frequencies from delta up to gamma.

***Table 2.3. Polysomnography definitions for descriptive sleep variables***

| **Variable** | **Definition** |
|---|---|
| Time in Bed | From 'lights off' to 'lights on' as assessed via PSG events |
| Duration | Beginning of sleep period to end of sleep period |
| Sleep Onset Latency | Time (minutes) to reach the first occurrence of stage N2 sleep |
| Sleep Efficiency | Sleep efficiency referred to sleep period |
| Wake After Sleep Onset | Time (minutes) spent awake during sleep period |
| Total Sleep Time | Total amount of time spent sleeping |
| Awakenings | A duration of awakening during the sleep period that equates to 60 seconds or greater |
| Arousals | A duration of 3 seconds or longer where frequency band thresholds are exceeded<br><br>Thresholds used:<br>- Delta 0.5-4.0Hz<br>- Theta 4.0-8.0Hz<br>- Alpha 8.0-12.0Hz<br>- Sigma 12.0-16.0Hz<br>- Beta 16.0-20.0Hz |
| Stage N1% | Percentage of time (as a function of TST) spent in Stage N1 |
| Stage N2% | Percentage of time (as a function of TST) spent in Stage N2 |
| Stage N3% | Percentage of time (as a function of TST) spent in Stage N3 |
| Stage REM% | Percentage of time (as a function of TST) spent in Stage REM |
| Sleep Stage Transitions | The number of transitions into or out of a sleep stage during the sleep period |


**Figure 2.1.** Embla A10 unit (Flaga hf. Medical Devices, Reykjavik, Iceland**)** for ambulatory PSG monitoring

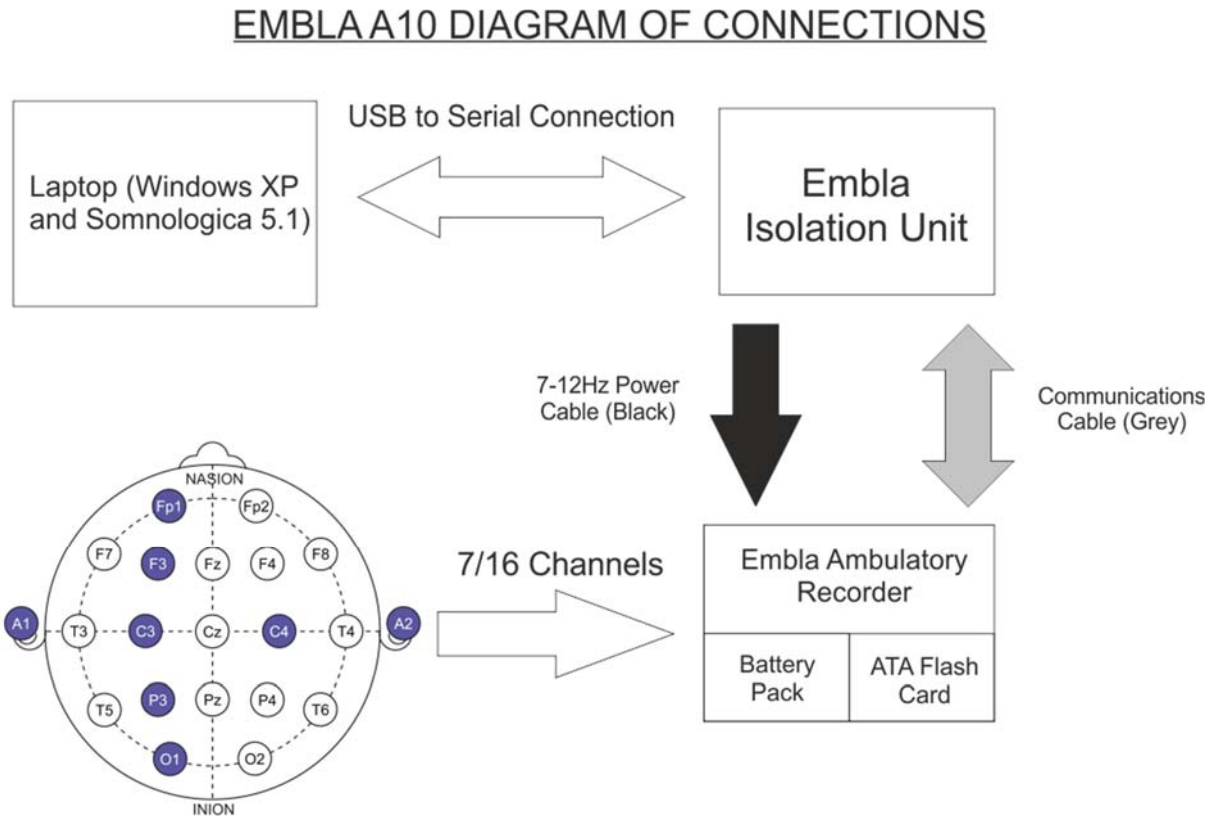



**Figure 2.2.** An illustration of the equipment setup protocol, and the EEG montage that was used. The montage displayed shows seven channels which are C3-A2, C4-A1, O1-P3, Fp1-F3, EOGL-A1, EOGL-A1 and Electromyogram-submentalis (SMG).

#### 2.3.1.2. Actigraphy

Actigraphy was recorded using *Actiwatch 2* (Figure 2.3.) devices in conjunction with *Respironics Actiware 6* software (Philips Respironics, USA). The actiwatch was set up to capture two consecutive weeks of data, with monitoring beginning on the first night of PSG. The devices were setup to record activity and photopic light data, at epochs of 30 seconds, for two weeks. Participants were also asked to complete a bed time diary during these two weeks, they were asked to complete the time they went to bed and the time they got up in the morning for each day; this data was used as a standardized way to calibrate the times on the *Actiwatch* device (Appendix D). For all variables obtained via actigraphy, the averaged data from the two-week recording were used. Photopic light data for this study was not utilised.

***Table 2.4. Actigraphic definitions for descriptive sleep variables as computed by Respironics Actiware 6***

| Variable | Definition |
|---|---|
| Duration/Time in Bed | Period from 'Lights Out' to 'Lights On' specified using a bed-time diary |
| Total Sleep Time | Total number of epochs (Minutes) scored as sleep during 'time in bed' |
| Sleep Efficiency | The percentage of time spent in bed sleeping as a function of total time in bed |
| WASO | The total number of epochs scored as wake after sleep onset |
| Sleep Onset Latency | Time required for sleep to start after initiating intent to sleep. Controlled by the sleep interval detection algorithm |
| Awakenings | Total number of continuous blocks of epochs where each epoch is scored as wake |


**Figure 2.3.** *Actiwatch 2* device by Phillips Respironics, USA. The device was setup to capture 14 days of data, monitoring activity and photopic light using the inbuilt accelerometer.

### 2.3.2. Descriptions and Properties of Psychometric Instruments

Two questionnaire sets were given to the participants to complete; the first set focussed on health status and symptomatology while the second set focussed on psychological factors. It must be noted that NHC participants completed identical questionnaires to the clinical groups, except for the Fibromyalgia Impact Questionnaire.

#### 2.3.2.1. Fibromyalgia Impact Questionnaire (FIQ)

The FIQ (Appendix E) is designed to measure components of health status that are most affected by FMS. It is composed of 10 items, with the first item comprising of 11 questions related to physical functioning, rated on a 4 point Likert type scale from *Always* to *Never* or *Not Applicable* (scored 0-3). Item 1 is scored by summing the items and dividing by the number of questions answered, as patients may not be able to answer some of them due to inapplicability; Items 2 and 3 (labelled 12 & 13) ask the patient to mark the number of days, out of a maximum of seven; that they felt good; and that they were unable to work because of fibromyalgia symptoms respectively. Items 2 and 3 are scored inversely, so a lower number indicates a greater disability. Lastly items 4 to 10 (labelled 14-20) are horizontal 100mm linear scales, marked in 10mm increments on which respondents can rate work difficulty, pain, fatigue, morning tiredness, stiffness, anxiety and depression (Burckhardt, Clark, & Bennett, 1991). The FIQ includes items from the *Arthritis Impact Measurement Scale* (AIMS) and the *Health Assessment Questionnaire* (HAQ). Each of the 10 items can achieve a maximum score of 10, thus the maximum score that can be obtained is 100, with higher scores indicating a greater FMS impact. A typical FMS patient will score around 50, severely affected patients usually score 70 or greater. The FIQ has been shown to have good construct validity, test-retest reliability and sensitivity to change (Bennett, 2005b).

#### 2.3.2.2. Pittsburgh Sleep Quality Index (PSQI)

The PSQI (Appendix E) is designed to assess sleep quality in clinical populations; it is a self-rated questionnaire assessing sleep quality and disturbances over the previous 1-month period. Items assess (and deliver *component* scores for) subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep-disturbances, use of sleeping medication and daytime dysfunction. It is also able to deliver a diagnostic sensitivity and specificity in differentiating between 'good' and 'poor' sleepers in the region of 90%, and was found to have good reliability and validity. The PSQI incorporates a global score, calculated from its component scores or subscales; the global score has a maximum possible score of 21; a general cut-off for the global score is 5, the lower the score is the better the overall quality of sleep (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989).

#### 2.3.2.3. Epworth Sleepiness Scale (ESS)

The ESS (Appendix E) is a measure of daytime sleepiness. Participants rate their chances of falling asleep (or *dozing off*) in eight different situations commonly encountered in daily life, such as when sitting and reading (Johns, 1991). For each of the eight situations, respondents provide ratings from 0 (*would never doze*) to 3 (*high chance of dozing*). The scale is scored by summing the values, thus there is a maximum possible score of 24. ESS scores 10 or more are considered sleepy; scores 18 or greater are indicative of a high level of daytime sleepiness (Johns, 1991); additionally, the ESS has been found to have a high level of internal consistency (Johns, 1992).

#### 2.3.2.4. Fatigue Severity Scale (FSS)

The FSS (Appendix E) is a self-rated questionnaire consisting of nine statements that rate the severity of fatigue symptoms during the past week. Statements are rated on a scale from 1-7 with the lower end in disagreement, increasing to the upper end in agreement. It was demonstrated to have good internal consistency, reliability and validity; The FSS is scored by summing up the raw scores; scores of 36 or more are used as a cut-off to determine fatigue severity, with a greater score indicating greater amounts of fatigue (Krupp, LaRocca, Muir-Nash, & Steinberg, 1989).

#### 2.3.2.5. Brief Pain Inventory Short Version (BPI-S)

The brief pain inventory (Appendix E) is used to assess intensity of pain and interference of pain in a patients' life. It also evaluates pain relief, quality and perception of the cause of pain; it was first developed to assess pain dimensions in cancer patients (Cleeland & Ryan, 1994); however it has also been shown to be a reliable tool in pain assessment in

non-cancer pain patients (Keller et al., 2004). The scale produces two sub-scales of pain severity and pain interference and both are assessed differently. Questions 3-6 are used as an assessment of pain severity and comprise of a 11 point Likert type scale that ranges from 'No Pain' (0) to 'pain as bad as you can imagine' (10). The score is calculated by averaging these four items, with a greater score indicating greater pain severity.

Item 9 of the BPI-S is used to measure how much pain has interfered with seven daily activities (labelled from A-G) in the past 24 hours. These are scored on 11 point Likert type scales from 'Does not interfere' (0) to 'Completely interferes' (10). This sub-scale is scored as a mean of the seven items, with a maximum score of 10 and a greater score indicating greater pain interference. The scale also comprises of a pain manikin for patients to indicate areas on the body in which they feel pain, this is useful as an extra tool to assess widespread versus localised pain (Keller et al., 2004)

The visual analogue scale for pain (under item 10 in our BPI-S) is a single item measure. It is a 10 point Likert type scale and was added as a simple supplementary assessment of pain severity (McCormack, Horne, & Sheather, 1988).

#### 2.3.2.6. National Institute of Health Restless Legs Screening Questionnaire (NIH-RLS)

The NIH screening questionnaire for RLS (Appendix E) is a four item diagnostic instrument. An individual is considered to have RLS if he/she answered 'yes' to the first three items; the fourth item considers the frequency of occurrence of RLS symptoms and assesses the severity of the RLS (Popat et al., 2010).

#### 2.3.2.7. Centre for Epidemiologic Studies Depression Scale (CES-D)

The CES-D (Appendix E) is a self-report scale designed to measure depressive symptoms in the general population. The items of the scale are symptoms of depression used in previously validated longer scales. The CES-D is a 20 item measure and rates the frequency participants have felt a certain way, from 'Rarely or none of the time (less than 1 day) to 'Most or all of the time (5-7 days). The final scores range from 0-60, high scores on the CES-D indicate high levels of distress. A score of 16 or greater suggests a clinically significant level of psychological distress; about 20% of the general population would be expected to score in this range. It is shown to have very high internal consistency and reliability, and is deemed suitable for epidemiological studies (Radloff, 1977).

#### 2.3.2.8. State and Trait Anxiety Inventory (Forms 1 and 2; STAI)

The STAI (Appendix E) was developed to provide a reliable assessment for state and trait anxiety in research and clinical practice. It consists of two 20-item scales, one measuring the emotional state of anxiety (Form 1) and another measuring the personality trait of anxiety (Form 2). Items are rated on a 4-point Likert type scale in response to self-reported feelings of anxiety 'right now, at this moment' and 'generally'. Scores in each scale range from 20-80, with higher scores suggesting greater levels of anxiety. Low scores tend to suggest mild anxiety, median scores moderate anxiety and high scores severe anxiety (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983).

#### 2.3.2.9. Multidimensional Scale of Perceived Social Support (MSPSS)

The MSPSS (Appendix E) is a validated 12-item instrument designed to assess perceptions about support from family, friends and significant others. The items are divided into factor groups related to the source of support, with scores ranging from 1 to 7. A total score is also calculated by averaging the ratings for all 12 items. Greater scores are indicative of higher levels of perceived social support (Zimet, Powell, Farley, Werkman, & Berkoff, 1990).

#### 2.3.2.10. Multidimensional Health Locus of Control Scale Form C (MHLOC)

MHLOC (Appendix E) was developed to assess health locus of control in the general population. It consists of three six-item subscales that measure internality, powerful others externality and chance externality. Form C however is designed to be condition specific and can be tailored to specific conditions such as *fibromyalgia* or *osteoarthritis*. Similar to forms A and B, it contains two six-item subscales measuring internality and chance externality, however the powerful others externality subscale is split into two three-item subscales (External Doctors & External Others). Each subscale item is rated from 1 'strongly disagree' to 6 'strongly agree', and the scores of each subscale are the sum of the rated items. For the 'internality' and 'chance' subscale, they give a possible score range from 6-36, with a higher score indicative of greater internality or greater chance externality. For the 'doctor' or 'other people' externality subscales, gives a possible score range from 3-18, again with a higher score indicating greater 'doctor' or 'other people' externality (Wallston, Stein, & Smith, 1994).

#### 2.3.2.11. Pain Catastrophizing Scale (PCS)

The PCS (Appendix E) was developed to assess three components of catastrophizing (rumination, magnification and helplessness) in a 13 item self-rated questionnaire. Each item is rated on a 5-point Likert type scale from 0 (not at all) to 4 (all the time). PCS total score is calculated by summing responses to all 13 items, the total score can range from 0-52; a greater score indicates a greater level of pain catastrophization; the PCS also incorporates three subscales, rumination (items 8-11), magnification (items 6, 7 & 13) and helplessness (items 1-5 & 12); these component scores are calculated by summing their respective items. (Sullivan, Bishop, & Pivik, 1995).

#### 2.3.2.12. Eysenck Personality Questionnaire (EPQ-R)

The EPQ-R (Appendix E) is a questionnaire designed to gauge four dimensions of personality; Psychoticism/socialisation, extraversion/introversion, neuroticism/stability and a fourth *Lie* scale. It consists of 106 *yes* or *no* questions that are scored using a specialised scoring tool; Each subscale are independent of each other and higher scores indicate greater comparative levels of psychoticism, extraversion, neuroticism or propensities to lie (Eysenck & Eysenck, 1977).

### 2.4. Procedure

Section 2.4.1. details flowcharts depicting the study sequence for each participant, from giving consent to study completion. There are separate diagrams for clinical patients and healthy controls.

#### 2.4.1. Clinical Patients

FMS and OA patients were recruited in and around the Greater Manchester area, either through direct referral from the *rheumatology outpatient clinic* (FMS) or through invitations sent to patients on the *orthopaedic surgery waiting list* (OA). Interested participants were sent full study details (Appendix F) to review, a researcher was contactable to answer any questions they may have had. Each participant was given a 24 hour 'cool-off' period after being given study information to consider taking part in the research.

Once the potential participant has expressed a wish to proceed with the study, they were mailed a health screening form (Appendix B) with a return envelope. The screening form was to ensure eligibility, and was reviewed by the researcher. These include calculating questionnaire scores for sleep quality, pain experience and general health condition to ensure eligibility was met on these criteria. Once the participant met

eligibility, the patients were seen by a consultant rheumatologist (*Trafford General Hospital*) prior to signing consent. For FMS patients, this was to ensure they met the ACR 1990 criteria for fibromyalgia, and for OA patients, to ensure they had localized chronic pain, in addition to understanding their medical history and what types of drug therapies these patients may be on. It was also explained to the patient that they may be asked to come off the medication they are on for the duration of the study period. Additionally, patients were assessed on whether they have any diagnosed sleep disorders (those with diagnosed sleep disorders, such as insomnia or sleep apnea were excluded), OSA was loosely assessed by evaluating whether they exhibited typical OSA characteristics (i.e. weight, age, self-report).

Once the patients were happy to take part and were accepted onto the study, the researcher went through the consent form (Appendix G) with them before signing. Two consecutive weeknights were scheduled by the researcher for the study to commence, this would be after taking into account any potential drug weaning off period.

On the first night visit, the researcher visited the patients home with a secondary aide (*rheumatology nurse*) to conduct the domiciliary PSG; the patients were asked to complete two sets of questionnaires (Appendix E) and begin wearing the actiwatch, which was setup to record activity for two consecutive weeks from 1900hrs. Prior to the PSG, the participants were asked to refrain from taking certain drugs/medication, drinking coffee or alcohol, and consuming nicotine during the evening of the recording. After attaching EEG, EOG and SMG channels, the participant was free to move around until bed time; participants were instructed to press an event button every time they get into and out of bed. The researcher attended each morning to remove the electrodes and setup the machine for the next evening where this process repeated.

Actiwatches and bed time diaries were collected 14 days after the first night of PSG, and the participants were verbally debriefed about the study. Each participant was given a full sleep report based on their PSG and Actigraphy.

### 2.4.2. Healthy Controls

Healthy control participants were recruited through advertisements (Appendix C) placed in newspapers and on public notice boards in and around the Leicestershire and Greater Manchester area.

Interested participants were sent a study information sheet and a health screening questionnaire (Appendix B). Once a participant returned the health screening questionnaire, the researcher assessed their suitability for the study before confirming with the participant their interest in taking part. Once the participants were happy to take

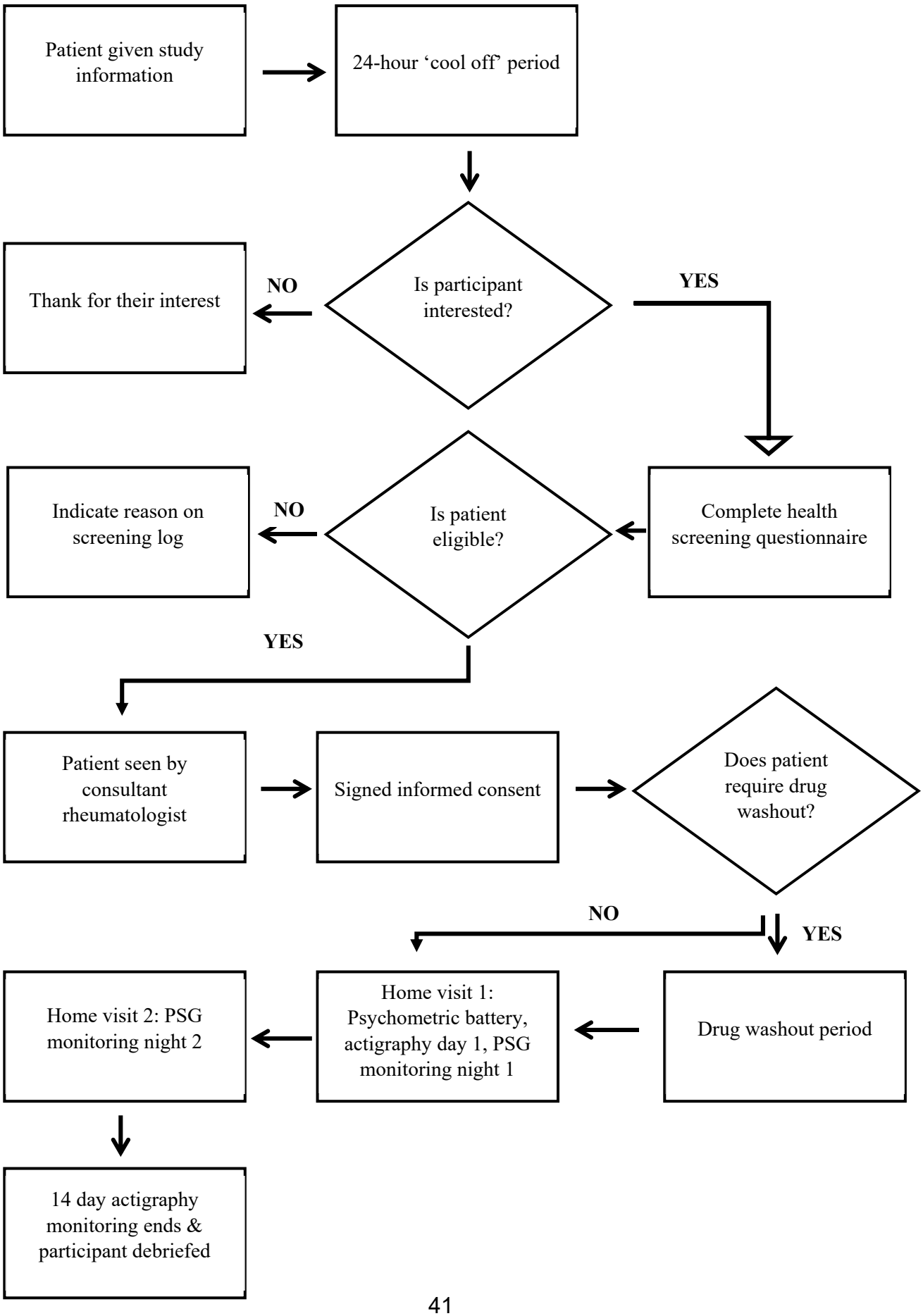
part and were accepted onto the study, the researcher went through the consent form (Appendix G) with them before signing. Two consecutive weeknights were scheduled by the researcher for the study to commence.

On the first night visit, the researcher visited the patients home with a secondary aide (*rheumatology nurse*/trained sleep researcher) to conduct the domiciliary PSG; the patients were asked to complete two sets of questionnaires (Appendix E) and begin wearing the actiwatch, which was setup to record activity for two consecutive weeks from 1900hrs. Prior to the PSG, the participants were asked to refrain from taking certain drugs/medication, drinking coffee or alcohol, and consuming nicotine during the evening of the recording. After attaching EEG, EOG and SMG channels, the participant was free to move around until bed time; participants were instructed to press an event button every time they get into and out of bed. The researcher attended each morning to remove the electrodes and setup the machine for the next evening where this process repeated.

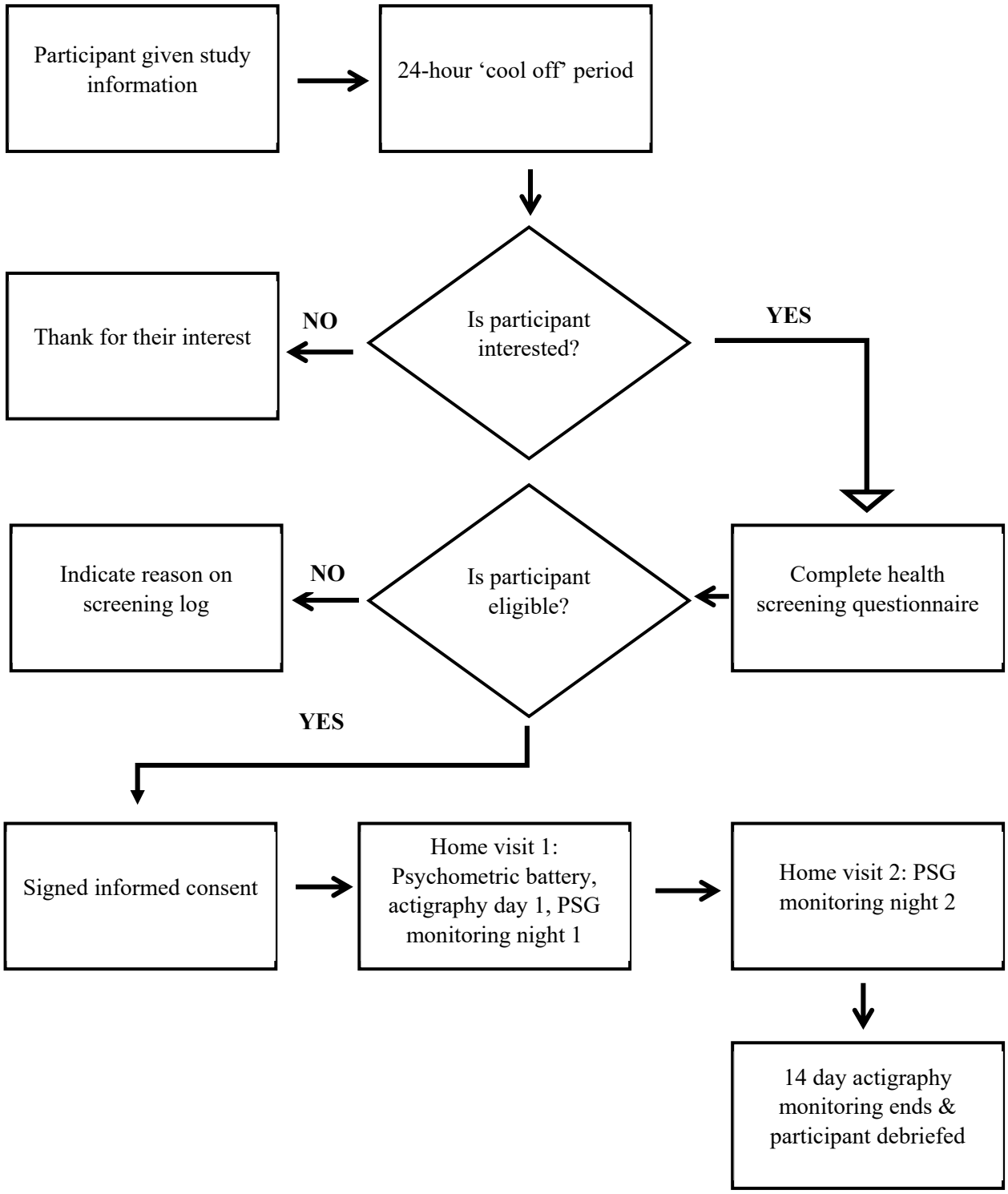
Actiwatches and bed time diaries were collected 14 days after the first night of PSG, and the participants were verbally debriefed about the study. Each participant was given a full sleep report based on their PSG and Actigraphy.

### 2.4.3. Data Collection Flow Charts

#### 2.4.3.1. Clinical Patients



**2.4.3.2. Healthy Controls**



## 2.5. Preparation of equipment for sleep recording

### 2.5.1. Polysomnography

The *Embla A10* unit utilises two lithium batteries. These were charged each night prior to the recording using standard Sony chargers. Each participant recording was setup using Somnologica and anonymised to a participant identification number. Sampling rates, gain factors and band pass filter settings were calibrated. The unit digitises data onto a PCMCIA memory card, which is inserted into the machine and connected to the battery pack. The machine is connected to a power isolation unit which feeds into the computer using a serial data connection (Figure 1.2.). Each night's recording was set to begin recording at 2000 hours and end the next morning at 0900 hours. The impedance of each channel was ascertained during the electrode wiring up process using a standard *Embla* model impedance meter. All channels were reduced to 10kΩs or less to decrease the risk of noise in the traces.

### 2.5.2. Actiwatch

Each actiwatch was charged the night prior to the first PSG recording using an *Actiwatch Docking Station* (Philips Respironics). Using the Actiware software, each participant recording was setup and anonymised according to the participant identification number. The devices were setup to record continuously 30 second epochs of activity and photopic light from 1900 hours on the first night for fourteen consecutive days.

## 2.6. Electrode attachment and removal

Electrode sites were measured using a tape measure according to the standardised 10-20 system of electrode placement (Jasper, 1958). Each site is marked with a *Chinagraph* pencil which is water soluble. A special abrasive paste (Lemonprep) was then used to gently clean the skin before EEG scalp electrodes were attached with EC2 (Grass Technologies) paste. The paste is designed to completely fill the cup of the electrode providing both adhesive and conductive properties. A square piece of gauze material is then placed over the electrode to secure it and finally a small piece of microporous tape to ensure the electrode does not become dislodged. Other electrodes including EOG, EMG, ground and Mastoid are attached by cleaning each area gently with the same light abrasive paste and attached using the adhesive gel on each 'wet-gel electrode'. These are then secured using a small piece of microporous tape. Inter-electrode impedance was reduced to 10kΩ, checked using an impedance meter.

The electrode leads were subsequently connected to the 'Embla A10' unit ready for recording. To prevent electrode wires from tangling during the night and for the comfort of the participant, all wires were secured using a protective sleeve. The *Embla* unit included a strap so that the participant can carry the machine around comfortably prior to sleeping.

The electrodes are removed by detaching the leads from the *Embla* unit and warm water applied to each electrode site, slowly peeling each electrode off the scalp and face.

## 2.7. Data Management

### 2.7.1. Polysomnography

The *Embla A10* (Flaga-Medcare Somnologica 5® software, Flaga hf medical devices, Reykjavik, Iceland) digitizes each channel/trace into a separate file. The file formats used are EBM for each channel used and EBE for event markers (e.g. event button presses). Each night's recording resulted in eight files in total (one EBE and seven EBM files). EEG and EOG traces were high pass filtered at 0.3 Hz and low pass filtered at 30 Hz. The EMG trace was high pass filtered at 10 Hz and low pass filtered at 70 Hz.

#### 2.7.1.1. Sleep Scoring

PSG sleep scoring was only performed for the second night of PSG monitoring. Each night of data was imported into Somnologica 5.1., each were viewed and scored on a computer monitor with a minimum resolution of 1600 x 1200 as per AASM recommendations. Each night was scored in 30-s epochs by a trained sleep researcher using the AASM criteria defined by Silber and colleagues (2007) (Silber et al., 2007). Arousals were computed automatically by the system; the sensitivity of detection was calibrated to be in accordance with AASM defined criteria; this is an abrupt shift in frequency lasting for at least 3 seconds with 10 seconds of stable sleep preceding. Arousals from 20% of participant recordings were scored visually to ensure reliability of the auto-scorer.

For concordance in sleep staging, each night of data was divided into quartiles; each quartile was subsequently divided equally into 15 minute segments; a random 15-minute segment from each quartile was then scored by an independent secondary rater. Inter-rater concordance was then calculated based on each 15-minute segment. All sleep recordings met the 83% concordance guideline (Rosenberg & Van Hout, 2013).

The beginning of sleep scoring was determined by 'lights out' time. This was achieved by an event button that the participant depressed when going to sleep and ends

when the button was depressed at wake time. This protocol was also used for the definition of the values of: sleep onset latency; wake after sleep onset; sleep efficiency; and total sleep time. For participants who failed/forgot to press the event marker button, values from their bedtime diary was used for *lights out* and *lights on*.

Sleep onset latency is defined as the period it takes from 'lights out' to the first two epochs of uninterrupted stage N2 sleep.

#### 2.7.1.2. Spindle Analysis

Analysis of spindle morphology was carried out by using spectral power density in the bands associated with spindle frequency (14-20Hz). Averaged spectral power has been shown to be the most robust method of analysing spindles as opposed to other methods (Knoblauch, Martens, Wirz-Justice, & Cajochen, 2003).

#### 2.7.1.3. Spectral Analysis

C3-A2, C4-A1, fp1-F3 and O1-P3 channels were available for spectral analysis, this was conducted using open source software written in the python programming language (avg_q, Feige). Sleep staging events from Somnologica were exported into a text file for each night of sleep; the RAW (ebm) EEG and event files were then imported into the avg_q software and processed. Spectral analysis was performed after demeaning, detrending and applying a Welch taper to each single FFT window. Each analysis window equates to 512 points (2.56 seconds) long, giving a frequency resolution of 1/2.56 = 0.39Hz. 23 overlapping windows cover each 30s epoch. An artefact rejection algorithm was also used to discard outlier epochs from the computation of average spectral power. Each frequency band (delta, theta, alpha, sigma, beta, and gamma) was decomposed and power averaged over the whole night of sleep. Frequency bands were also separated into sleep stages N2, N3 and REM and cycles per night (for cycle per cycle analysis). Sleep cycles are defined as the beginning of the REM period and ending when the subsequent REM period begins (thus naturally the first cycle of sleep will not include a REM period). Due to NREM sleep intruding into REM at particular time points, a NREM period of 15 minutes or greater must be present before that REM period should end (Merica & Gaillard, 1986). Following standard practice, the natural logarithmic transformations for all power bands were computed (log[e]^x where x is log of the value) in order to normalise (Gaussian) the distribution for multivariate analyses.

For the analysis, only the second night of PSG data was analysed. Additionally, the C3-A2 channel was selected for spectral analysis as it was deemed to produce the most robust signal, the traces were separated into frequency bins of Total (0.1-48Hz),

Delta-1 (0.1-1Hz), Delta-2 (1-3.5Hz), Theta (3.5-8Hz), Alpha (8-12Hz), Sigma-1 (12-14Hz), Sigma-2 (14-16Hz), Beta-1 (16-24Hz), Beta-2 (24-32Hz) and Gamma (32-48Hz).

For inferential analyses, non-parametric Kruskall Wallis rank test was employed to investigate group differences in each powerband, over the whole night and also during the first three cycles of sleep. To investigate specific group differences, multiple Mann-Whitney comparisons were used with Bonferroni corrections applied.

### 2.7.2. Actigraphy

*Actiware 6* software (Philips Respironics) was used to automatically calculate rest intervals. Total time in bed was determined by entering bed time and wake time from the sleep diaries.

### 2.7.3. Psychometrics

The questionnaires were scored in accordance with author instructions. Questionnaire data were analysed using IBM SPSS ver. 22**.**

## 2.8. Data Analyses

All data were entered into IBM SPSS ver. 22. All variables underwent a standard data cleaning procedure to ensure variables were of the correct range and entered correctly into the dataset. All data were deemed to have been entered correctly at the time of analysis.

### 2.8.1. Missing Data

Pattern analysis was applied to all outcome variables and cases to explore possible areas of missing data (250 variables in total). The analysis indicated that 24.50% of variables, 19.57% of cases and 0.794% of values either contained missing data or are missing (figure 2.4). The data appeared to show no distinct pattern of missing data (figure 2.5), thus the values were deemed missing completely at random with no monotonicity observed. Additionally, the most common pattern indicated no missing data (figure 2.6).

Due to the data showing no observation of monotonicity and data missing at random, in addition, the missing values were at less than 1% it was deemed not necessary to employ replacement methods such as imputation; the missing values have a low probability of affecting the final outcome. Moreover, the missing values/variables did not constitute a part of the main outcome set. Figures 2.4-2.6 illustrate summaries of missing values.

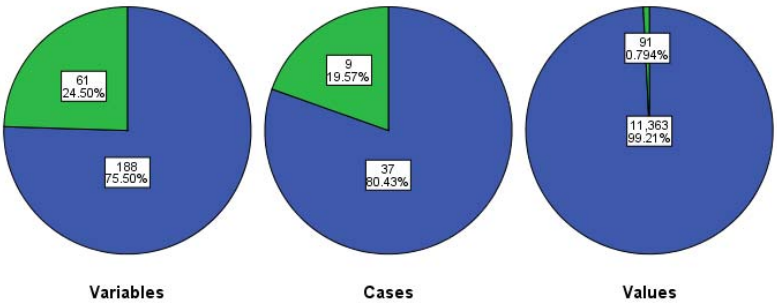



**Figure 2.4. S**ummary of missing variables sorted by variables missing, cases missing and values missing. The green shade depicts percentage missing.

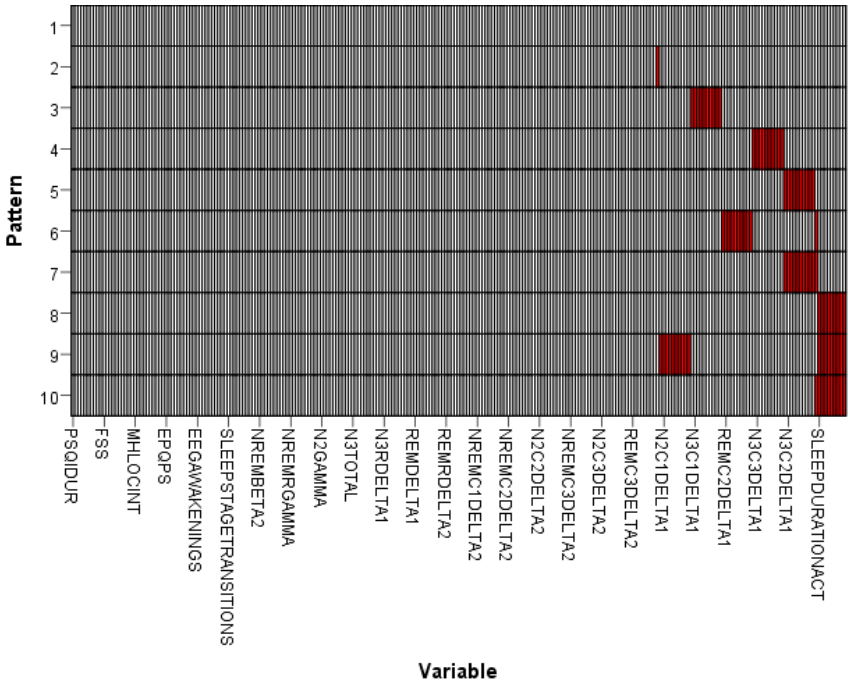



**Figure 2.5.** Missing pattern chart, with Y axis indicating the pattern, and X axis indicating the variable. The red blocks indicate missing data, and the white indicate not missing. This chart shows no distinct pattern to the missing data and no monotonicity.

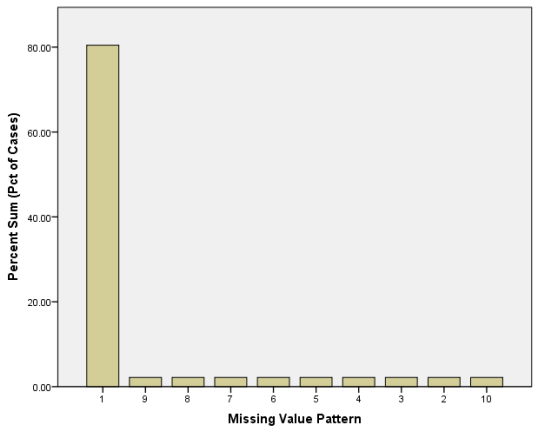



**Figure 2.6.** Histogram showing the most common pattern of missing data, with the Y axis indicating percentage of cases following each pattern along the X axis. The most common pattern is no missing data (1).

### 2.8.2. Outliers

Potential outliers in the data were checked using the 'outlier labelling rule' as identified by Tukey (Tukey, 1977). The rule is based on taking the difference between the 25$^{th}$ and 75$^{th}$ percentile of values for each variable and multiplying by a factor of 2.2 (Hoaglin & Iglewicz, 1987). The result is either added to the 75$^{th}$ percentile value or removed from the 25$^{th}$ percentile value. The resulting upper and lower bound values can be used to explore potential values that fall outside this range and therefore determine whether outliers are present.

There were no distinct outliers found that would affect the final outcome of the analyses, thus all values were included in the final analysis.

### 2.8.3. Statistical Analysis

Inferential statistics were used to compare mean differences between FMS, OA and NHC participants in order to answer the research questions. All assumptions of data were checked for each inferential statistic used. These are described in more detail throughout each results chapter.

#### 2.8.3.1. Data Assumptions

All dependent variables analysed are assumed to be at the interval level. They are also assumed to be of a normal distribution. To test for normality, Z scores were calculated to determine if the data are skewed or kurtotic, this was conducted by dividing the skewness and kurtosis by their respective standard errors; if the Z score is greater than ±1.96 it would be deemed non-normal. Although analysis of variance (ANOVA) is relatively robust to non-normal distributions, certain situations such as platykurtosis may negatively affect the outcome and inflate the Type I error rate significantly. In situations such as this, log transformations were attempted to normalise the data.

In situations where transformations are not practical (e.g. for the spectral analysis data), non-parametric tests were used instead (e.g. Kruskall-Wallis; Mann-Whitney) to compare the groups. Alpha is set at 5%, in cases where multiple comparisons are made, a Bonferroni correction was applied to the alpha level.

Homogeneity of variance was ascertained using the Levene's F test. For situations where unequal variances were found, the Welch's F statistic was used instead, omitting the need for equal variances, additionally, post-hoc comparisons were conducted with a Games-Howell correction for multiple comparisons. Partial Eta squared expresses the

amount of variance that is accounted for by each specific variable; it is used as an effect size index in all parametric multivariate analyses.

# 3. Results I: Descriptive and Demographic Data

## 3.1. Participants

A total of 20 FMS patients were approached for the study, one FMS patient was excluded as they displayed atypical FMS characteristics. 19 FMS participants were recruited into the study; all met the ACR 1990 criteria for fibromyalgia (general widespread pain, and 11/18 tender points), and ages ranged from 19 to 58. The total FIQ score indicated that the FMS impact on their day to day functioning was moderate to severe (*M*=65.91, *SD*=16.03). FMS patients were newly diagnosed (*mean*=5 months; range=3-12 months) with a symptom prevalence of 6.4 years. None of the FMS patients were taking NSAIDS and one patient was required to have a two-week drug washout.

A total of 54 OA patients showed interest, 16 dropped out/failed to respond, and 21 were excluded due to ineligibility. 17 patients with OA were recruited into the study. Their age ranged from 19 to 63, these patients were on a waiting list for various orthopaedic surgeries including knee, hip and shoulder operations. OA patients were diagnosed using radiography by orthopaedic surgeons at Trafford General Hospital. OA diagnosis was within a 1-year time period (*mean*=6.53 months; range=4-11 months). None of the OA patients were taking NSAIDS and none were required to have a drug washout period.

Ten healthy controls were recruited into the study to act as a baseline measure. Their age ranged from 23 to 61, they were recruited from the community in and around the Leicestershire, and Greater Manchester areas. All participants met the inclusion criteria for the study.

### 3.1.1. Participant Characteristics

***Table 3.1. Demographic characteristics of fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS** *M ± SD (n)* | **OA** *M ± SD (n)* | **NHC** *M ± SD (n)* |
|---|---|---|---|
| **Age** | 40.74 ± 11.45 (19) | 46.47 ± 11.61 (17) | 38.40 ± 13.79 (10) |
| **BMI** | 26.72 ± 6.93 (15)* | 30.20 ± 5.12 (17)** | 23.04 ± 2.73 (10) |

*Missing data; ** OA significantly greater BMI than NHC, p<.01; FMS, fibromyalgia syndrome; OA, osteoarthritis; NHC, normal healthy controls.

There are no significant differences between the groups in terms of age (p=n.s.). However, patients with osteoarthritis had a significantly greater BMI than normal healthy controls (p=.008).

Table 3.2 displays percentages on marital status, ethnicity, employment and education for the three participant groups. These give a general overview of the groups. As the values were not imperative for the study, no further statistical analyses were conducted for this. It may be of worth to note that the majority of the participants were of Caucasian ethnicity. In addition, the majority of the healthy control group come from an educated background as opposed to the clinical groups. It should also be noted that shift workers were only in the FMS group, however there should be no difficult implications, as participants were monitored on consecutive days in which they were not working, although there should be some caution when approaching the results.

***Table 3.2. Demographic percentages in participants with fibromyalgia, osteoarthritis and normal healthy controls***

| | FMS (n=19) | OA (n=17) | NHC (n=10) |
|---|---|---|---|
| ***Marital Status (%)*** | | | |
| Single | 21.1 | 29.4 | 20 |
| Married | 42.1 | 47.1 | 40 |
| Cohabiting | 15.8 | 5.9 | 30 |
| Separated | 10.5 | 11.8 | 0 |
| Divorced | 10.5 | 11.8 | 10 |
| Widowed | 0 | 5.9 | 0 |
| ***Ethnicity (%)*** | | | |
| Caucasian | 89.5 | 94.1 | 60 |
| Chinese | 0 | 0 | 20 |
| Black | 5.3 | 0 | 0 |
| Asian | 5.3 | 0 | 20 |
| Mixed | 0 | 5.9 | 0 |
| ***Employment (%)*** | | | |
| Day Time Work | 42.1 | 41.2 | 70 |
| Shift Work Inc. Nights | 15.8 | 0 | 0 |
| Shift Work Day | 0 | 29.4 | 10 |
| Unemployed/Retired | 42.1 | 29.4 | 20 |
| ***Education (%)*** | | | |
| No Formal Qualification | 21.1 | 11.8 | 0 |
| Degree | 26.3 | 17.6 | 20 |
| O-Level or GCSE Equiv. | 26.3 | 35.3 | 10 |
| Postgrad | 5.3 | 11.8 | 40 |
| As/A Level | 15.8 | 11.8 | 20 |
| Vocational | 5.3 | 11.8 | 10 |

### 3.2. Pain Scores

Pain was assessed using the Brief Pain Inventory and a 10-point visual analogue scale; their means and standard deviations are displayed in table 3.3. One-way independent analysis of variance was conducted on all three variables of pain severity, pain interference and on the visual analogue scale. The results of the ANOVAs are displayed in table 3.3. In some cases, where homogeneity of variance was not met, a Welch's *F* test was used instead, this is denoted in table 3.3.

For the Brief Pain Index's subscale of pain severity, normality was checked for each group looking at the skewness and kurtosis in the scores. To determine normality, either skewness or kurtosis scores were divided by its standard error, if the result is greater

than ±1.96, it would be deemed non-normal. Fibromyalgia (Skew=1.74; Kurt=0.17) and osteoarthritis (Skew=0.64; Kurt=-0.70) groups were deemed to be normally distributed, however NHCs were found to be positively skewed (4.60) and leptokurtotic (7.50). As the analysis of variance is relatively robust to non-normal distributions, it was not deemed necessary for data transformations. In this case, Levene's F test for homogeneity of variance was not met ($F$=7.28, p=.002), thus the Welch's F statistic was used instead. Table 3.3 displays the result of the test, a significant difference between the three groups was found (p<.001).

Post-hoc comparisons were conducted using the Games-Howell to correct for multiple comparisons, for a more reserved analysis from use of the Welch's F. FMS and OA groups were found to be significantly different to NHC with a mean difference of 6.07 and 4.83 respectively (p<.001). Comparisons between FMS and OA were found to not be significantly different (p=n.s.). Our clinical groups were thus shown to have similar levels of pain severity.

For the second subscale of the BPI (pain interference), FMS (Skew=0.21; Kurt=-0.41) and OA (Skew=0.35; Kurt=-0.35) were normally distributed, NHC were again found to be positively skewed (4.60) and leptokurtic (7.50). Unequal variances were also assumed in this case due to significant difference in variance between means ($F$=8.09, p=.001), thus Welch's F was used. An overall significant difference was observed within the groups (p<.001). Post-hoc analysis using Games-Howell correction found a significant difference between the clinical groups and the healthy control group with a mean difference of 6.29 and 4.53 for FMS and OA respectively (p<.001). There were no differences observed between FMS and OA (p=n.s.), implying similar levels of pain interference for both groups.

The 10-point visual analogue scale for pain indicated normality for FMS (Skew=0.12; Kurt=-1.08) and OA (Skew=-0.56; Kurt=-0.89), but positive skew (4.60) and leptokurtic (7.50) for NHC. Levene's indicated unequal variances ($F$=11.31, p<.001), thus Welch's F was used. An overall significant difference was observed (p<.001). Post-hoc comparisons with Games-Howell correction found a significant difference between the clinical groups and NHC group with mean differences of 7.46 and 5.93 for FMS and OA respectively (p<.001). No difference was observed between FMS and OA (p=n.s.).

Overall, pain measures have suggested that our clinical groups are statistically equal in terms of pain severity, pain interference and on a 10-point visual analogue scale. In turn, they are all significantly different to our pain free NHC group. However, the means

displayed in table 3.3. Show a trend of FMS participants exhibiting a greater pain experience followed by OA and lastly NHC. Figure 3.1. Highlights the differences in pain experience visually. Appendix H shows the pain manikins provided by the BPI for our three groups; with FMS showing widespread pain, OA localised pain and NHC showing no pain.

***Table 3.3. Pain characteristics of fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS** *M* ± *SD (n)* | **OA** *M* ± *SD (n)* | **NHC** *M* ± *SD (n)* | ***F*** | ***df*** | ***p*** | $\eta_p^2$ |
|---|---|---|---|---|---|---|---|
| **BPI-S**[1] | 6.17 ± 1.75 (19) | 4.93 ± 2.01 (17) | 0.10 ± 0.32 (10) | 144.098† | 2, 24.62 | .000*** | .674 |
| **BPI-I**[2] | 6.30 ± 2.04 (19) | 4.55 ± 2.43 (17) | 0.01 ± 0.04 (10) | 116.103† | 2, 22.62 | .000*** | .606 |
| **VAS**[3] | 7.56 ± 1.74 (16)* | 6.03 ± 2.85 (17) | 0.10 ± 0.32 (10) | 166.268† | 2, 22.06 | .000*** | .672 |

1. Brief Pain Inventory – Pain Severity, 2. Brief Pain Inventory – Pain Interference, 3. Visual Analogue Scale for Pain; *N=16 due to missing data; ***p<.001; † - Welch's F Statistic;

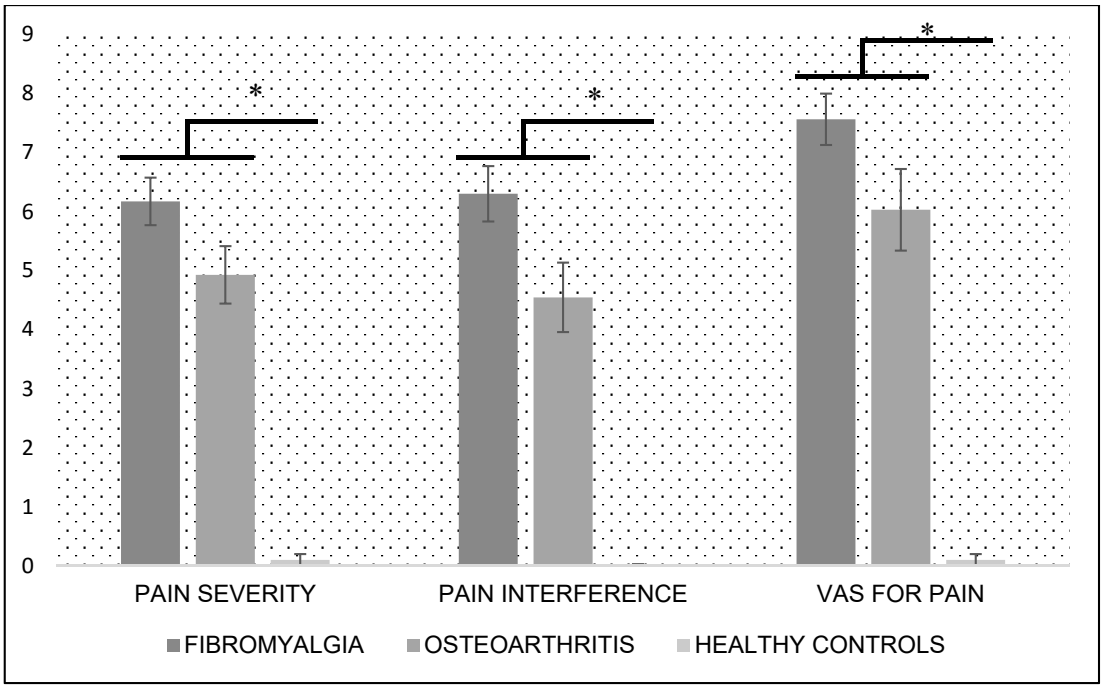



**Figure 3.1.** Bar chart comparing pain scores in fibromyalgia, osteoarthritis and healthy control participants. The Y-axis depicts the mean scores in visual analogue scale, pain interference and pain severity. Standard error bars are shown for each group. *$p$<.001

### 3.3. Subjective Sleep Characteristics

Sleep characteristics were measured using the PSQI, ESS and FSS, measuring subjective sleep quality, sleepiness and fatigue, three of the most common sleep complaints in patients with FMS. Table 3.4. Displays the means and standard deviations of these variables in all three groups. One way independent ANOVAs were conducted to investigate group differences in these three variables.

Sleep quality was measured using the PSQI, table 3.4 displays the global sleep score produced with the PSQI. A higher score indicates poorer sleep quality, and a score greater than five, an indicator for clinical sleep dysfunction. Normality tests indicated that FMS (Skew=-1.06; Kurt=0.34), OA (Skew=0.04; Kurt=-1.26) and NHC (Skew=-0.50; Kurt=-0.92) were normally distributed. Levene's test indicated unequal variances between means ($F$=4.87, p=.012), thus a Welch's F was used for inferential analysis (Table 3.4.). An overall significant effect was found (p<.001). Post-hoc analysis with a Games-Howell correction observed a significant difference between the clinical groups and the healthy control group, with mean differences of 10.19 and 7.18 for FMS and OA respectively (p<.001). Between FMS and OA, a significant difference was observed with a mean difference of 3.01 (p=.023).

Sleepiness was measured using the Epworth Sleepiness Scale. Tests for normality indicated FMS (Skew=-0.38; Kurt=0.11), OA (Skew=1.47; Kurt=-0.74) and NHC (Skew=1.25; Kurt=0.45) were normally distributed. Levene's test for equality of variance indicated that the means were of equal variances ($F$=.507, p>.05). One-way ANOVA showed an overall significant main effect (p=.011). Post-hoc comparisons with a Bonferroni correction applied found that FMS had a significantly greater sleepiness score than both OA and NHC participants with mean difference of 3.42 (p=.033) and 3.99 (p=.034) respectively. No difference was observed between OA and NHC (p=n.s.).

Fatigue was assessed using the Fatigue Severity Scale. FMS (Skew=-1.24; Kurt=1.02), OA (Skew=0.98; Kurt=0.07) and NHC (Skew=0.85; Kurt=0.16) were shown to be normally distributed. Levene's test indicated equal variances between the groups ($F$=1.569, p>.05). One-way ANOVA showed a significant main effect (p<.001). Post-hoc comparisons with a Bonferroni correction applied found that FMS participants had significantly greater fatigue than OA (*M diff*=14.41, p<.001) and NHC (*M diff*=29.87, p<.001); in turn, OA also exhibited significantly greater fatigue than the NHC group (*M diff*=15.46, p<.001).

Measures of sleep characteristics in these three groups have presented a consistent trend in the means, of the greatest score achieved by FMS participants, followed by OA, and then NHC. Inferential analyses also indicated consistently that the FMS group have significantly worse sleep quality, greater sleepiness, and greater fatigue than the NHC and OA groups.

***Table 3.4. Subjective sleep characteristics of fibromyalgia, osteoarthritis and healthy control participants.***

| | **FMS** *M* ± *SD* *(19)* | **OA** *M* ± *SD (17)* | **NHC** *M* ± *SD* *(10)* | ***F*** | ***df*** | ***p*** | **$\eta^2$** |
|---|---|---|---|---|---|---|---|
| **PSQI**[1] | 13.89 ± 3.40 | 10.88 ± 3.08 | 3.70 ± 1.16 | 89.225† | 2, 28.15 | .000*** | .648 |
| **ESS**[2] | 9.89 ± 4.54 | 6.47 ± 3.20 | 5.90 ± 3.45 | 4.998 | 2, 43 | .011* | .189 |
| **FSS**[3] | 52.47 ± 6.74 | 38.06 ± 10.57 | 22.60 ± 10.91 | 35.238 | 2, 43 | .000*** | .621 |

1. Pittsburgh Sleep Quality Index Global Score, 2. Epworth Sleepiness Scale, 3. Fatigue Severity Scale; ***p<.001, *p<.05; † Welch's F Statistic;

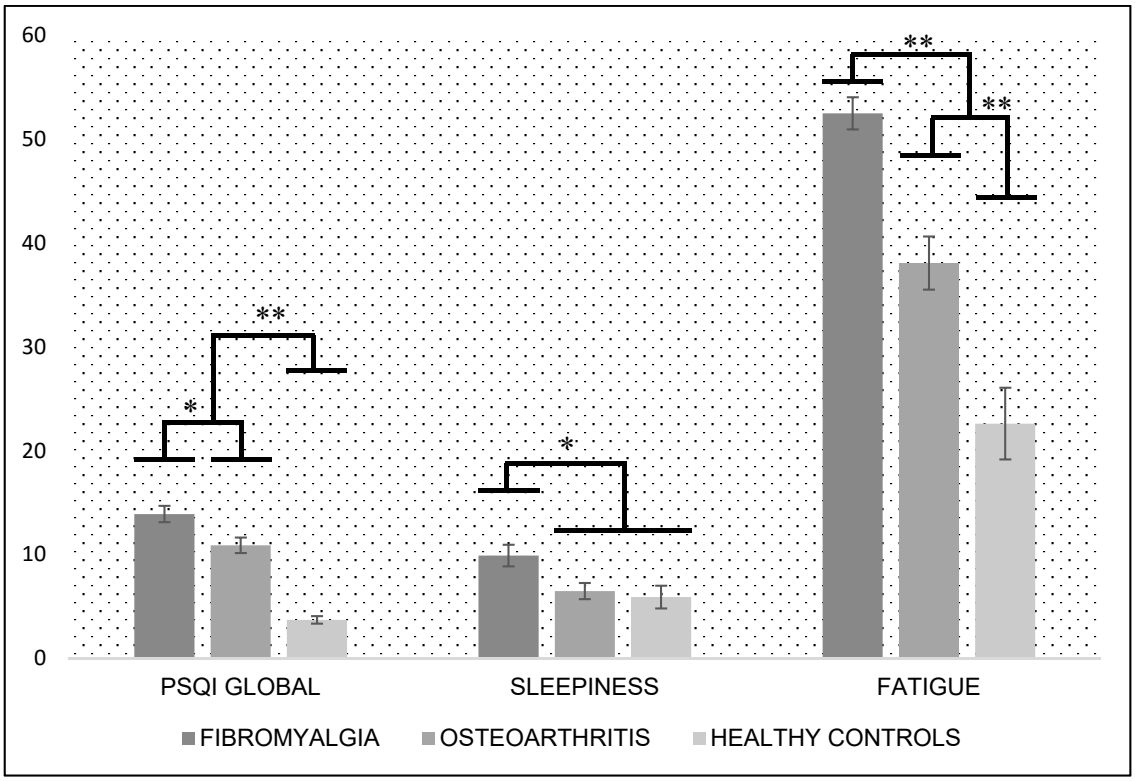



**Figure 3.2.** Bar chart comparing subjective sleep scores in fibromyalgia, osteoarthritis and healthy control participants. The Y-axis depicts the mean scores in the Global PSQI, Epworth Sleepiness Scale and Fatigue Severity Scale. Standard error bars are shown. **p<.001; *p<.05;

# 4. Results II: Sleep Comparisons

In this chapter, subjective and objective sleep is compared across all three participant groups including fibromyalgia, osteoarthritis and healthy control groups. Subjectively, sleep is compared in overall sleep quality using the PSQI and its subscales; sleepiness is compared using the Epworth Sleepiness Scale; and daytime fatigue is measured using the Fatigue Severity Scale. It should be noted, although some of this data was already presented previously in Chapter 3, the present analysis takes a more in depth look at the PSQI and its subscales and its relationships/differences within our sample groups.

Sleep was objectively measured using both polysomnography and actigraphy to investigate differences between groups on various sleep variables (TST, WASO, S.E., SOL etc.). Where actigraphy was recorded over a two-week period, it allowed a general overview of the participants' sleep, in addition, recording throughout the day using actigraphy, allowed an insight into general activity levels and measures of circadian rhythm.

In order to answer the main hypothesis regarding the microstructure of sleep, the polysomnography data was processed using spectral analysis to determine the amplitude differences in certain frequency bins and during certain stages of sleep or certain cycles of over one night of sleep.

## 4.1. Subjective Sleep Variables

Table 4.1. Displays means and standard deviations of subjective sleep variables including the PSQI, ESS and FSS. Looking at the means, on the outset, there appeared to be a trend of FMS patients having a worse mean score across all the scales, followed by OA patients and lastly healthy control participants. This is true for all subscales of the PSQI apart from sleep onset latency.

### 4.1.1. PSQI

One way independent ANOVAs were conducted between the three groups on all PSQI subscales, sleepiness and fatigue.

#### 4.1.1.1. Sleep Duration

For sleep duration (PSQI-A; Total Sleep Time), normality tests indicated that FMS (Skew=-1.27; Kurt=-0.92), OA (Skew=0.15; Kurt=-1.05) and NHC (Skew=1.51; Kurt=-0.92) were normally distributed.

Levene's test showed non-equal variances between groups ($F$=3.51, p=.039), accordingly a Welch's F statistic was used (Table 4.1). An overall significant effect was observed (p<.001). Post-hoc comparisons with a Games-Howell correction found significant effects between the clinical groups and the healthy control group, with mean differences of 1.65 (p<.001) and 1.11 (p=.003) for FMS and OA respectively. No significant differences between FMS and OA were observed (p=n.s.).

#### 4.1.1.2. Sleep Disturbance

For the sleep disturbance subscale, in normality tests, FMS (Skew=2.95; Kurt=0.41) and OA (Skew=-2.49; Kurt=-0.14) were both skewed positively and negatively respectively. In addition, the NHC group had 0 variance for this subscale.

Levene's test additionally observed unequal variances between the groups ($F$=10.552, p<.001). Due to the NHC group observing zero variance, it was not possible to calculate a Welch's F statistic thus the standard between groups ANOVA was used instead. An overall significant effect was found between the groups (p<.001). Post-hoc comparisons with a Bonferroni correction found significant differences between the clinical groups and NHC, with mean differences of 1.21 (p<.001) and .76 (p<.001) for FMS and OA respectively. FMS was also shown to have a greater sleep disturbance than OA, with a mean difference of .45 (p=.003). This indicates a significantly greater sleep disturbance for both clinical groups as opposed to the NHC group, additionally a greater sleep disturbance in FMS patients as opposed to OA.

#### 4.1.1.3. Sleep Onset Latency

The sleep onset latency subscale measured the time participants think it takes for them to fall asleep. In normality tests, FMS (Skew=-0.43; Kurt=-1.91) although slightly negatively skewed and platykurtotic, falls within the range for normally distributed data. For OA (Skew=2.44; Kurt=-2.44) and NHC (Skew=2.13; Kurt=2.71), both were found to be skewed and kurtotic.

Levene's test found equal variances amongst the groups ($F$=1.449, p>.05). In the one-way independent ANOVA, an overall significant effect was observed (p=.001). Post-hoc comparisons with Bonferroni correction found a significant difference between the clinical groups and the NHCs, with a mean difference of 1.21 (p=.004) and 1.39 (p=.001) for FMS and OA respectively. No difference was observed between FMS and OA (p=n.s.).

#### 4.1.1.4. Daytime Dysfunction

For the PSQI daytime dysfunction subscale, FMS (Skew=0.40; Kurt=-0.65) and NHC (Skew=0; Kurt=-1.93) were normally distributed; however, the OA group (Skew=2.49; Kurt=-0.14) were positively skewed.

Levene's test indicated equal variances among the groups ($F$=1.526, p>.05). An overall significant effect was found between the three groups (p<.001). Post-hoc comparisons with Bonferroni corrections found significant differences between the clinical groups and NHC with mean differences of 1.34 (p<.05) and .74 (p=.007) for FMS and OA respectively. There was also a significant difference found between FMS and OA with a mean difference of .61 (p=.008). FMS patients are shown to have a greater daytime dysfunction due to sleep than OA, both of which are greater than NHC.

#### 4.1.1.5. Sleep Efficiency

For the sleep efficiency subscale, a greater score indicates poorer sleep efficiency. FMS (Skew=-1.86; Kurt =-0.38), OA (Skew=-0.23; Kurt=-1.30) and NHC (Skew=1.51; Kurt=-0.92) were all normally distributed.

Levene's test indicated unequal variances between groups ($F$=5.291, p=.009), thus the Welch's F was used. An overall significant effect was found (p<.001). Post-hoc comparisons with a Games-Howell correction found significant differences between the clinical groups and the NHC, with mean differences of 1.96 (p<.001) and 1.46 (p=.001) for FMS and OA respectively. There were no differences observed between FMS and OA (p=n.s.).

#### 4.1.1.6. Overall Sleep Quality

The subscale measuring overall sleep quality was not normally distributed for FMS (Skew=-3.24; Kurt=1.69) or NHC (Skew=-2.59; Kurt=1.05); OA group met a normal distribution (Skew=-0.29; Kurt=-0.63).

Levene's test indicated equal variances ($F$=1.162, p>.05). One-way ANOVA showed an overall effect between the groups (p<.001). Post-hoc analysis with a Bonferroni correction found the clinical groups had significantly worse overall sleep quality than NHC participants with mean differences of 1.83 (p<.001) and 1.32 (p<.001) for FMS and OA respectively. FMS and OA showed no significant differences (p=n.s.).

#### 4.1.1.7. Use of Medication for Sleep

Lastly the final subscale of the PSQI is whether the participants utilized somnolence aids/medication. FMS (Skew=2.16; Kurt=-0.37) and OA (Skew=4.56; Kurt=5.39) were found to be non-normal, with positive skew and kurtosis. The NHC group appeared to have no variance in their data, which is expected.

Levene's test indicated unequal variances ($F$=11.393, p>.05), however due to the NHC group lacking variance in their data, a Welch alternative could not be run, it was thus decided to employ the standard ANOVA statistic. The overall results indicated no significant differences between the groups (p=n.s.).

#### 4.1.1.8. PSQI Global Score

The PSQI outputs a global sleep score for each participant. A higher score indicates poorer sleep quality, and a score greater than five, an indicator for clinical sleep dysfunction. Normality tests indicated that FMS (Skew=-1.06; Kurt=0.34), OA (Skew=0.04; Kurt=-1.26) and NHC (Skew=-0.50; Kurt=-0.92) were normally distributed.

Levene's test indicated unequal variances between means ($F$=4.87, p=.012), thus a Welch's F was used for inferential analysis. An overall significant effect was found (p<.001). Post-hoc analysis with a Games-Howell correction observed a significant difference between the clinical groups and the healthy control group, with mean differences of 10.19 and 7.18 for FMS and OA respectively (p<.001). Between FMS and OA, a significant difference was observed with a mean difference of 3.01 (p=.023).

### 4.1.2. Epworth Sleepiness Scale

Sleepiness was measured using the Epworth Sleepiness Scale. Tests for normality indicated FMS (Skew=-0.38; Kurt=0.11), OA (Skew=1.47; Kurt=-0.74) and NHC (Skew=1.25; Kurt=0.45) were normally distributed.

Levene's test for equality of variance indicated that the means were of equal variances ($F$=.507, p>.05). One-way ANOVA showed an overall significant main effect (p=.011). Post-hoc comparisons with a Bonferroni correction applied found that FMS had a significantly greater sleepiness score than both OA and NHC participants with mean difference of 3.42 (p=.033) and 3.99 (p=0.34) respectively. No difference was observed between OA and NHC (p=n.s.).

### 4.1.3. Fatigue Severity Scale

Fatigue was assessed using the Fatigue Severity Scale. FMS (Skew=-1.24; Kurt=1.02), OA (Skew=0.98; Kurt=0.07) and NHC (Skew=0.85; Kurt=0.16) were shown to be normally distributed.

Levene's test indicated equal variances between the groups ($F$=1.569, p>.05). One-way ANOVA showed a significant main effect (p<.001). Post-hoc comparisons with a Bonferroni correction applied found that FMS participants had significantly greater fatigue than OA (*M diff*=14.41, p<.001) and NHC (*M diff*=29.87, p<.001); in turn, OA also exhibited significantly greater fatigue than the NHC group (*M diff*=15.46, p<.001).

### 4.1.4. Sleep variables as calculated from PSQI

#### 4.1.4.1. Sleep Efficiency Percentage

Percentage sleep efficiency was also calculated from the PSQI measure (Table 4.1) using the following equation $\frac{Wake\ Time}{Total\ Time\ in\ Bed} * 100$ . This is not to be confused with the sleep efficiency subscale which is part of the overall PSQI score. FMS (Skew=-0.48; Kurt=-1.18) and NHC (Skew=-0.51; Kurt=1.05) were normally distributed, however OAs (Skew=-2.09; Kurt=2.06) were negatively skewed and leptokurtotic.

Levene's test indicated unequal variances ($F$=5.568, p=.007); overall, a significant effect between the groups were found (p<.001). Post-hoc comparisons with a Games-Howell correction found the clinical groups to have significantly less sleep efficiency than NHC with mean differences of 30.41 (p<.001) and 19.74 (p=.010) for FMS and OA respectively. No differences were observed between FMS and OA (p=n.s.). Overall sleep efficiency was worse in the clinical groups compared to NHC. FMS and OA exhibited similar levels of sleep efficiency.

#### 4.1.4.2. Total Sleep Time

For subjective total sleep time as measured by PSQI, normality scores indicated a normal distribution for all three groups FMS (Skew=-0.23; Kurt=-0.86), OA (Skew=1.05; Kurt=-0.05) and NHC (Skew=-0.05; Kurt=-0.98).

Levene's test indicated a similar difference in variance between means ($F$=3.040, $p$=.058). From the outset, the clinical groups had a much lower TST as compared to NHC, with FMS having the least amount of perceived sleep. Multivariate analysis indicated an overall significant difference within the group (Table 4.1). Post-hoc analysis with Bonferroni corrections found that FMS patients have a significantly lower amount of self-

reported TST than NHC participants (*Mdiff*=138.32, *p*<.001). However, no differences were observed between FMS and OA (*Mdiff*=66.32, *p*=.062) or OA and NHC (*Mdiff*=72.00, *p*=.103).

#### 4.1.4.3. Time in Bed

Measures of total time in bed taken as the difference between subjective bed time and wake time also indicated a normal distribution of scores for FMS (Skew=-0.20; Kurt=0.26), OA (Skew=0.51; Kurt=-1.08) and NHC (Skew=0.64; Kurt=0.29).

Levene's test found a significant difference in variance within the groups (*F*=3.040, *p*=.015) thus a Welch's F was used for test robustness. The outset suggested a greater amount of time spent in bed for the clinical patients compared to the healthy controls, however the analysis did not find a significant effect between them.

#### 4.1.4.4. Sleep Onset Latency

Subjective sleep onset latency found a slightly skewed distribution for FMS patients (Skew=2.79; Kurt=0.96), a skewed and kurtotic distribution for OA (Skew=6.83; Kurt=13.92) and a normal distribution for NHC (Skew=1.09; Kurt=-0.22).

Levene's test found a significant difference in variance within the groups (*F*=4.456, *p*=.017) thus a Welch's F was used. The outset suggested a much longer perceived sleep onset latency for the clinical patients as compared to the healthy control group. Post-hoc analysis with a Games-Howell correction found a significantly greater self-reported sleep onset latency in FMS patients as compared to NHC (*Mdiff*=54.90, *p*=.010). Although no significant differences were found between FMS and OA (*Mdiff*=15.41, *p*=n.s.) or OA and NHC (*Mdiff*=39.49, *p*=n.s.).

***Table 4.1. Subjective sleep characteristics of fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS** *M ± SD (19)* | **OA** *M ± SD (17)* | **NHC** *M ± SD (10)* | ***F*** | ***df*** | ***p*** | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| **PSQI-A**[1] | 1.95 ± 1.13 | 1.41 ± 1.06 | 0.30 ± 0.48 | 17.409† | 2, 28.59 | .000*** | .292 |
| **PSQI-B**[2] | 2.21 ± 0.42 | 1.76 ± 0.44 | 1.00 ± 0.00 | 9.609 | 2, 43 | .000*** | .607 |
| **PSQI-C**[3] | 2.11 ± 0.94 | 2.29 ± 0.85 | 0.90 ± 0.88 | 13.433 | 2, 43 | .001** | .282 |
| **PSQI-D**[4] | 1.84 ± 0.69 | 1.24 ± 0.44 | 0.50 ± 0.53 | 12.024 | 2, 43 | .000*** | .461 |
| **PSQI-E**[5] | 2.26 ± 0.99 | 1.76 ± 1.09 | 0.30 ± 0.48 | 29.229† | 2, 28.42 | .000*** | .397 |
| **PSQI-F.**[6] | 2.63 ± 0.68 | 2.12 ± 0.70 | 0.80 ± 0.42 | 22.127 | 2, 43 | .000*** | .554 |
| **PSQI-G**[7] | 0.79 ± 1.18 | 0.35 ± 0.86 | 0.00 ± 0.00 | 4.373 | 2, 43 | .091 | .106 |
| **PSQI**[8] | 13.89 ± 3.40 | 10.88 ± 3.08 | 3.70 ± 1.16 | 89.225† | 2, 28.15 | .000*** | .648 |
| **ESS**[9] | 9.89 ± 4.54 | 6.47 ± 3.20 | 5.90 ± 3.45 | 4.998 | 2, 43 | .011* | .189 |
| **FSS**[10] | 52.47 ± 6.74 | 38.06 ± 10.57 | 22.60 ± 10.91 | 35.238 | 2, 43 | .000*** | .621 |
| **PSQI-S.E.**[11] | 59.13 ± 20.22 | 69.80 ± 13.95 | 89.54 ± 7.24 | 22.810† | 2, 28.66 | .000*** | .356 |
| **PSQI-TST**[12] | 293.68 ± 94.12 | 360.00 ± 88.74 | 432.00 ± 31.46 | 9.427 | 2, 43 | .000*** | .305 |
| **PSQI-TIB**[13] | 505.89 ± 66.06 | 521.47 ± 94.15 | 484.50 ± 43.49 | 1.116† | 2, 27.27 | .342 | .035 |
| **PSQI-SOL**[14] | 66.50 ± 71.98 | 51.09 ± 66.00 | 11.60 ± 7.05 | 8.038† | 2, 23.40 | .002*** | .108 |

1. PSQI Sleep Duration, 2. PSQI Sleep Disturbance, 3. PSQI Sleep Onset Latency, 4. PSQI Daytime Dysfunction, 5. PSQI Sleep Efficiency, 6. PSQI Sleep Quality, 7. PSQI Medication for Sleep, 8. PSQI Global Sleep Score, 9. Epworth Sleepiness Scale, 10. Fatigue Severity Scale, 11. PSQI Percentage Sleep Efficiency, 12. PSQI Total Sleep Time (Minutes), 13. PSQI Time in Bed (Minutes), 14. PSQI Sleep Onset Latency; *p<.05, **p<.01, ***p<.001; †Welch's F;

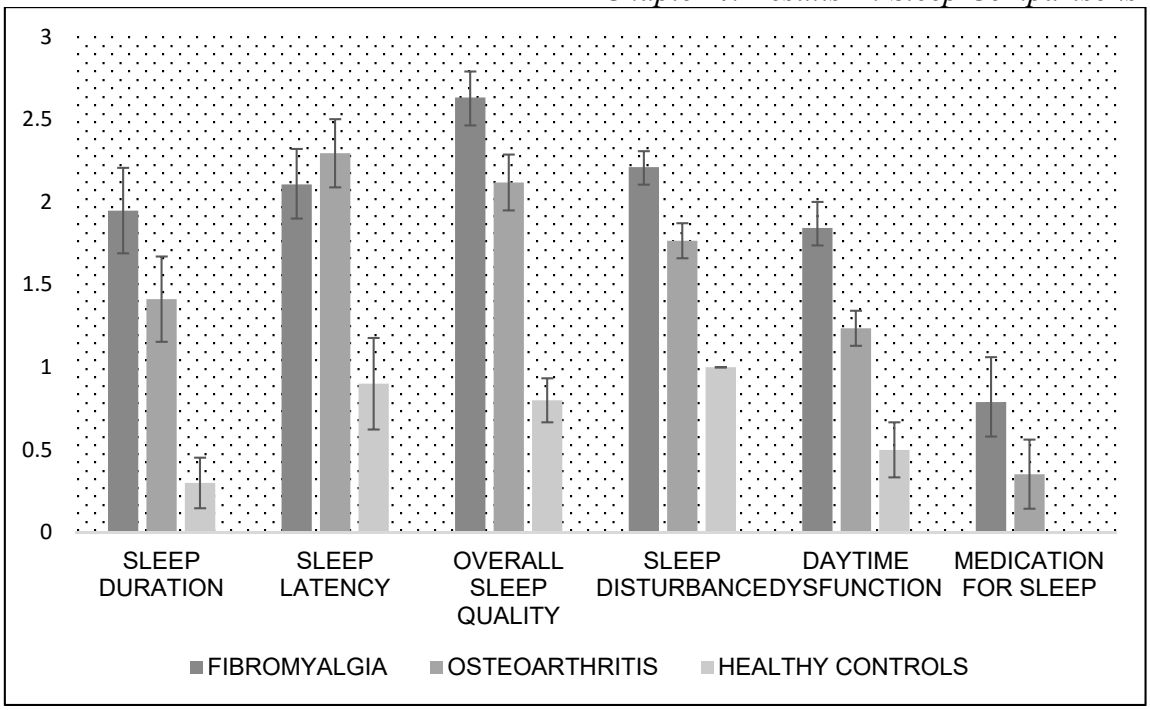



**Figure 4.1.** Bar chart comparing subjective sleep scores in fibromyalgia, osteoarthritis and healthy control participants. The Y-axis depicts the mean scores in all subscales of the PSQI. The X-axis depicts each subscale of the PSQI. Standard error bars are displayed.

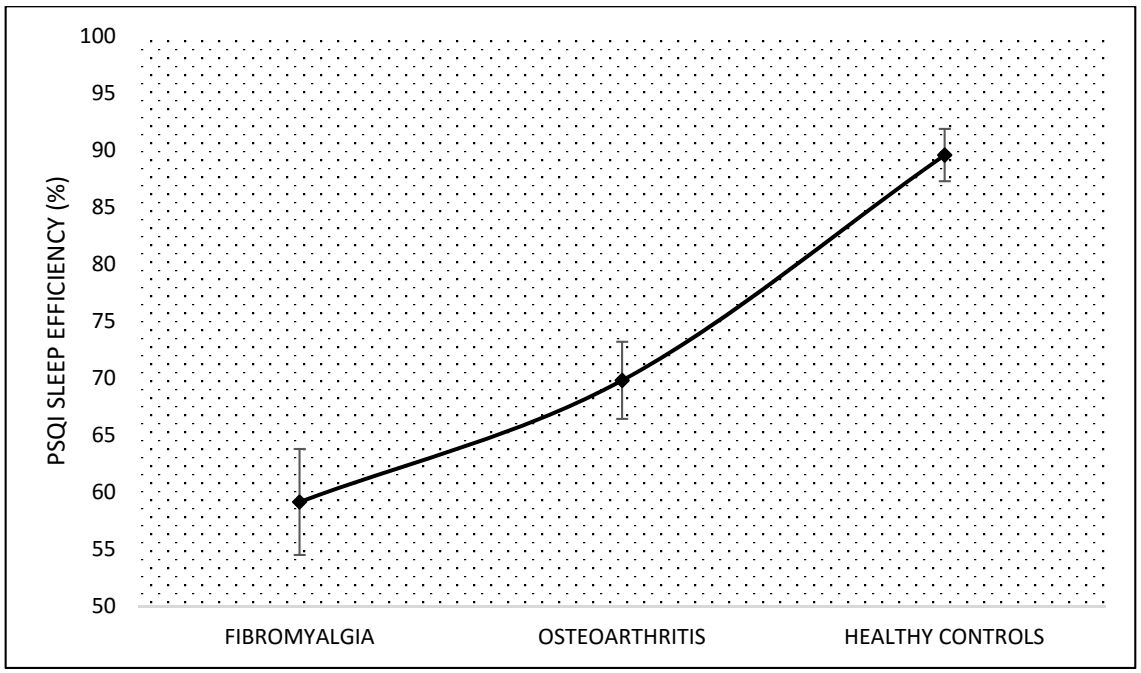



**Figure 4.2.** Plot of means comparing subjectively assessed sleep efficiency percentages in fibromyalgia, osteoarthritis and healthy control participants. The Y-axis depicts the mean sleep efficiency percentage as calculated from the PSQI. Standard error bars are shown for each observation.

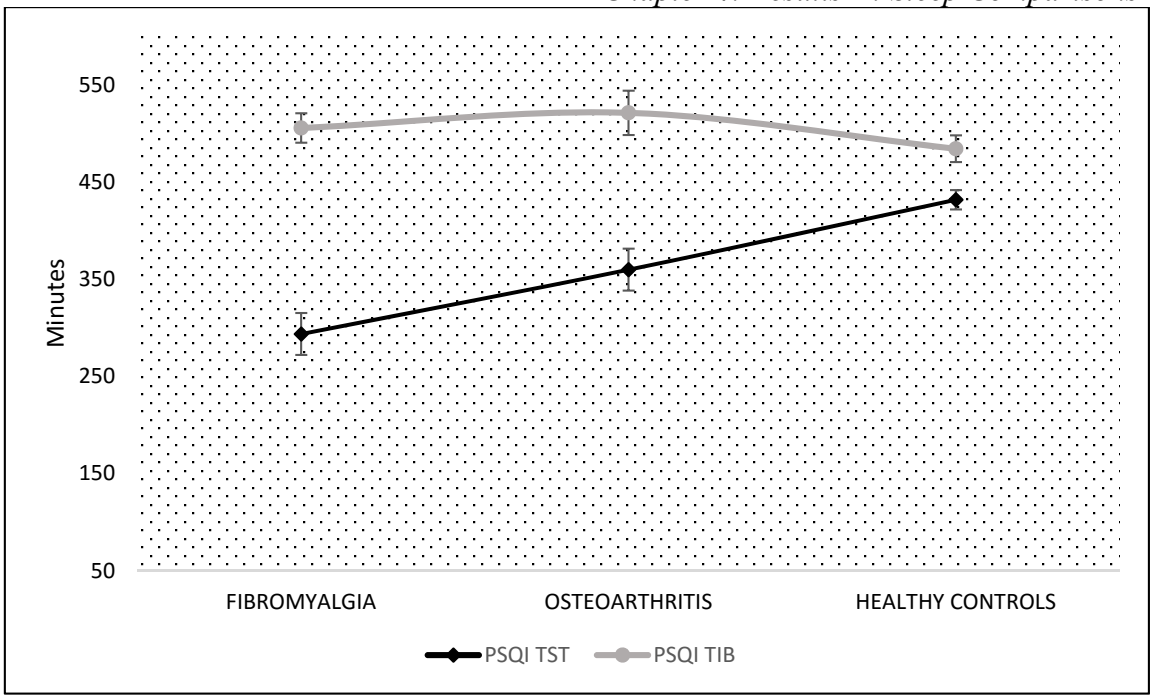



**Figure 4.3.** Plot of means comparing subjectively assessed total sleep time and total time in bed in fibromyalgia, osteoarthritis and healthy control participants. The Y-axis depicts the time in minutes. Standard error bars are shown for each observation.

## 4.2. Actigraphy and Polysomnography Comparisons

Objective measurements of sleep were compared using a correlational analysis applied to the sleep variables between actigraphy and polysomnography data. This was done to observe the differences or similarities between a single night of monitoring versus a two-week period of observation. Assumptions for parametric analysis was met prior to running a 'Pearson's Product Moment Correlation' and this was applied to variables TST, SOL, WASO and S.E. across the whole group. Table 4.2. Summarizes results from the Pearson's correlation, it shows significant correlations between all variables apart from 'Total Sleep Time'. Due to the more accurate nature of determining sleep onset time and wake time via PSG, it was deemed that a weaker correlation with 'Total Sleep Time' was due to the downsides of the actigraphic methodology. Figures 4.4-4.8 display graphically, the relationships between these variables.

***Table 4.2. Pearson's correlations between sleep variables in polysomnography and actigraphy across the whole group.***

| **Variable (*N*=43)** | **TST (ACT)** | **SOL (ACT)** | **WASO (ACT)** | **S.E. (ACT)** |
|---|---|---|---|---|
| **TST (PSG)** | .223 (*p*=.151) | | | |
| **SOL (PSG)** | | .502 (*p*=.001)** | | |
| **WASO (PSG)** | | | .314 (*p*=.040)* | |
| **S.E. (PSG)** | | | | .310 (*p*=.043)* |

TST=Total Sleep Time; SOL=Sleep Onset Latency; WASO=Wake after Sleep Onset; S.E. =Sleep Efficiency; ACT=Actigraphy; PSG=Polysomnography; **significant at the .001 level; *significant at the .05 level;

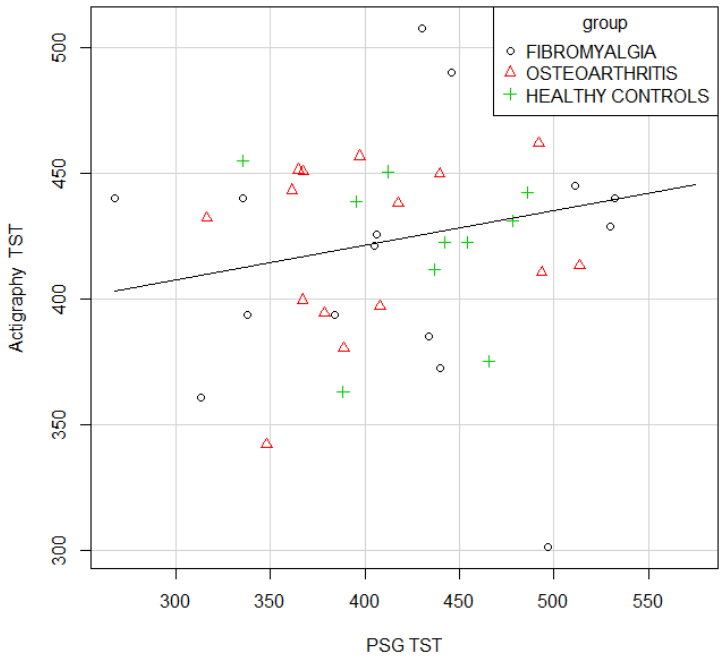



**Figure 4.4.** Scatter plot comparing PSG total sleep time on the X-axis to actigraphy total sleep time on the Y-axis.

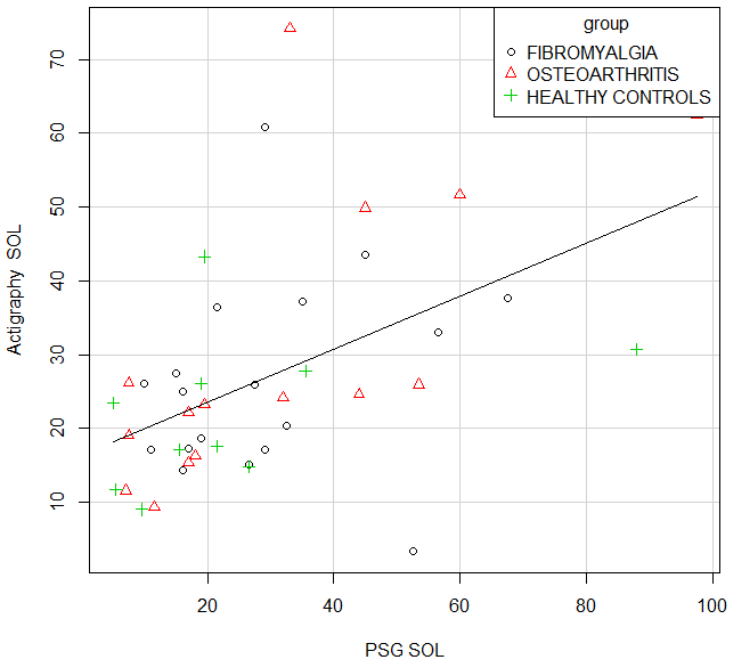



**Figure 4.5.** Scatter plot comparing PSG sleep onset latency on the X-axis to actigraphy sleep onset latency on the Y-axis.

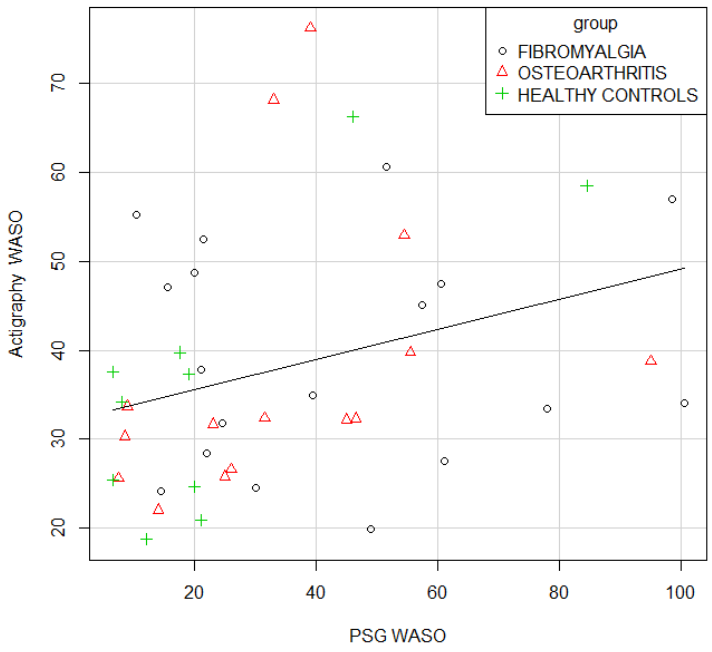



**Figure 4.6.** Scatter plot comparing PSG wake after sleep onset on the X-axis to actigraphy wake after sleep onset on the Y-axis.

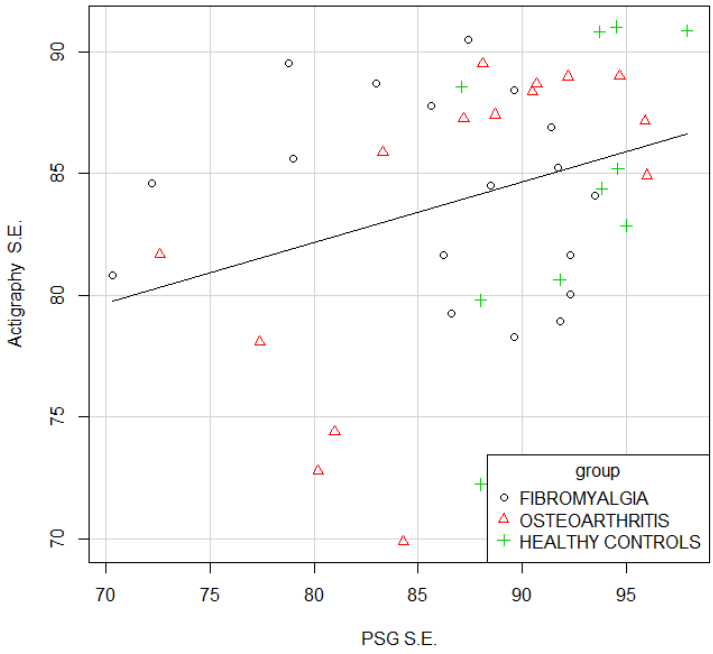



**Figure 4.7.** Scatter plot comparing PSG sleep efficiency on the X-axis to actigraphy sleep efficiency on the Y-axis.

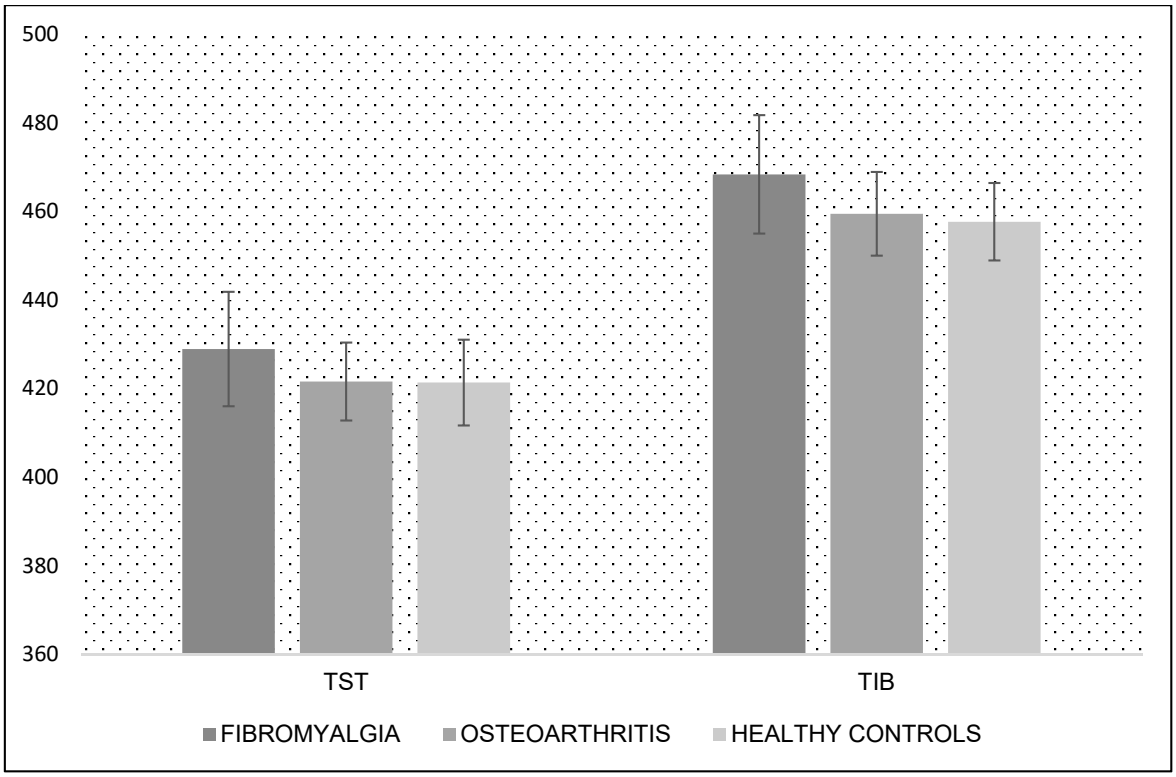



**Figure 4.8.** Bar chart depicting total sleep time and total time in bed using actigraphy between fibromyalgia, osteoarthritis and healthy control participants. Standard error bars are shown.

## 4.3. Objective Sleep Variables

### 4.3.1. Actigraphy Scores

Actigraphy was conducted on all participants for a two-week period. 3 actiwatches exhibited recording failure during data collection (1 FMS & 2 OA), thus their actigraphy data could not be used for analysis. The mean values across the two-week period were used for all further actigraphic analyses (*n size*: FMS=18; OA=15; NHC=10). Table 4.4 displays the means and standard deviations of sleep variables from actigraphy parameters between the three groups. In the FMS group there was one actiwatch failure, and in the OA group there were two actiwatch failures; this brought the groups sizes to 18:15:10 for FMS, OA and NHC respectively.

Looking at the distribution of these scores, in variables sleep duration, sleep efficiency and total sleep time, all three groups were normally distributed. However, in sleep onset latency, wake after sleep onset and total sleep time, the OA group had a positive skew distribution (Table 4.3.).

Tests for homogeneity of variance indicated that all variables were of equal variance between the three groups. This included sleep duration ($F$=3.103), sleep onset latency ($F$=2.453), sleep efficiency ($F$=2.454), wake after sleep onset ($F$=.029), total sleep time ($F$=2.082) and awakenings ($F$=.493) which were all significantly greater than the alpha level (p>.05)

***Table 4.3. Skewness and Kurtosis Z scores for actigraphic sleep variables in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS Skew** *n=18* | **FMS Kurt** *n=18* | **OA Skew** *n=15* | **OA Kurt** *n=15* | **NHC Skew** *n=10* | **NHC Kurt** *n=10* |
|---|---|---|---|---|---|---|
| **Duration**[1] | -0.56 | -0.18 | -1.72 | 0.51 | -1.79 | 1.04 |
| **SOL**[2] | 1.59 | -0.18 | **2.06*** | 0.33 | 1.17 | 0.44 |
| **Efficiency**[3] | -0.04 | 1.28 | -1.90 | -0.20 | -1.18 | 0.31 |
| **WASO**[4] | 0.29 | -1.20 | **2.77*** | 1.62 | 1.36 | 0.09 |
| **TST**[5] | -0.92 | 0.16 | -1.48 | 0.28 | -1.52 | 0.14 |
| **Awakenings**[6] | 1.09 | -0.71 | **2.43*** | 1.72 | -0.49 | -0.02 |

1. Sleep Duration, 2. Sleep Onset Latency, 3. Sleep Efficiency Percentage, 4. Wake after Sleep Onset, 5. Total Sleep Time, 6. Awakenings; *Z>±1.96;

One way independent ANOVAs were run on each variable comparing the means between the groups. Overall none of the variables were found to be significantly different between the groups (Duration; SOL; Efficiency; WASO; TST; Awakenings). However, it is beneficial to note that the standard deviations are relatively high for each of the parameters. Figures 4.9 to 4.11 display graphically, the mean values for each group and variable.

***Table 4.4. Actigraphic sleep profiles of fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS (*M* ± *SD*)** *n=18* | **OA (*M* ± *SD*)** *n=15* | **NHC (*M* ± *SD*)** *n=10* | ***F*** | ***p*** | **$\eta^2$** |
|---|---|---|---|---|---|---|
| **Duration**[1] | 468.29 ± 56.63 | 459.43 ± 37.16 | 457.69 ± 27.67 | .247 | .783 | .012 |
| **SOL**[2] | 26.65 ± 13.62 | 30.41 ± 19.60 | 22.14 ± 10.28 | .885 | .421 | .042 |
| **Efficiency**[3] | 80.06 ± 4.54 | 78.32 ± 10.41 | 81.40 ± 9.67 | .118 | .889 | .006 |
| **WASO**[4] | 61.01 ± 20.18 | 66.24 ± 46.10 | 53.94 ± 37.75 | .154 | .857 | .008 |
| **TST**[5] | 407.26 ± 57.12 | 393.19 ± 49.56 | 403.75 ± 40.87 | .153 | .859 | .008 |
| **Awakenings**[6] | 33.03 ± 9.89 | 31.12 ± 8.79 | 32.66 ± 8.71 | .214 | .809 | .011 |

1. Sleep Duration, 2. Sleep Onset Latency, 3. Sleep Efficiency Percentage, 4. Wake after Sleep Onset, 5. Total Sleep Time, 6. Awakenings

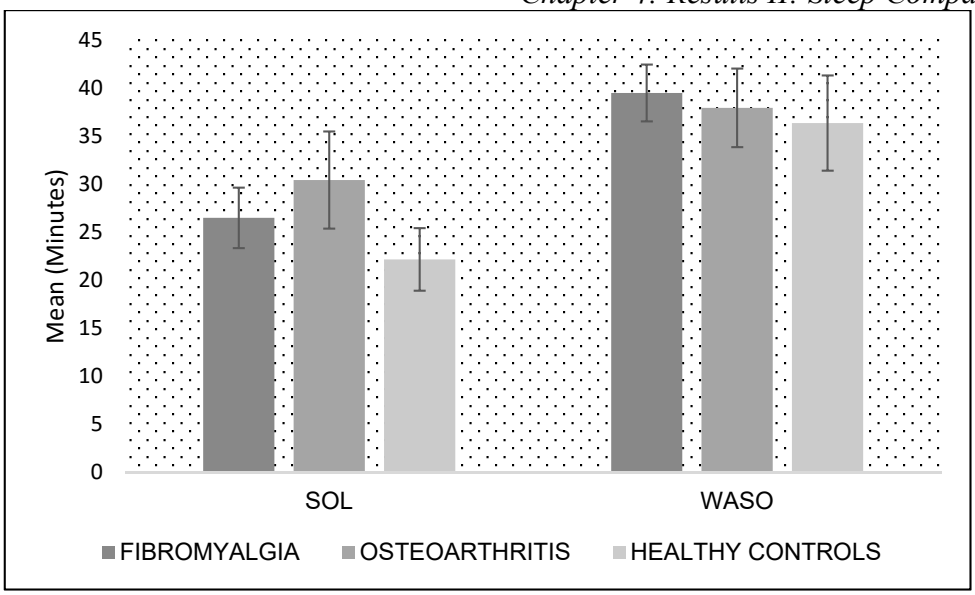



**Figure 4.9.** Bar graph depicting sleep onset latency and wake after sleep onset using actigraphy between fibromyalgia, osteoarthritis and healthy control participants.

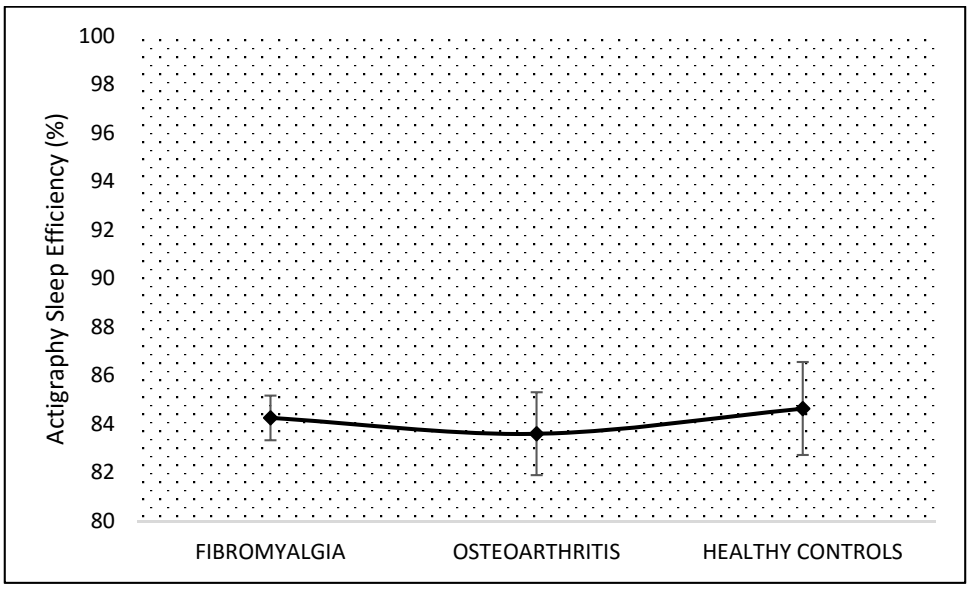



**Figure 4.10.** Plot of means depicting sleep efficiency measured using actigraphy between fibromyalgia, osteoarthritis and healthy control participants. Includes standard error bars for each observation.

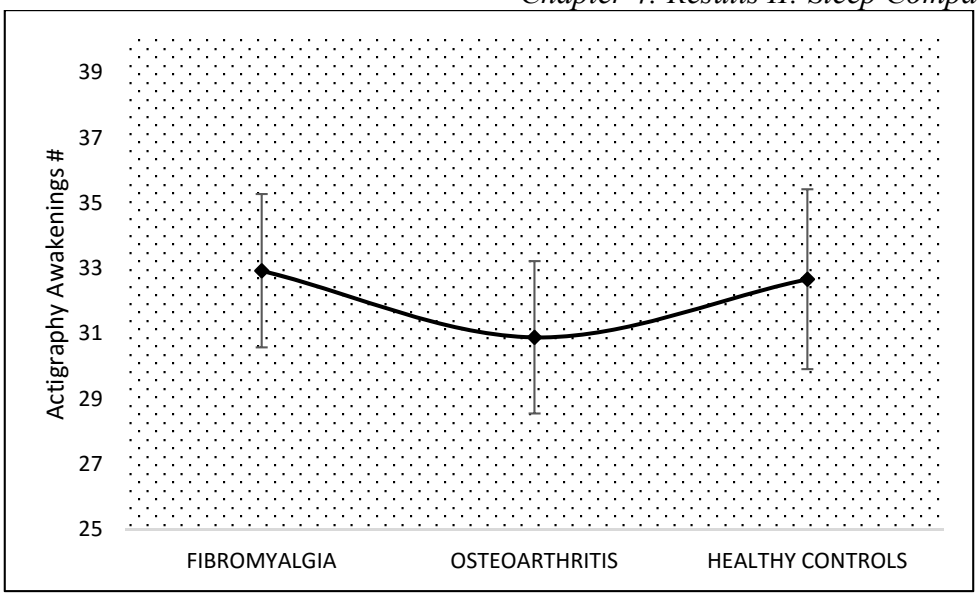



**Figure 4.11.** Plot of means depicting awakenings measured using actigraphy between fibromyalgia, osteoarthritis and healthy control participants. Includes standard error bars for each observation.

### 4.3.2. Polysomnography Sleep Variables

For PSG measured sleep variables including TST, SOL, WASO and S.E. one way independent ANOVAs were run to compare the three groups. Normality and equality of variance scores are displayed in Table 4.5. All variables met the homogeneity of variance assumption.

***Table 4.5. Skewness and Kurtosis Z scores and Levene's test for PSG sleep variables in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS Skew** *n=19* | **FMS Kurt** *n=19* | **OA Skew** *n=17* | **OA Kurt** *n=17* | **NHC Skew** *n=10* | **NHC Kurt** *n=10* | **Levene's** ***F, p*** |
|---|---|---|---|---|---|---|---|
| **TST**[1] | -0.38 | -0.78 | 1.02 | -0.51 | -1.15 | 0.18 | 2.78, n.s. |
| **SOL**[2] | 1.75 | 0.17 | **2.30*** | **1.97*** | **3.40*** | **4.65*** | 0.77, n.s. |
| **S.E.**[3] | **-1.98*** | -0.09 | -0.47 | -0.74 | -0.54 | -0.77 | 2.67, n.s. |
| **WASO**[4] | 1.73 | -0.12 | 1.59 | 0.43 | **3.06*** | **3.40*** | 1.42, n.s. |

1. Total Sleep Time, 2. Sleep Onset Latency, 3. Wake after Sleep Onset, 4. Sleep Efficiency; *Z>±1.96;

Table 4.6 displays the polysomnography results for total sleep time, sleep onset latency, wake after sleep onset and sleep efficiency. No significant differences between the three groups were found, except for sleep efficiency, which showed a statistically significant difference in sleep efficiency within the three groups (p=0.25).

Post-hoc comparisons with a Bonferroni correction showed that the fibromyalgia group were less sleep efficient compared to healthy controls (*Mdiff*=7.22, p=.028). However, no significant differences were observed between OA and NHC, or with FMS and OA. These results are demonstrated graphically in figures 4.12 to 4.15.

***Table 4.6. Polysomnographic sleep variables in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS (*M* ± *SD*)** *n=19* | **OA (*M* ± *SD*)** *n=17* | **NHC (*M* ± *SD*)** *n=10* | ***F*** | ***p*** | **$\eta^2$** |
|---|---|---|---|---|---|---|
| **TST[1]** | 431.26 ± 84.61 | 407.18 ± 56.18 | 429.40 ± 46.71 | .639 | .533 | .029 |
| **SOL[2]** | 29.76 ± 16.18 | 32.47 ± 23.80 | 24.55 ± 24.20 | .447 | .643 | .020 |
| **WASO[3]** | 47.16 ± 32.75 | 38.29 ± 25.34 | 24.10 ± 24.15 | 2.156 | .128 | .091 |
| **S.E. [4]** | 85.22 ± 7.74 | 86.08 ± 6.98 | 92.44 ± 3.61 | 4.032 | .025* | .158 |

1. Total Sleep Time, 2. Sleep Onset Latency, 3. Wake after Sleep Onset, 4. Sleep Efficiency; *p<.05;

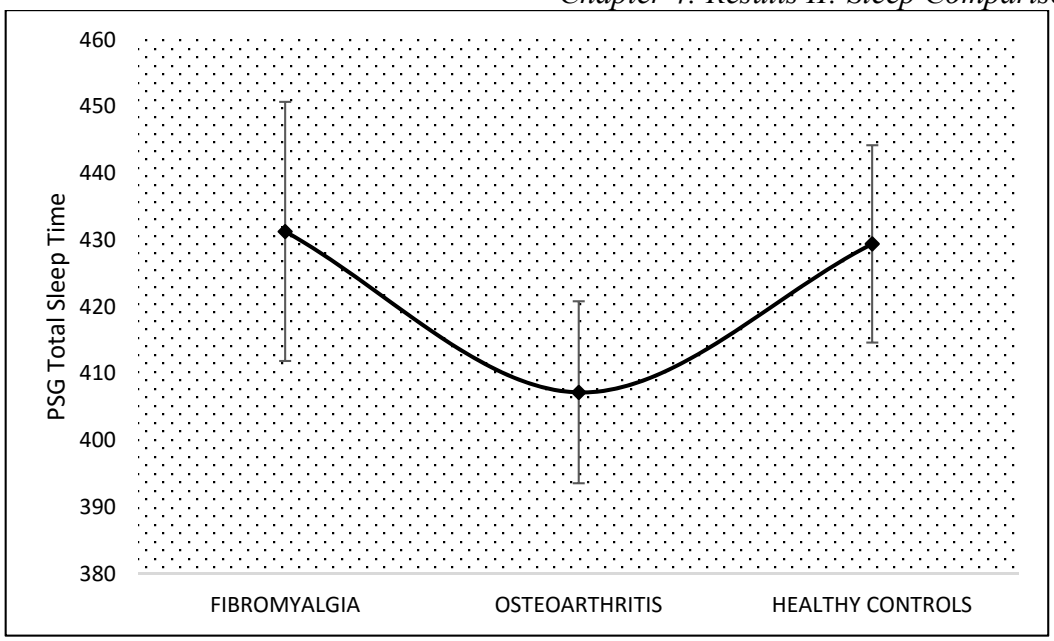



**Figure 4.12.** Plot of means depicting total sleep time measured using polysomnography between fibromyalgia, osteoarthritis and healthy control participants. Includes standard error bars for each observation.

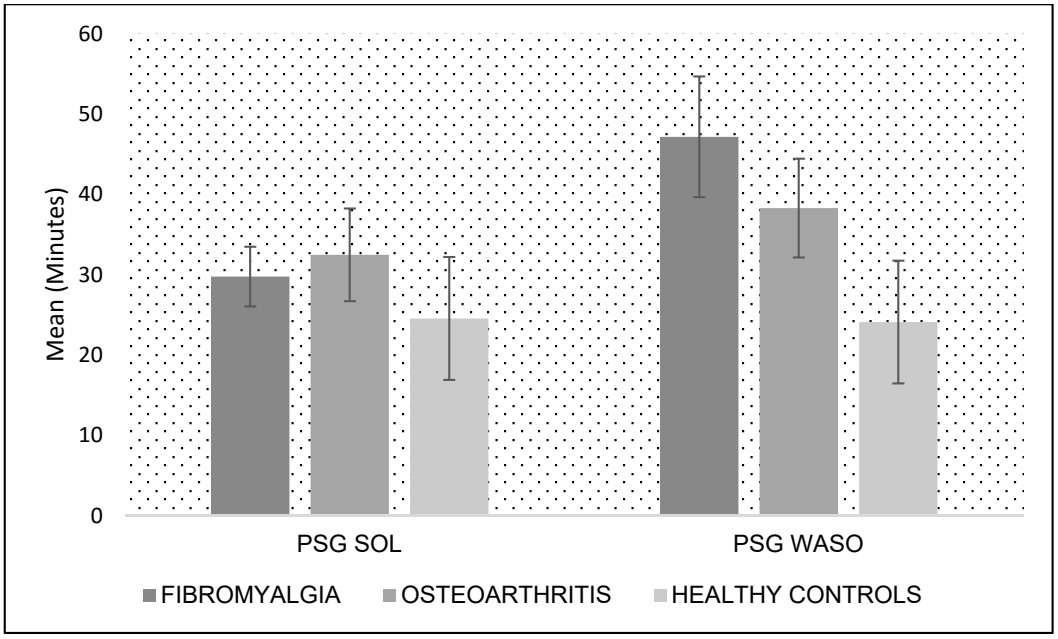



**Figure 4.13.** Bar chart depicting sleep onset latency and wake after sleep onset as measured using polysomnography between fibromyalgia, osteoarthritis and healthy control participants. Standard error bars are displayed.

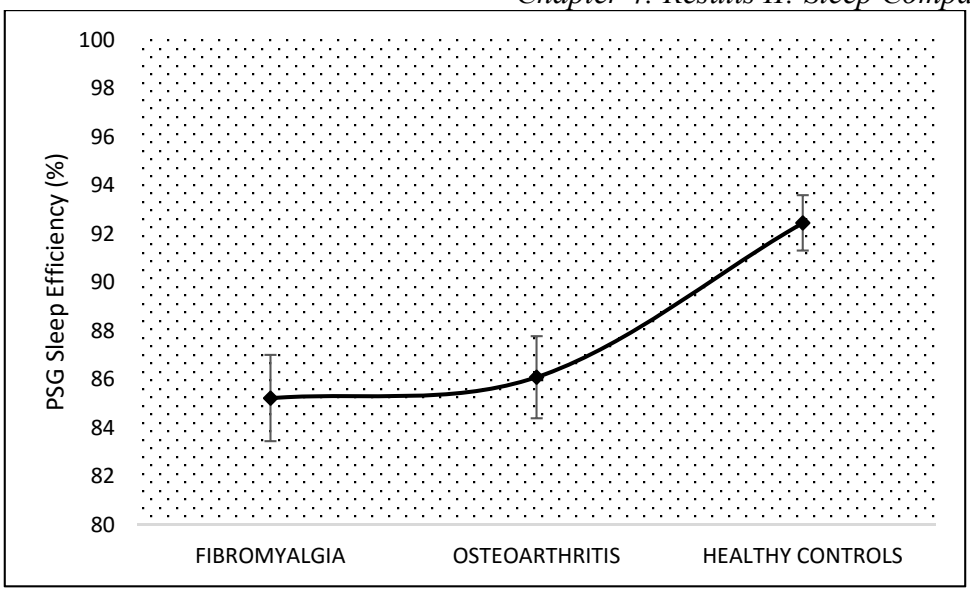



**Figure 4.14.** Plot of means depicting sleep efficiency as measured using polysomnography between fibromyalgia, osteoarthritis and healthy control participants. Includes standard error bars for each observation.

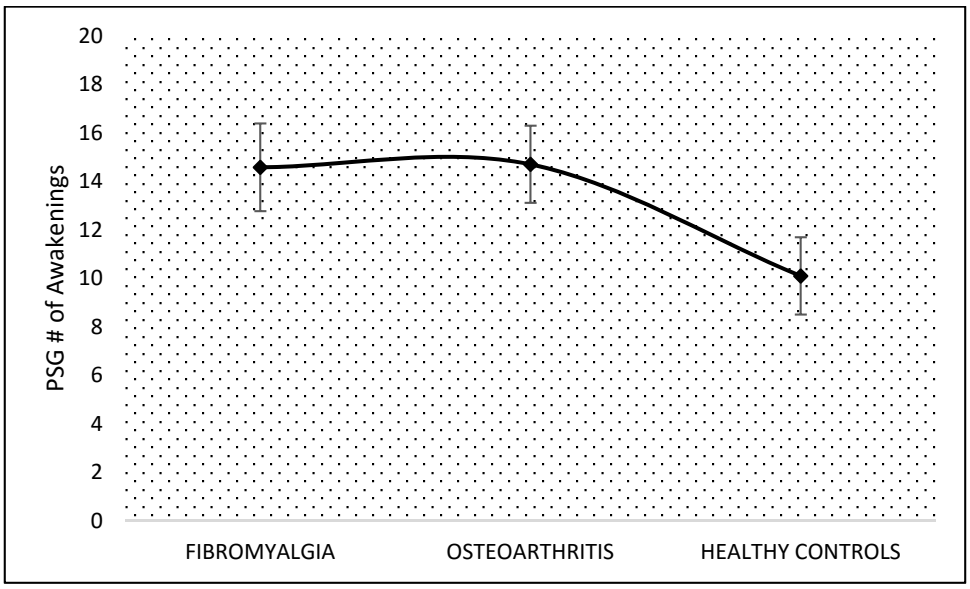



**Figure 4.15.** Plot of means depicting number of awakenings as measured using polysomnography between fibromyalgia, osteoarthritis and healthy control participants. Includes standard error bars for each observation.

### 4.3.3. Sleep Staging and Awakenings

The amount each group spent in each sleep stage was compared across the three groups. In addition, the number of sleep stage transitions, awakenings and arousals were also compared; these are utilised as measures of sleep fragmentation or sleep continuity. The results of the PSG data are displayed in table 4.8. Analysis of normality and homogeneity of variance are displayed in table 4.7. All variables met the assumption of equality of variance.

***Table 4.7. Skewness and Kurtosis Z scores and Levene's test for PSG sleep staging variables in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS Skew** *n=19* | **FMS Kurt** *n=19* | **OA Skew** *n=17* | **OA Kurt** *n=17* | **NHC Skew** *n=10* | **NHC Kurt** *n=10* | **Levene's** ***F, p*** |
|---|---|---|---|---|---|---|---|
| **N1[1]** | **4.26*** | **5.72*** | **2.45*** | 1.28 | **4.36*** | **6.91*** | 1.83, n.s. |
| **N2[2]** | 1.25 | -0.37 | -0.47 | -0.31 | 0.55 | -0.42 | 1.92, n.s. |
| **N3[3]** | -1.40 | 0.05 | **2.21*** | 1.39 | 0.85 | -0.13 | 1.08, n.s. |
| **REM[4]** | -0.85 | -0.41 | 0.27 | -0.44 | 0.60 | -0.24 | 0.87, n.s. |
| **SST[5]** | 0.91 | -0.17 | **2.32*** | 1.75 | 1.64 | 0.53 | 1.21, n.s. |
| **SST PH[6]** | 0.22 | -0.60 | 1.22 | 0.30 | 0.93 | 0.42 | 2.94, n.s. |
| **Awakenings[7]** | **4.54*** | **7.98*** | 0.95 | -0.59 | 1.08 | -0.51 | 0.22, n.s. |
| **Awakening-I[8]** | **2.57*** | **3.75*** | 0.05 | -1.30 | 0.71 | -0.81 | 0.55, n.s. |
| **Arousals[9]** | **3.38*** | **4.28*** | **2.92*** | 1.82 | 1.25 | -0.71 | 0.57, n.s. |
| **Arousal-I[10]** | **4.44*** | **7.18*** | **3.29*** | **3.19*** | 1.17 | -0.76 | 0.85, n.s. |

1. Non-REM Stage 1, 2. Non-REM Stage 2, 3. Non-REM Stage 3, 4. REM Stage, 5. Sleep Stage Transitions, 6. Sleep Stage Transitions per Hour of Sleep, 7. Number of Awakenings, 8. Awakening Index, 9. Number of Arousals, 10. Arousal Index; *Z>±1.96;

Overall, no significant differences in sleep staging were observed between the groups, apart from sleep stage transitions, a useful indicator for sleep fragmentation. This was shown to be particularly significant, when evaluated per hour of sleep. Observing the mean values, there was a numerical difference between the clinical groups and the healthy control group, which also had a large standard deviation. The figures 4.15 and 4.16 help visualise the mean values for these variables.

Post-hoc comparisons with a Bonferroni correction for multiple comparisons found, for sleep stage transitions a significantly greater number of SST for FMS compared to NHC (*Mdiff*=42.49, p=.043); a significantly greater number of SST for OA compared to NHC (*Mdiff*=46.99, p=.025); however, no differences between the clinical groups (p=n.s.). For SST per hour of sleep, a similar finding where FMS had greater SSTPH than NHC (*Mdiff*=4.52, p=.032); in addition to a greater SSTPH for OA compared to NHC (*Mdiff*=6.57, p=.001); and lastly no significant difference between FMS and OA (p=n.s.).

Overall, the groups had no significant differences between major sleep staging variables, however the sleep of the clinical groups appeared to be more fragmented (See Hypnograms [Appendix I]) than healthy controls via the measure of sleep stage transitions.

***Table 4.8. Polysomnographic sleep variables in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS (*M* ± *SD*)** *n=19* | **OA (*M* ± *SD*)** *n=17* | **NHC (*M* ± *SD*)** *n=10* | ***F*** | ***p*** | **$\eta^2$** |
|---|---|---|---|---|---|---|
| **NREM1**[1] | 2.15 ± 2.25 | 2.56 ± 2.13 | 4.32 ± 5.88 | 1.449 | .246 | .063 |
| **NREM2**[2] | 47.73 ± 12.33 | 46.51 ± 7.84 | 46.52 ± 9.06 | .080 | .924 | .004 |
| **NREM3**[3] | 26.41 ± 10.98 | 28.99 ± 8.69 | 23.52 ± 8.40 | 1.030 | .366 | .046 |
| **REM**[4] | 23.72 ± 3.37 | 21.94 ± 4.58 | 25.63 ± 4.51 | 2.612 | .085 | .108 |
| **SST**[5] | 119.79 ± 46.50 | 124.29 ± 46.13 | 77.30 ± 24.06 | 4.334 | .019* | .168 |
| **SST PH**[6] | 14.69 ± 4.06 | 16.74 ± 5.34 | 10.17 ± 2.42 | 7.297 | .002** | .253 |
| **Awakenings**[7] | 14.58 ± 7.89 | 14.71 ± 6.56 | 10.10 ± 5.04 | 1.703 | .194 | .073 |
| **Awakening-I**[8] | 2.03 ± 0.90 | 2.15 ± 0.85 | 1.40 ± 0.64 | 2.748 | .075 | .113 |
| **Arousals**[9] | 148.58 ± 131.46 | 125.71 ± 127.35 | 104.90 ± 75.88 | .454 | .638 | .021 |
| **Arousal-I**[10] | 20.04 ± 18.32 | 18.74 ± 19.40 | 14.28 ± 9.57 | .371 | .692 | .017 |

1. Non-REM Stage 1, 2. Non-REM Stage 2, 3. Non-REM Stage 3, 4. REM Stage, 5. Sleep Stage Transitions, 6. Sleep Stage Transitions per Hour of Sleep, 7. Number of Awakenings, 8. Awakening Index, 9. Number of Arousals, 10. Arousal Index; *p<.05; **p<.01;

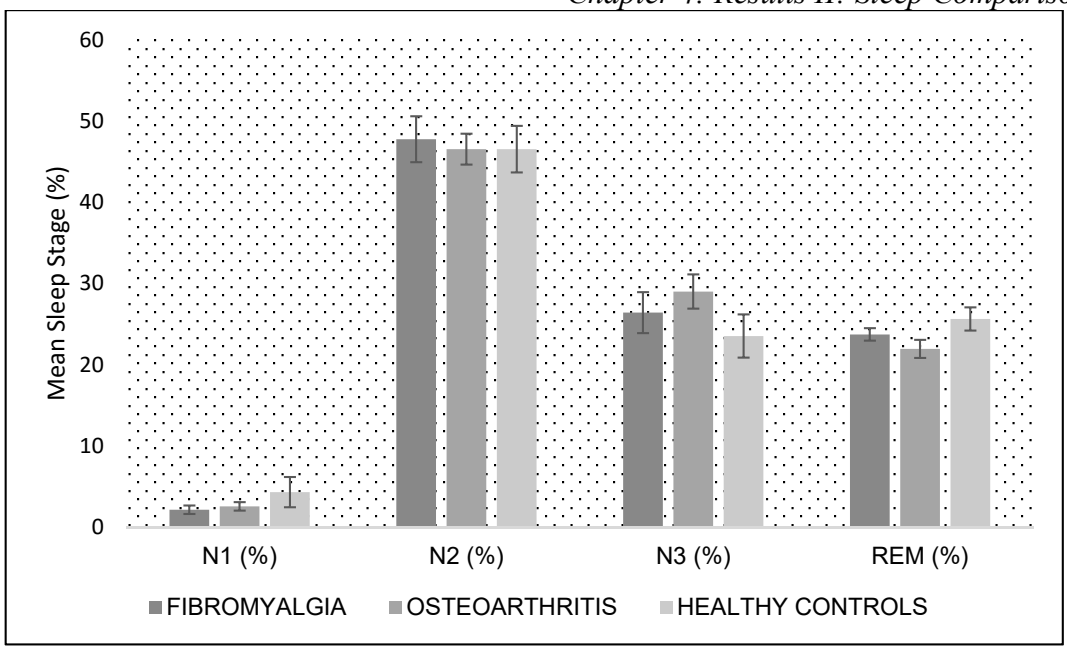



**Figure 4.16.** Bar chart depicting percentage of time spent in each stage of sleep as measured using polysomnography between fibromyalgia, osteoarthritis and healthy control participants.

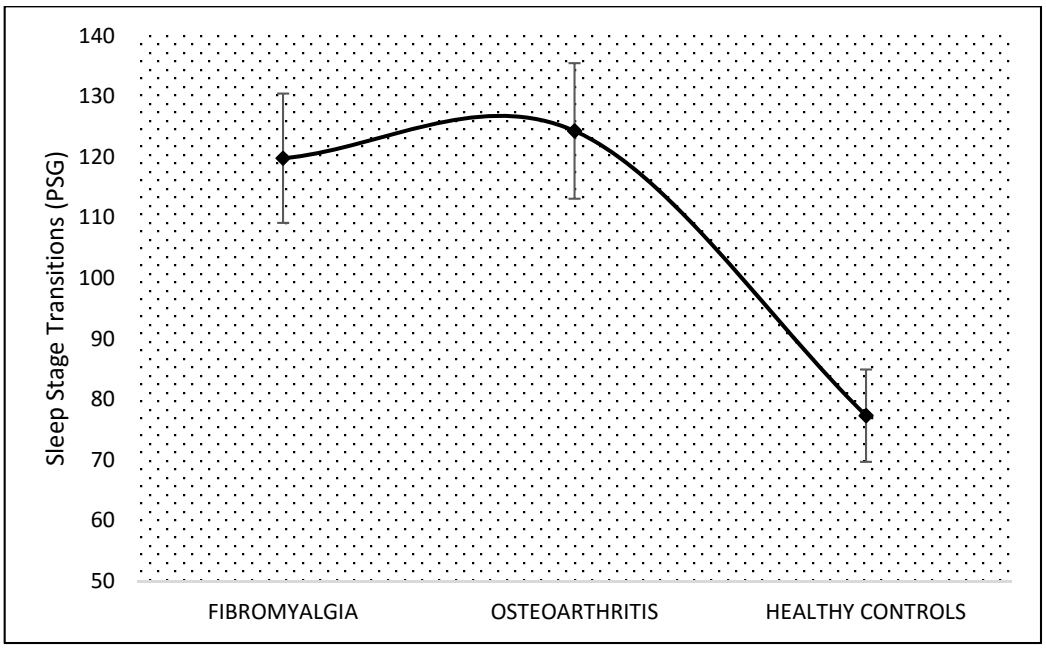



**Figure 4.17.** Plot of means depicting number of sleep stage transitions as measured using polysomnography between fibromyalgia, osteoarthritis and healthy control participants. Includes standard error bars for each observation.

## 4.4. Subjective and Objective Differences in Sleep Variables

Differences in subjective and objective measures of total sleep time, sleep onset latency and sleep efficiency were examined. Paired samples t-tests were run on each group to observe differences between PSQI assessed TST, SOL and SE, and PSG assessed TST, SOL and SE. Table 4.7 displays the results. The results indicated that the clinical groups significantly underestimated the amount of sleep they had, and no significant differences were found in the NHC group. No differences in SOL perception were observed. In addition, a significant difference was also observed in subjective reports of sleep efficiency vs objectively measured sleep efficiency, where the clinical groups reported a much lower sleep efficiency (as calculated from the PSQI) than was objectively recorded (via PSG) vs the NHC group. Figures 4.18-4.20 display graphically the difference in subjective and objective scores.

***Table 4.9. T-Test results looking at differences between subjective and objective scores for FMS, OA and NHC in TST, SOL and SE***

| | **FMS (n=19)** | | | **OA (n=17)** | | | **NHC (n=10)** | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***t*** | ***df*** | ***p*** | ***t*** | ***df*** | ***p*** | ***t*** | ***df*** | ***p*** |
| **TST[1]** | -5.28 | 18 | .000** | -2.15 | 16 | .047* | .282 | 9 | n.s. |
| **SOL[2]** | 2.06 | 18 | .055 | 1.14 | 16 | n.s. | -1.68 | 9 | n.s. |
| **SE[3]** | -5.72 | 18 | .000** | -4.73 | 16 | .000** | -1.44 | 9 | n.s. |

1. Subjective vs Objective Total Sleep Time, 2. Subjective vs Objective Sleep Onset Latency, 3. Subjective vs Objective Sleep Efficiency Percentage; *p<.05; **p<.001;

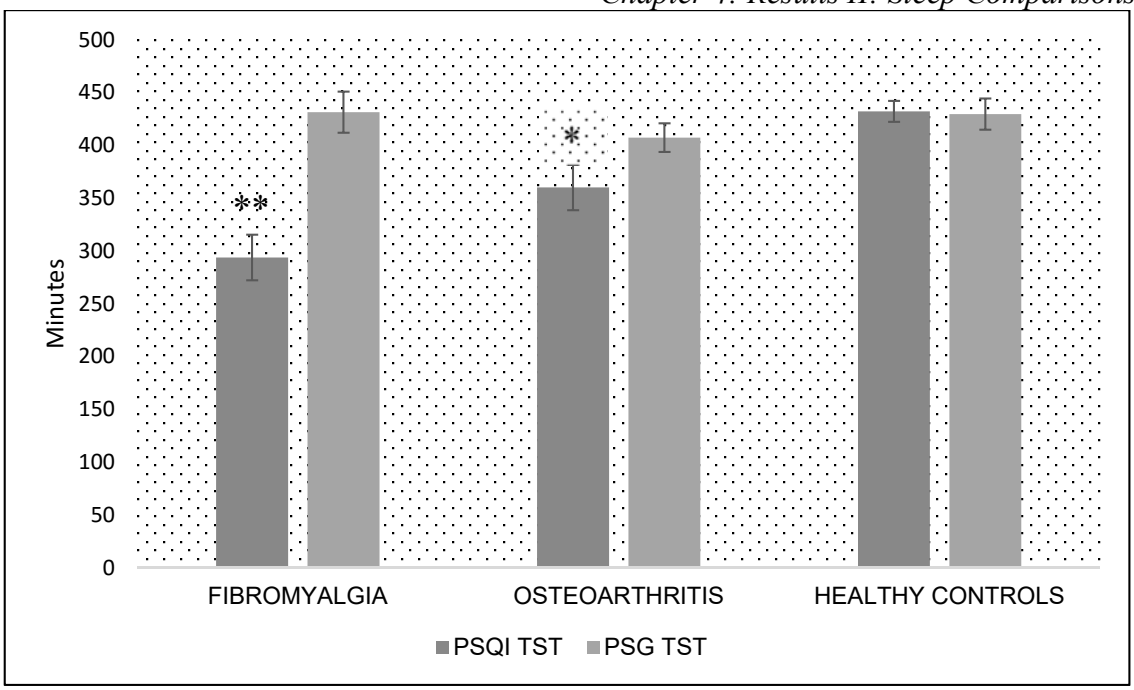



**Figure 4.18.** Plot of means comparing subjective and objective total sleep time as measured using the PSQI and polysomnography. Shows data for fibromyalgia, osteoarthritis and healthy control participants. Includes standard error bars for each observation. *p<.05 **p<.001;

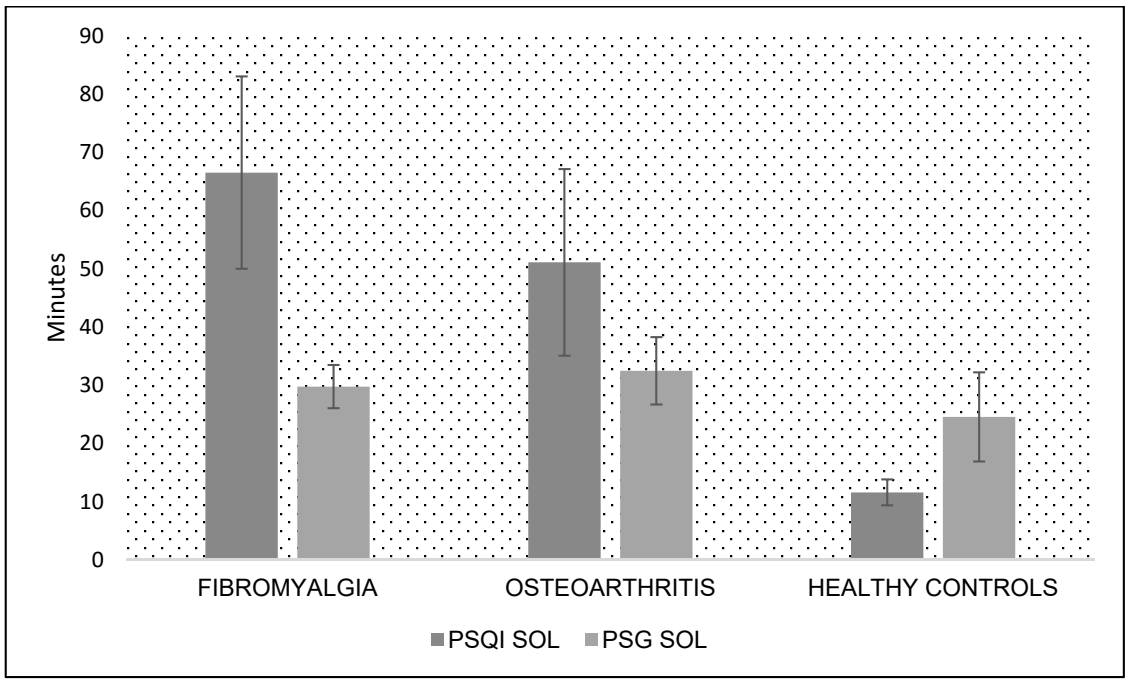



**Figure 4.19.** Plot of means comparing subjective and objective sleep onset latency as measured using the PSQI and polysomnography. Shows data for fibromyalgia, osteoarthritis and healthy control participants. Includes standard error bars for each observation.

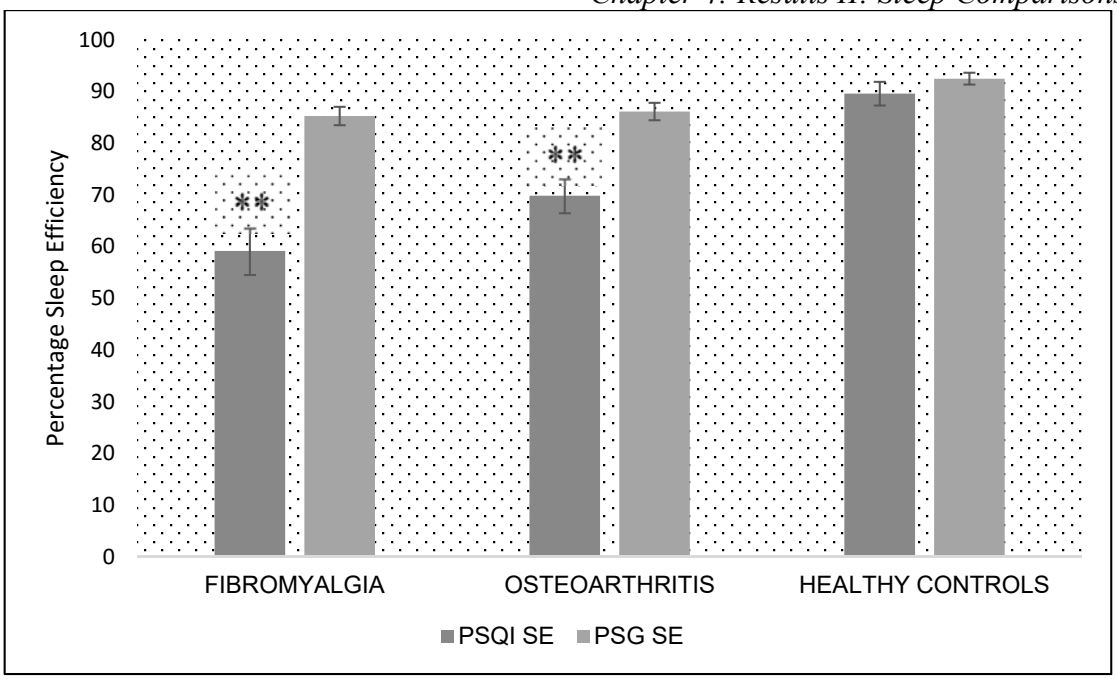



**Figure 4.20.** Plot of means comparing subjective and objective sleep efficiency as measured using the PSQI and polysomnography. Shows data for fibromyalgia, osteoarthritis and healthy control participants. Includes standard error bars for each observation. **p<.001;

Looking at these results, to further compare the significant findings in the clinical groups, differences in subjective vs objectively recorded TST and SE were calculated. The results were then compared between the clinical groups. For TST, an independent samples t-test (with assumed equality of variance) found that the FMS (*M*=-137.58±113.68) group had a greater discrepancy than OA (*M*=-47.18±90.45) in self-reported total sleep time [*t* (34) =-2.62, *p*=.013)] where they reported a significantly lower TST than the OA group.

For sleep efficiency, no differences between the FMS group (*M*=-26.09±19.87) or OA group (*M*=-16.28±14.20) were found [*t* (34) =1.685, *p*=n.s.)]. Figure 4.21 displays graphically the differences in TST and SE difference scores.

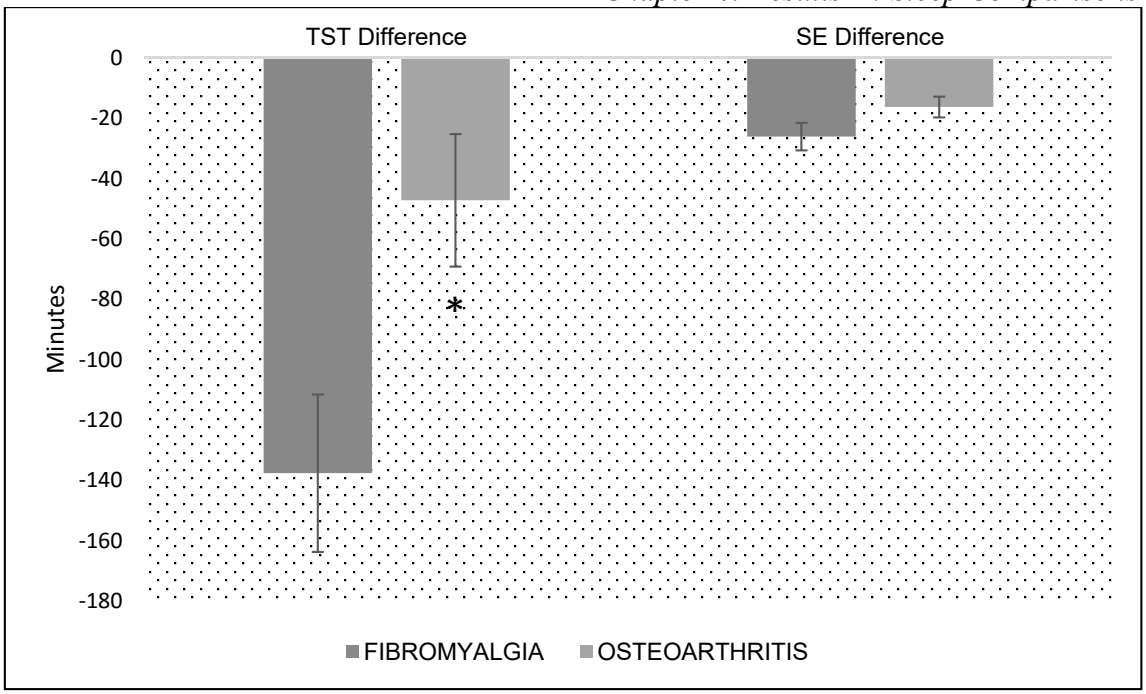



**Figure 4.21.** Plot of means comparing the subjective and objective difference values for total sleep time and sleep efficiency between fibromyalgia and osteoarthritis. Includes standard error bars for each observation. *p<.05;

## 4.5. Spectral Analysis

The aim of spectral analysis for the PSG data from the three groups was to investigate the microstructure of sleep in FMS patients. Not only to answer the primary hypothesis of 'do patients exhibit a greater alpha power in delta wave sleep' but also to explore other areas of sleep structure in these patient groups. One of which is looking at the higher frequency ranges such as sigma, which can be used as a robust indicator of sleep spindle activity (Knoblauch et al., 2003).

The following data represents findings obtained from the C3-A2 channel from the second night of PSG recording. The second night was used as a way for the patient/participant to adjust to sleeping with the PSG, thus giving a more reliable reading. The C3-A2 channel was opted for, as that was what appeared to be the most robust, with the least amount of noise.

Tables 4.10 to 4.13 display the means and standard deviations of logarithmic averaged absolute spectral power in their individual frequency bands with a range from 0.1Hz to 48Hz. These are values that are separated in terms of sleep stages and also in terms of cycles per night for the first three cycles. Table 4.9 shows data across the whole night of sleep; Table 4.11 to 4.13 are data from cycles 1-3.

### 4.5.1. Whole Night Sleep Analysis

#### 4.5.1.1. Comparisons for NREM Merged

Looking at the full night of sleep (Table 4.10), on the outset, gradients where the greatest absolute power was observed for the FMS group, followed by OA and lastly NHC having the lowest spectral power, were observed for the alpha (8-12Hz), sigma-2 (14-16Hz) and beta-1 (16-24Hz) frequency. During NREM sleep no significant differences were observed between the three groups for absolute power other than sigma-2, this was also true for N2 sleep separated. Post-hoc analysis with Bonferroni corrections for multiple comparisons were conducted using the Mann-Whitney U test. During NREM merged, no significant differences were found between FMS and OA ($U$=150.00, $p$=n.s.). No significant differences were found between FMS and NHC ($U$=53.00, $p$=n.s.). However, the OA group had significantly greater sigma-2 power than the NHC group ($U$=33.00, $p$=0.003).

#### 4.5.1.2. Comparisons for N2

For the whole of N2, a similar gradient observation was made for alpha, sigma-2 and beta-1. However, sigma-2 was the only significant variable. After post-hoc analysis for sigma-2, no significant differences were observed for FMS compared to OA ($U$=146.00, $p$=n.s.) and FMS compared to NHC ($U$=50.00, $p$=n.s.); however, the statistic showed a significant difference prior to corrections for multiple comparisons, which may indicate a need for further data to increase the power statistic. Lastly OA were found to have a significantly greater sigma-2 power than NHC ($U$=35.00, $p$=.033).

#### 4.5.1.3. Comparisons for N3 & REM

During N3 slow wave sleep, significant differences were observed between the groups in terms of total absolute power, delta-1 (0.1-1Hz) and sigma-2 (14-16Hz). Post-hoc analysis for total absolute power (0.1-48Hz range) in N3 showed no significant differences between FMS and OA groups ($U$=108.00, $p$=n.s.) or FMS and NHC ($U$=80.00, $p$=n.s.). However, OA had significantly lower total absolute power than the NHC group ($U$=37.00, $p$=.045).

For delta-1, no differences were observed between FMS and OA ($U$=95.00, $p$=n.s.), but may be worth to note a significant effect prior to corrections for multiple comparisons. FMS and NHC groups also showed no significant differences ($U$=69.00, $p$=n.s.). Nevertheless, a significant difference was observed between OA and NHC group

(*U*=25.00, *p*=.006) where the OA group had significantly lower delta-1 power than the healthy control group.

Lastly sigma-2 showed no differences between FMS and OA (*U*=158.00, *p*=n.s.) or FMS and NHC (*U*=49.00, *p*=n.s. [sig. prior to bf. correction]). OA patients had significantly greater sigma-2 power than the NHC group (*U*=37.00, *p*=.045).

REM sleep showed no differences in absolute power between any of the groups.

### 4.5.2. Comparisons per Sleep Cycle Analysis

Differences in absolute power spectra were analysed for the first three cycles of sleep to determine any differences between the three groups.

#### 4.5.2.1. Cycle 1

For the first cycle of sleep (Table 4.11), no differences in absolute power spectra across the 0.1-48Hz frequency range for either NREM, N2 or N3 were observed. However, the same gradients were observed for alpha and sigma-2 with the greatest amount of absolute power in FMS, then OA and lowest being NHC. The same was true for alpha, sigma-2 and beta-2 in N2. REM was not reported for cycle 1 due to the method by which we conducted cycle analysis.

#### 4.5.2.2. Cycle 2

For the second cycle of sleep (Table 4.12), no significant differences in absolute power spectra were observed for NREM merged, N2 or REM. However similar gradients were observed for the alpha frequency for NREM merged, N2 and N3, where FMS had the greatest power, followed by OA and the lowest being the NHC group. During N3, significant mean differences were observed for total averaged power and also delta-1. Post-hoc comparisons for total averaged power found no differences between FMS and OA (*U*=95.00, *p*=n.s.) or FMS and NHC (*U*=61.00, *p*=n.s.). OA patients had a significantly lower total averaged power than NHC (*U*=24.00, *p*=.012). Comparisons for delta-1 found a significantly lower power in OA patients as compared to FMS patients (*U*=77.00, *p*=.033), and NHC participants (*U*=13.00, *p*<.001). No differences were observed between FMS and NHC group (*U*=51.00, *p*=n.s.).

#### 4.5.2.3. Cycle 3

##### 4.5.2.3.1. Comparisons for NREM Merged

Significant differences in sigma-2 were found for the whole period of NREM sleep during cycle 3 (Table 4.13). Gradient trends were observed for alpha and sigma-2. Post-hoc comparisons found no significant differences between FMS and OA ($U$=151.00, $p$=n.s.) or NHC ($U$=48.00, $p$=n.s. [although FMS had significantly greater power prior to multiple comparison corrections]). OA had a significantly greater sigma-2 power than NHC ($U$=29.00, $p$=.012).

##### 4.5.2.3.2. Comparisons for N2

For N2, significant differences were observed in the delta-1 and sigma-2 frequency. Similar gradient trends were observed for alpha and beta-2. Post-hoc comparisons for delta-1 found no differences between FMS and OA ($U$=112.00, $p$=n.s.) or NHC ($U$=57.00, $p$=n.s.). OA patients had significantly lower delta-1 power than NHC ($U$=36.00, $p$=.039). For sigma-2, no differences were observed between FMS and OA ($U$=160.00, $p$=n.s.) or NHC ($U$=45.00, $p$=n.s. [although FMS had significantly greater sigma-2 power prior to corrections for multiple comparisons]). OA patients had a significantly greater sigma-2 power than NHC participants ($U$=23.00, $p$=.003).

##### 4.5.2.3.3. Comparisons for N3 and REM

For NREM 3, no significant differences were observed across the frequency bands apart from delta-1 where the clinical groups appear to have lower delta power than the NHC group. The same gradient trends are observed for sigma-2. Post-hoc analysis for delta-1 showed no significant differences between FMS and OA ($U$=132.00, $p$=n.s.), or NHC ($U$=50.00, $p$=n.s.). OA patients were found to have significantly lower delta-1 power than NHC ($U$=25.00, $p$=.006). Lastly, no significant differences were observed during the REM period for cycle 3 of sleep.

### 4.5.3. Fast Frequency Sleep Interruptions

#### 4.5.3.1. Comparisons for Alpha Wave activity

In relation to alpha wave activity during slow wave sleep, no significant differences were observed between the three groups. However, there was a trend towards an increase in alpha power in FMS patients compared with OA and both clinical groups had a numerically greater alpha power than healthy controls. This was true for averaged spectral power for N3 across the whole night (Table 4.10; Figure 4.22). The alpha power during

SWS in FMS was 3.19±1.03 compared with OA 2.92±0.60 and the healthy control group 2.66±0.35. Although there appears to be greater variability in the FMS patients. Looking at this effect cycle by cycle, the effect is strongest during cycle 2 of sleep, with cycles 1 and 3 not showing a clear difference between the clinical groups, although the clinical groups have shown a stronger power in alpha frequency consistently throughout the cycles as compared to the healthy control group. This may indicate a likely effect of pain on sleep restoration.

In addition to slow wave sleep, numerically, alpha power was generally stronger in FMS patients, with OA having the second greatest alpha power and the lowest being NHC. This is observed to be true for both NREM as a whole, and N2 separated, in addition to sleep cycles 1, 2 and 3 (Figure 4.22).

#### 4.5.3.2. Comparisons for Sigma-2 (14-16Hz)

The averaged power in the sigma-2 variable were found to have significant group differences at certain periods of the night. The activity shown in the sigma-2 falls within possible spindle activity in the range of 11-16 Hz. During the whole period of sleep, there were differences observed in NREM sleep, N2 and N3 separated. There appeared to be the greatest numerically observed power in the FMS group, followed by OA and lowest being the NHC group. However only the OA group appeared to have a significantly greater amount of sigma-2 power than the NHC group for all three sleep stage groupings. This was due to the greater variability of sleep in FMS patients.

During cycle 1 of sleep, the same mean trends can be observed, the strongest difference seen during N2, however during N3, FMS had a lower sigma-2 power than OA patients. Although during cycle 1, no objective differences were found between the three groups. Cycle 2 showed similar results, with cycle 3 showing the strongest differences in the three groups. During this period, again it was found that the OA group had significantly greater sigma-2 power than the NHC group with no differences found for the FMS group. This may further imply the sigma-2 intrusions are perhaps solely a function/result of chronic pain.

### 4.5.4. Comparisons for Delta (Slow Wave Activity)

During periods of the night, the groups showed significant differences in slow wave activity in the delta-1 range (0.1-1 Hz), where the OA group appeared to have significantly lower delta-1 power than FMS and NHC groups during N3. This was found to be true for averaged power across the whole night where the OA group had lower delta-1 power than the healthy control group. During cycle 2 of sleep, OA were found to have significantly lower delta-1 power than both FMS and NHC, and during cycle 3 lower delta-1 power compared to NHC was found for OA patients during N2 and N3. This may further indicate a modified sleep structure as a function of chronic pain, in this patient groups.

Figures 4.22 to 4.26 depict the spectral power for each frequency at different stages of sleep and for cycle by cycle observations.

***Table 4.10. Profiles of Absolute Spectral Power for fibromyalgia, osteoarthritis and healthy control participants***

Logarithmic absolute mean power in all frequency bands (Total 0.1-48Hz, Delta-1 0.1-1Hz, Delta-2 1-3.5Hz, Theta 3.5-8Hz, Alpha 8-12Hz, Sigma-1 12-14Hz, Sigma-2 14-16Hz, Beta-1 16-24Hz, Beta-2 24-32Hz, Gamma 32-48Hz) in the sleep EEG (C3-A2 derivation) for sleep stages NREM Merged, N2-3 and REM.

| Sleep Stage | Group *(n)* | Total | Delta-1 | Delta-2 | Theta | Alpha | Sigma-1 | Sigma-2 | Beta-1 | Beta-2 | Gamma |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **NREM1-3** | **FMS** *(19)* | 5.64 ± .59 | 4.63 ± .69 | 4.54 ± .54 | 3.73 ± .60 | 2.99 ± .63 | 1.84 ± .67 | 1.12 ± .80 | 1.17 ± .80 | .35 ± .88 | .28 ± 1.02 |
| | **OA** *(17)* | 5.49 ± .30 | 4.36 ± .42 | 4.49 ± .29 | 3.67 ± .33 | 2.82 ± .53 | 1.65 ± .50 | .98 ± .39 | 1.08 ± .38 | .10 ± .37 | -.21 ± .31 |
| | **NHC** *(10)* | 5.68 ± .30 | 4.77 ± .35 | 4.64 ± .31 | 3.70 ± .27 | 2.70 ± .38 | 1.82 ± .50 | .61 ± .27 | .97 ± .46 | .18 ± .60 | -.03 ± .62 |
| ***K(p)*** | | 1.944(p=n.s.) | 5.304(p=n.s.) | 1.021(p=n.s.) | .451(p=n.s.) | 1.554(p=.460) | .504(p=n.s.) | **6.276(p=.043)*** | 1.789(p=n.s.) | 1.824(p=n.s.) | 5.681(p=n.s.) |
| **N2** | **FMS** *(19)* | 5.24 ± .35 | 4.02 ± .41 | 4.11 ± .31 | 3.50 ± .44 | 2.88 ± .49 | 1.82 ± .54 | 1.15 ± .62 | 1.20 ± .54 | .34 ± .58 | .21 ± .70 |
| | **OA** *(17)* | 5.17 ± .28 | 3.84 ± .36 | 4.14 ± .26 | 3.50 ± .34 | 2.76 ± .50 | 1.67 ± .51 | 1.09 ± .42 | 1.18 ± .36 | .18 ± .36 | -.15 ± .30 |
| | **NHC** *(10)* | 5.28 ± .24 | 4.14 ± .30 | 4.21 ± .22 | 3.51 ± .27 | 2.70 ± .42 | 1.97 ± .52 | .72 ± .27 | 1.08 ± .50 | .28 ± .64 | .07 ± .68 |
| ***K(p)*** | | 1.745(p=n.s.) | 4.896(p=n.s.) | .874(p=n.s.) | .635(p=n.s.) | 1.034(p=n.s.) | 2.567(p=n.s.) | **6.467(p=.039)*** | 2.502(p=n.s.) | 2.071(p=n.s.) | 4.733(p=n.s.) |
| **N3** | **FMS** *(19)* | 6.29 ± .90 | 5.50 ± .93 | 5.18 ± .84 | 4.08 ± .92 | 3.19 ± 1.03 | 1.88 ± 1.07 | 1.04 ± 1.21 | 1.11 ± 1.31 | .33 ± 1.43 | .34 ± 1.59 |
| | **OA** *(17)* | 5.97 ± .27 | 5.07 ± .38 | 4.97 ± .28 | 3.90 ± .31 | 2.92 ± .60 | 1.62 ± .53 | .82 ± .41 | .94 ± .42 | -.01 ± .40 | -.29 ± .34 |
| | **NHC** *(10)* | 6.27 ± .28 | 5.58 ± .35 | 5.19 ± .25 | 3.93 ± .23 | 2.66 ± .35 | 1.64 ± .44 | .44 ± .33 | .79 ± .49 | .04 ± .60 | -.16 ± .60 |
| ***K(p)*** | | **6.000(p=.05)*** | **9.809(p=.007)**** | 3.999(p=n.s.) | .506(p=n.s.) | 3.439(p=n.s.) | .055(p=n.s.) | **6.267(p=.044)*** | 1.318(p=n.s.) | .963(p=n.s.) | 5.031(p=n.s.) |
| **REM** | **FMS** *(19)* | 4.56 ± .45 | 3.03 ± .55 | 3.45 ± .42 | 3.13 ± .53 | 2.20 ± .65 | .61 ± .60 | .33 ± .60 | 1.24 ± .59 | .42 ± .60 | -.01 ± .55 |
| | **OA** *(17)* | 4.46 ± .42 | 2.86 ± .51 | 3.35 ± .43 | 3.02 ± .47 | 2.08 ± .57 | .59 ± .42 | .39 ± .41 | 1.33 ± .41 | .44 ± .46 | -.08 ± .32 |
| | **NHC** *(10)* | 4.43 ± .28 | 2.93 ± .25 | 3.36 ± .21 | 2.92 ± .39 | 1.96 ± .56 | .48 ± .45 | .17 ± .46 | 1.12 ± .58 | .31 ± .68 | .03 ± .77 |
| ***K(p)*** | | 1.248(p=n.s.) | 1.171(p=n.s.) | .314(p=n.s.) | 2.567(p=n.s.) | 1.495(p=n.s.) | .682(p=n.s.) | 2.305(p=n.s.) | 3.584(p=n.s.) | 1.447(p=n.s.) | .829(p=n.s.) |

FMS, patients with fibromyalgia syndrome; OA, patients with osteoarthritis; NHC, normal healthy controls; *$p<.05$; **$p<.01$;

### *Table 4.11. Means and Standard Deviations of Cycle 1 of Sleep*

Logarithmic absolute mean power in all frequency bands (Total 0.1-48Hz, Delta-1 0.1-1Hz, Delta-2 1-3.5Hz, Theta 3.5-8Hz, Alpha 8-12Hz, Sigma-1 12-14Hz, Sigma-2 14-16Hz, Beta-1 16-24Hz, Beta-2 24-32Hz, Gamma 32-48Hz) in the sleep EEG (C3-A2 derivation) for sleep stages NREM Merged, N2 & N3 during Cycle 1 of sleep.

| Sleep Stage | Group *(n)* | Total | Delta-1 | Delta-2 | Theta | Alpha | Sigma-1 | Sigma-2 | Beta-1 | Beta-2 | Gamma |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Cycle 1*** | | | | | | | | | | | |
| **NREM1-3** | **FMS** *(19)* | 6.01 ± .59 | 5.07 ± .57 | 5.00 ± .57 | 3.89 ± .51 | 3.00 ± .46 | 1.76 ± .51 | 1.03 ± .58 | 1.13 ± .50 | .35 ± .61 | .34 ± .77 |
| | **OA** *(17)* | 5.95 ± .43 | 4.90 ± .61 | 5.01 ± .45 | 3.97 ± .34 | 2.99 ± .62 | 1.72 ± .46 | 1.02 ± .38 | 1.18 ± .43 | .19 ± .42 | -.11 ± .41 |
| | **NHC** *(10)* | 6.16 ± .47 | 5.33 ± .57 | 5.19 ± .49 | 3.97 ± .31 | 2.79 ± .35 | 1.77 ± .48 | .62 ± .38 | 1.04 ± .55 | .21 ± .59 | .02 ± .81 |
| ***K(p)*** | | 1.188(p=n.s.) | 2.815(p=n.s.) | .531(p=n.s.) | .012(p=n.s.) | 1.846(p=n.s.) | .047(p=n.s.) | 5.929(p=n.s.) | .769(p=n.s.) | .984(p=n.s.) | 5.051(p=n.s.) |
| **N2** | **FMS** *(19)* | 5.46 ± .39 | 4.15 ± .48 | 4.44 ± .38 | 3.71 ± .50 | 2.95 ± .47 | 1.93 ± .54 | 1.34 ± .58 | 1.45 ± .53 | .65 ± .67 | .62 ± .87 |
| | **OA** *(16)* | 5.40 ± .28 | 3.95 ± .37 | 4.45 ± .31 | 3.76 ± .31 | 2.90 ± .47 | 1.90 ± .54 | 1.29 ± .40 | 1.46 ± .37 | .43 ± .37 | .08 ± .37 |
| | **NHC** *(10)* | 5.54 ± .30 | 4.31 ± .31 | 4.57 ± .34 | 3.80 ± .37 | 2.89 ± .44 | 2.07 ± .49 | .97 ± .41 | 1.30 ± .51 | .40 ± .52 | .18 ± .69 |
| ***K(p)*** | | 1.255(p=n.s.) | 4.253(p=n.s.) | .694(p=n.s.) | .014(p=n.s.) | .283(p=n.s.) | .916(p=n.s.) | 4.495(p=n.s.) | 1.020(p=n.s.) | 2.190(p=n.s.) | 4.969(p=n.s.) |
| **N3** | **FMS** *(18)* | 6.28 ± .58 | 5.48 ± .71 | 5.24 ± .58 | 3.98 ± .48 | 3.02 ± .45 | 1.67 ± .51 | .83 ± .49 | .95 ± .49 | .19 ± .66 | .22 ± .81 |
| | **OA** *(17)* | 6.19 ± .37 | 5.25 ± .49 | 5.24 ± .39 | 4.07 ± .32 | 3.03 ± .67 | 1.69 ± .49 | .93 ± .43 | 1.05 ± .46 | .09 ± .44 | -.21 ± .44 |
| | **NHC** *(10)* | 6.43 ± .37 | 5.71 ± .44 | 5.42 ± .39 | 4.05 ± .27 | 2.77 ± .33 | 1.67 ± .42 | .49 ± .40 | .92 ± .62 | .11 ± .65 | -.05 ± .86 |
| ***K(p)*** | | 2.679(p=n.s.) | 4.909(p=n.s.) | 1.457(p=n.s.) | .170(p=n.s.) | 2.616(p=n.s.) | .406(p=n.s.) | 5.616(p=n.s.) | .629(p=n.s.) | .391(p=n.s.) | 3.467(p=n.s.) |

FMS, patients with fibromyalgia syndrome; OA, patients with osteoarthritis; NHC, normal healthy controls. N.B. REM was not calculated for cycle 1 of sleep due to the nature of sleep cycle definition in this case.

### *Table 4.12. Means and Standard Deviations of Cycle 2 of Sleep*

Logarithmic absolute mean power in all frequency bands (Total 0.1-48Hz, Delta-1 0.1-1Hz, Delta-2 1-3.5Hz, Theta 3.5-8Hz, Alpha 8-12Hz, Sigma-1 12-14Hz, Sigma-2 14-16Hz, Beta-1 16-24Hz, Beta-2 24-32Hz, Gamma 32-48Hz) in the sleep EEG (C3-A2 derivation) for sleep stages NREM Merged, N2, N3 & REM, during Cycle 2 of sleep.

| Sleep Stage | Group *(n)* | Total | Delta-1 | Delta-2 | Theta | Alpha | Sigma-1 | Sigma-2 | Beta-1 | Beta-2 | Gamma |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Cycle 2*** | | | | | | | | | | | |
| **NREM1-3** | **FMS** *(19)* | 5.79 ± .64 | 4.89 ± .81 | 4.67 ± .63 | 3.70 ± .53 | 2.90 ± .53 | 1.65 ± .57 | .87 ± .57 | .98 ± .50 | .18 ± .65 | .13 ± .82 |
| | **OA** *(17)* | 5.62 ± .35 | 4.59 ± .51 | 4.61 ± .32 | 3.72 ± .34 | 2.86 ± .54 | 1.65 ± .53 | .90 ± .41 | 1.03 ± .43 | .06 ± .42 | -.27 ± .37 |
| | **NHC** *(10)* | 5.82 ± .45 | 5.00 ± .62 | 4.73 ± .44 | 3.73 ± .32 | 2.68 ± .39 | 1.71 ± .48 | .59 ± .33 | .90 ± .39 | .13 ± .56 | -.10 ± .65 |
| ***K(p)*** | | 1.141(p=n.s.) | 3.939(p=n.s.) | .445(p=n.s.) | .066(p=n.s.) | 1.287(p=n.s.) | .244(p=n.s.) | 4.414(p=n.s.) | .639(p=n.s.) | .952(p=n.s.) | 3.665(p=n.s.) |
| **N2** | **FMS** *(19)* | 5.31 ± .36 | 4.13 ± .45 | 4.21 ± .36 | 3.52 ± .45 | 2.86 ± .48 | 1.76 ± .58 | 1.05 ± .66 | 1.19 ± .54 | .34 ± .68 | .21 ± .88 |
| | **OA** *(17)* | 5.27 ± .29 | 3.98 ± .43 | 4.26 ± .27 | 3.56 ± .33 | 2.82 ± .51 | 1.73 ± .52 | 1.07 ± .40 | 1.21 ± .43 | .17 ± .41 | -.23 ± .32 |
| | **NHC** *(10)* | 5.33 ± .22 | 4.20 ± .37 | 4.25 ± .21 | 3.55 ± .24 | 2.77 ± .46 | 1.89 ± .51 | .67 ± .29 | 1.04 ± .43 | .18 ± .48 | -.02 ± .62 |
| ***K(p)*** | | .429(p=n.s.) | 1.201(p=n.s.) | .330(p=n.s.) | .013(p=n.s.) | .257(p=n.s.) | 1.105(p=n.s.) | 5.884(p=n.s.) | 1.968(p=n.s.) | 1.031(p=n.s.) | 3.671(p=n.s.) |
| **N3** | **FMS** *(18)* | 6.21 ± .45 | 5.51 ± .56 | 5.03 ± .48 | 3.91 ± .41 | 3.02 ± .49 | 1.62 ± .61 | .84 ± .51 | .91 ± .37 | .14 ± .55 | .12 ± .70 |
| | **OA** *(17)* | 5.92 ± .28 | 5.05 ± .42 | 4.87 ± .27 | 3.85 ± .31 | 2.89 ± .59 | 1.61 ± .57 | .78 ± .45 | .91 ± .44 | -.03 ± .43 | -.32 ± .39 |
| | **NHC** *(9)* | 6.31 ± .29 | 5.71 ± .31 | 5.12 ± .36 | 3.91 ± .23 | 2.69 ± .33 | 1.72 ± .49 | .41 ± .41 | .76 ± .49 | .02 ± .68 | -.19 ± .81 |
| ***K(p)*** | | **8.379(p=.015)*** | **13.537(p=.001)**** | 2.421(p=n.s.) | .534(p=n.s.) | 2.733(p=n.s.) | .339(p=n.s.) | 5.649(p=n.s.) | .922(p=n.s.) | 1.696(p=n.s.) | 5.946(p=n.s.) |
| **REM** | **FMS** *(18)* | 4.64 ± .54 | 3.07 ± .55 | 3.52 ± .50 | 3.24 ± .76 | 2.22 ± .70 | .76 ± .63 | .52 ± .64 | 1.30 ± .45 | .38 ± .43 | -.14 ± .27 |
| | **OA** *(17)* | 4.49 ± .43 | 2.80 ± .45 | 3.36 ± .44 | 3.06 ± .53 | 2.13 ± .64 | .70 ± .47 | .56 ± .46 | 1.48 ± .43 | .54 ± .48 | -.07 ± .28 |
| | **NHC** *(10)* | 4.72 ± .47 | 3.22 ± .67 | 3.62 ± .41 | 3.23 ± .53 | 2.22 ± .61 | .79 ± .43 | .47 ± .45 | 1.32 ± .57 | .41 ± .68 | .08 ± .92 |
| ***K(p)*** | | 1.526(p=n.s.) | 2.931(p=n.s.) | 1.778(p=n.s.) | .834(p=n.s.) | .766(p=n.s.) | .658(p=n.s.) | .300(p=n.s.) | 1.378(p=n.s.) | 1.038(p=n.s.) | .333(p=n.s.) |

FMS, patients with fibromyalgia syndrome; OA, patients with osteoarthritis; NHC, normal healthy controls; *$p$<.05; **$p$<.01;

### *Table 4.13. Means and Standard Deviations of Cycle 3 of Sleep*

Logarithmic absolute mean power in all frequency bands (Total 0.1-48Hz, Delta-1 0.1-1Hz, Delta-2 1-3.5Hz, Theta 3.5-8Hz, Alpha 8-12Hz, Sigma-1 12-14Hz, Sigma-2 14-16Hz, Beta-1 16-24Hz, Beta-2 24-32Hz, Gamma 32-48Hz) in the sleep EEG (C3-A2 derivation) for sleep stages NREM Merged, N2, N3 & REM, during Cycle 3 of sleep.

| Sleep Stage | Group *(n)* | Total | Delta-1 | Delta-2 | Theta | Alpha | Sigma-1 | Sigma-2 | Beta-1 | Beta-2 | Gamma |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Cycle 3*** | | | | | | | | | | | |
| **NREM1-3** | **FMS** *(19)* | 5.43 ± .49 | 4.42 ± .62 | 4.25 ± .50 | 3.56 ± .55 | 2.87 ± .52 | 1.76 ± .57 | 1.02 ± .63 | 1.02 ± .44 | .18 ± .48 | .11 ± .57 |
| | **OA** *(17)* | 5.36 ± .34 | 4.21 ± .48 | 4.33 ± .32 | 3.58 ± .35 | 2.83 ± .5.3 | 1.67 ± .52 | .98 ± .42 | 1.06 ± .39 | .06 ± .41 | -.24 ± .36 |
| | **NHC** *(10)* | 5.56 ± .28 | 4.65 ± .39 | 4.46 ± .25 | 3.61 ± .25 | 2.72 ± .42 | 1.89 ± .55 | .57 ± .18 | .90 ± .24 | .07 ± .26 | -.07 ± .34 |
| ***K(p)*** | | 1.965(p=n.s.) | 4.531(p=n.s.) | 1.711(p=n.s.) | .341(p=n.s.) | .711(p=n.s.) | 1.119(p=n.s.) | **7.530(p=.023)*** | 2.180(p=n.s.) | 1.841(p=n.s.) | 5.060(p=n.s.) |
| **N2** | **FMS** *(19)* | 5.26 ± .38 | 4.13 ± .45 | 4.08 ± .39 | 3.48 ± .52 | 2.85 ± .51 | 1.80 ± .57 | 1.08 ± .61 | 1.10 ± .45 | .23 ± .48 | .12 ± .59 |
| | **OA** *(17)* | 5.21 ± .28 | 3.93 ± .35 | 4.17 ± .24 | 3.51 ± .34 | 2.80 ± .52 | 1.70 ± .54 | 1.08 ± .42 | 1.15 ± .41 | .13 ± .40 | -.20 ± .34 |
| | **NHC** *(10)* | 5.39 ± .27 | 4.37 ± .39 | 4.29 ± .24 | 3.52 ± .28 | 2.74 ± .45 | 1.94 ± .57 | .64 ± .21 | .96 ± .23 | .11 ± .24 | -.02 ± .31 |
| ***K(p)*** | | 2.394(p=n.s.) | **7.407(p=.025)** | 2.663(p=n.s.) | .138(p=n.s.) | .331(p=n.s.) | 1.201(p=n.s.) | **8.932(p=.011)*** | 2.821(p=n.s.) | 1.122(p=n.s.) | 4.091(p=n.s.) |
| **N3** | **FMS** *(18)* | 5.74 ± .53 | 4.88 ± .73 | 4.55 ± .49 | 3.73 ± .54 | 2.95 ± .50 | 1.67 ± .55 | .88 ± .68 | .86 ± .50 | .07 ± .53 | .11 ± .64 |
| | **OA** *(17)* | 5.73 ± .36 | 4.79 ± .46 | 4.67 ± .35 | 3.77 ± .35 | 2.95 ± .57 | 1.64 ± .52 | .81 ± .43 | .93 ± .40 | -.03 ± .43 | -.25 ± .44 |
| | **NHC** *(10)* | 6.07 ± .24 | 5.35 ± .24 | 4.94 ± .34 | 3.89 ± .31 | 2.77 ± .42 | 1.84 ± .55 | .51 ± .25 | .91 ± .40 | .08 ± .42 | -.05 ± .49 |
| ***K(p)*** | | 4.882(p=n.s.) | **8.151(p=.017)*** | 4.624(p=n.s.) | .289(p=n.s.) | 1.576(p=n.s.) | 1.044(p=n.s.) | 5.043(p=n.s.) | .015(p=n.s.) | 1.211(p=n.s.) | 3.987(p=n.s.) |
| **REM** | **FMS** *(19)* | 4.60 ± .47 | 2.99 ± .57 | 3.49 ± .47 | 3.23 ± .56 | 2.29 ± .66 | .64 ± .57 | .36 ± .55 | 1.19 ± .45 | .26 ± .40 | -.19 ± .27 |
| | **OA** *(17)* | 4.48 ± .37 | 2.86 ± .47 | 3.38 ± .39 | 3.03 ± .43 | 2.09 ± .55 | .63 ± .46 | .44 ± .47 | 1.38 ± .48 | .43 ± .49 | -.13 ± .30 |
| | **NHC** *(10)* | 4.47 ± .33 | 3.02 ± .52 | 3.41 ± .27 | 2.96 ± .40 | 2.00 ± .56 | .49 ± .44 | .14 ± .36 | 1.01 ± .28 | .10 ± .41 | -.24 ± .34 |
| ***K(p)*** | | 1.054(p=n.s.) | 1.283(p=n.s.) | .942(p=n.s.) | 3.308(p=n.s.) | 2.144(p=n.s.) | .556(p=n.s.) | 3.120(p=n.s.) | 4.297(p=n.s.) | 3.428(p=n.s.) | 1.314(p=n.s.) |

FMS, patients with fibromyalgia syndrome; OA, patients with osteoarthritis; NHC, normal healthy controls; **p*<.05;

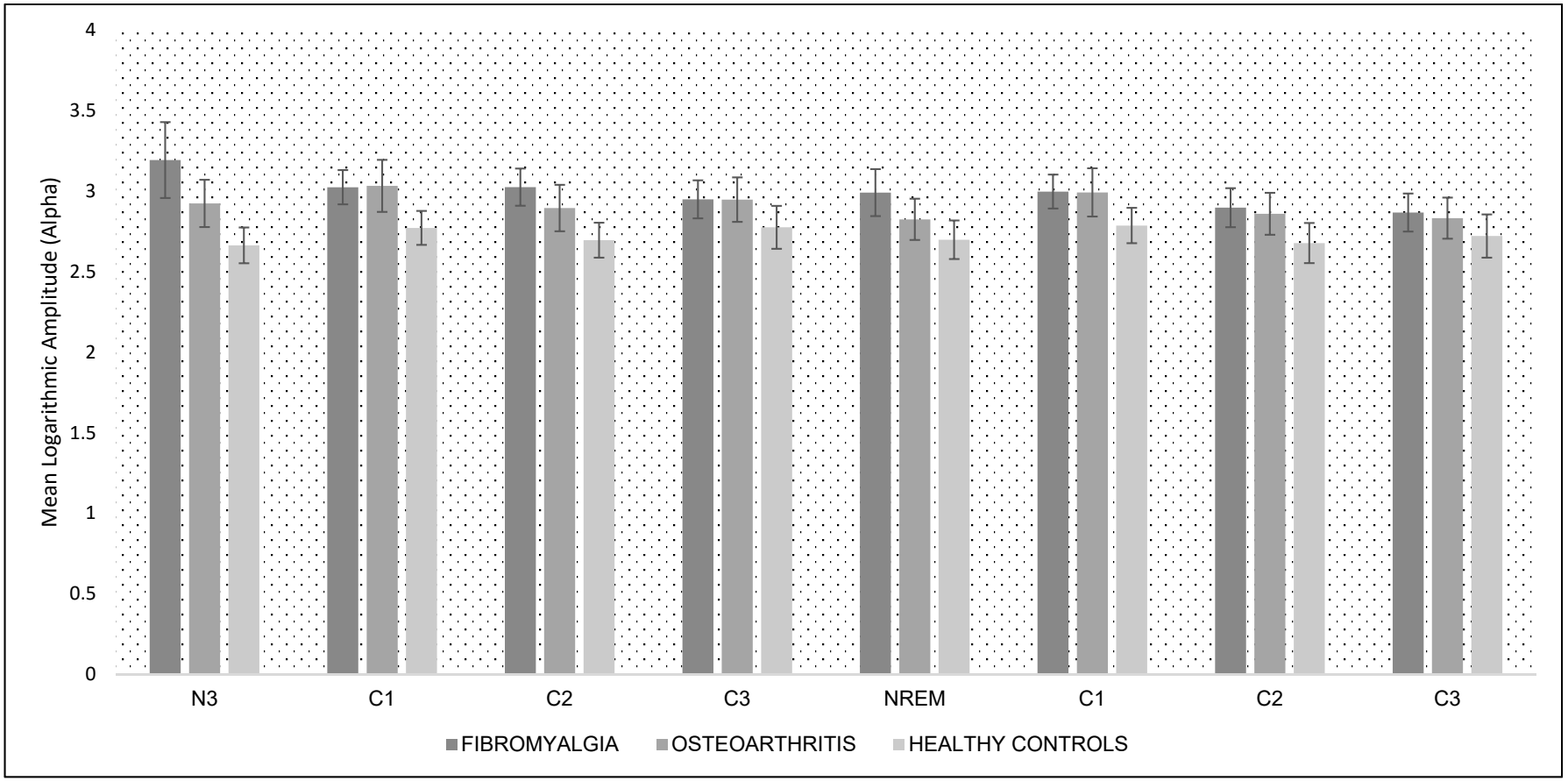



**Figure 4.22.** Bar graph depicting absolute spectral power (logarithmic) in the alpha frequency bin. Represents N3 and NREM sleep for the whole night and separated into the first three sleep cycles as measured using polysomnography between fibromyalgia, osteoarthritis and healthy control participants. ± Standard error bars are also displayed.

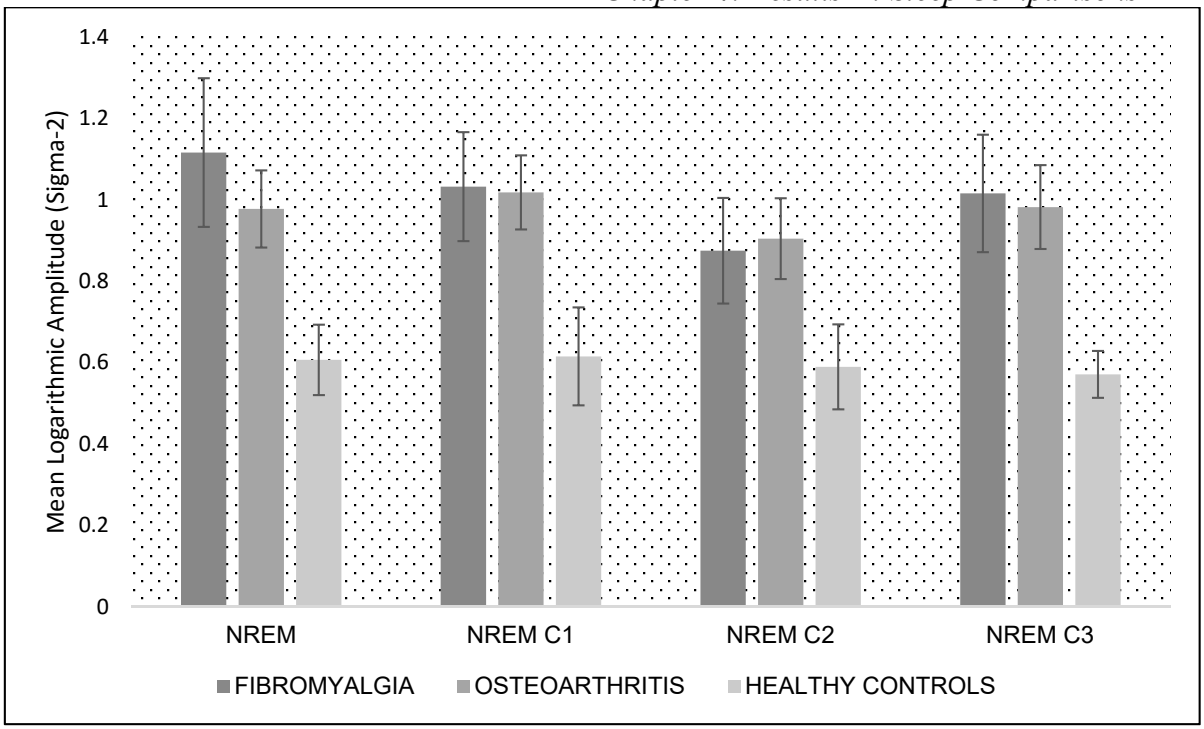



**Figure 4.23.** Bar graph depicting absolute spectral power (logarithmic) in the sigma-2 frequency bin. Represents the whole night of NREM sleep and NREM during the first three cycles of sleep. ± Standard error bars are also displayed.

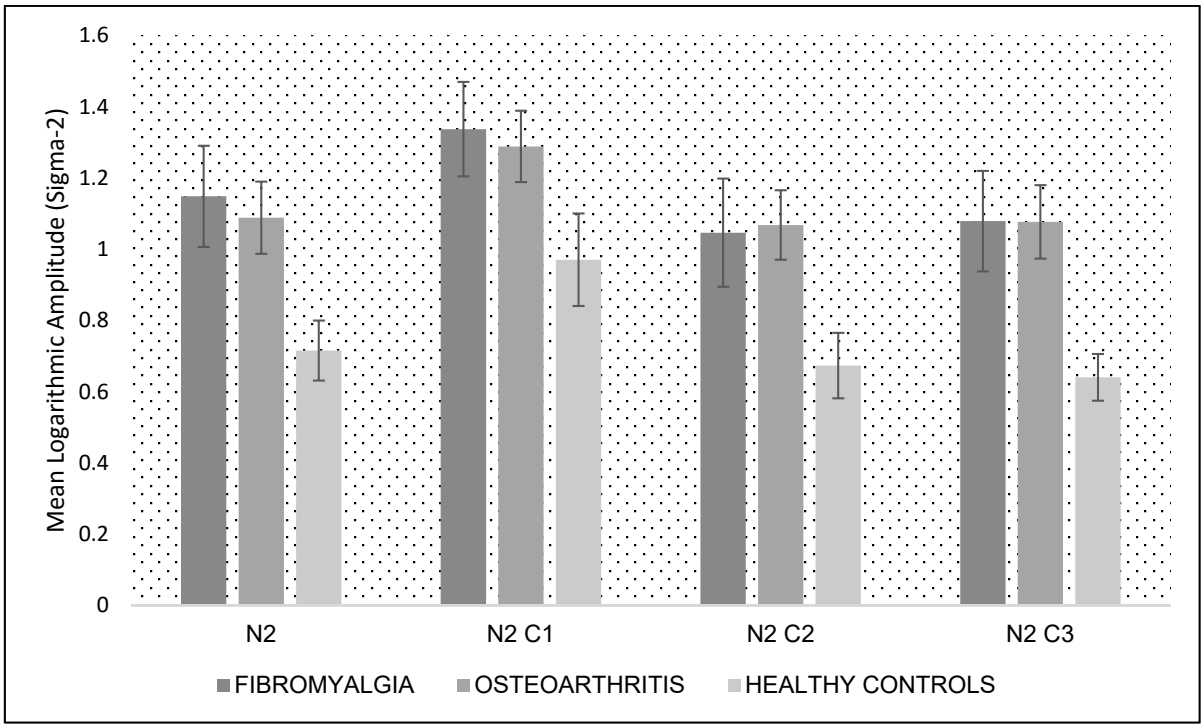



**Figure 4.24.** Bar graph depicting absolute spectral power (logarithmic) in the sigma-2 frequency bin. Represents the whole night of N2 sleep and N2 during the first three cycles of sleep. ± Standard error bars are also displayed.

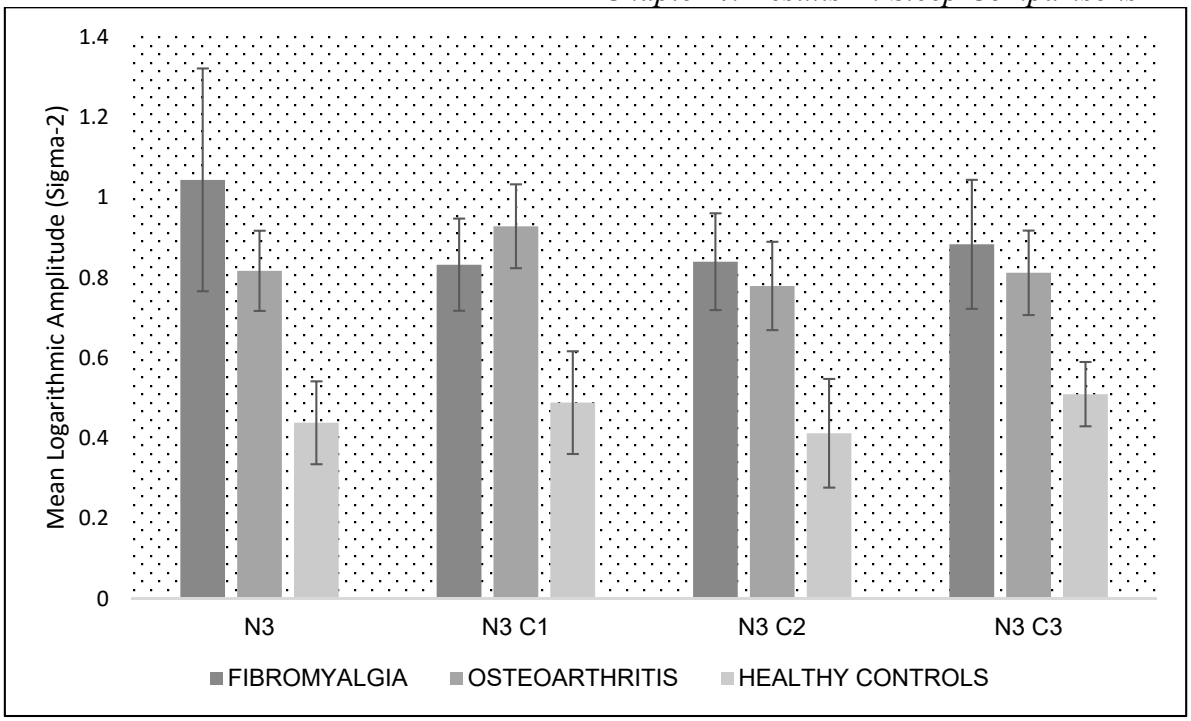



**Figure 4.25.** Bar graph depicting absolute spectral power (logarithmic) in the sigma-2 frequency bin. Represents the whole night of N3 sleep and N3 during the first three cycles of sleep. ± Standard error bars are also displayed.

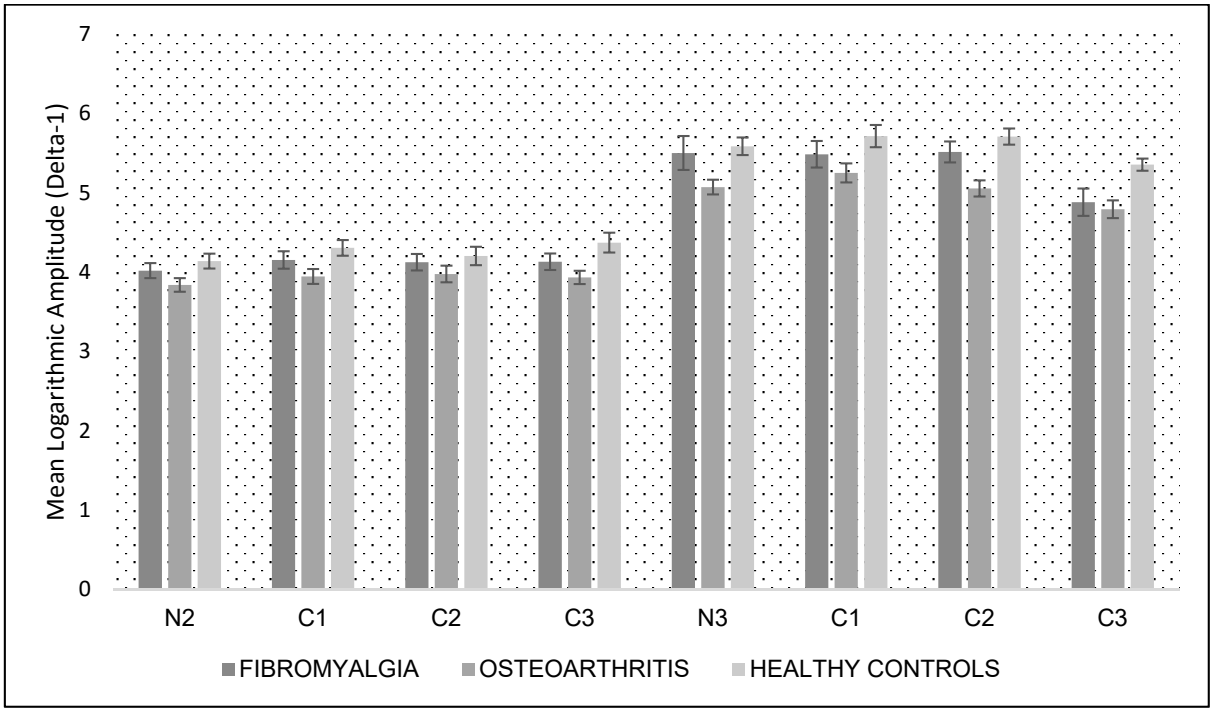



**Figure 4.26.** Bar graph depicting absolute spectral power (logarithmic) in the delta-1 frequency bin. Represents N2 and N3 sleep for the whole night and also the first three sleep cycles. ± Standard error bars are also displayed.

# 5. Results III: Psychosocial Comparisons

## 5.1. Psychosocial Model

Various psychosocial characteristics were measured to investigate differences in psychological status between FMS, OA and NHC participants. The aim of these measurements were to build a picture of the psychosocial profile of FMS sufferers. Tests of normality and equality of variances were run prior to conducting analyses of variance between the three groups in each measure and sub-measure. Overall for most of the assessments, the clinical groups record greater debilitation than the controls. In addition, the FMS patients tend to have greater values than those in the OA group. These were investigated further.

### 5.1.1. Depression and Anxiety

In the present study the FMS group appears to have the greatest amount of depression, state anxiety and trait anxiety, followed by OA and the lowest scores being the NHC group. The results show significant group differences for both depression and anxiety (Table 5.1). One way independent ANOVAs were conducted between the three groups on all three variables. For depression, normality tests using Z scores indicated that FMS (Skew=1.30; Kurt=.023), OA (Skew=1.29; Kurt=-0.52) and NHC (Skew=0.13; Kurt=-0.63) fell within a normal distribution range. The Levene's test indicated non-equal variances between groups ($F$=4.86, $p$=.013), thus a Welch's F statistic was used (Table 5.1). An overall significant main effect was observed ($p$<.001). Post-hoc comparisons with Games-Howell correction found significant effects between the clinical groups and the healthy control group, with mean differences of 18.31 ($p$<.001) and 11.26 ($p$<.001) for FMS and OA respectively. FMS and OA had similar levels of depression scores (*Mdiff*=7.05, $p$=.057).

For state anxiety (STAI-Y1), normality tests showed a normal distribution for FMS (Skew=1.14; Kurt=-0.03) and OA (Skew=1.10; Kurt=0.04). However, the healthy control group were both skewed and kurtotic (Skew=2.53; Kurt=2.49). The groups were found to have equality of variance ($F$=.881, $p$>.05). An overall significant main effect was observed ($p$=.001). Post-hoc analysis with Bonferroni correction applied found a significant effect between FMS and NHC (*Mdiff*=15.64, $p$<.001). However, no significant differences were observed between FMS and OA (*Mdiff*=6.21, $p$=n.s.) or OA and NHC (*Mdiff*=9.43, $p$=.052).

FMS (Skew=0.32; Kurt=-0.69), OA (Skew=-0.02; Kurt=-1.39) and NHC (Skew=0.32; Kurt=-0.30) were all normally distributed for trait anxiety. Levene's test indicated a homogeneity of variance within the groups ($F$=1.61, $p$>.05). A significant main effect was observed ($p$=.001). Post-hoc analysis with Bonferroni corrections observed a significantly greater trait anxiety between FMS with OA (*Mdiff*=9.81, $p$=.046) and with NHC (*Mdiff*=17.73, $p$=.001). However, no differences were found between OA and NHC (*Mdiff*=7.92, $p$=n.s.).

***Table 5.1. Means and standard deviations of depression and anxiety in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS (*M* ± *SD*)** *n=19* | **OA (*M* ± *SD*)** *n=17* | **NHC (*M* ± *SD*)** *n=10* | ***F*** | ***df*** | ***p*** | **$\eta^2$** |
|---|---|---|---|---|---|---|---|
| **CES-D[1]** | 23.11 ± 10.13 | 16.06 ± 7.44 | 4.80 ± 2.62 | 37.58† | 2, 27.50 | .000*** | .441 |
| **STAI-Y1[2]** | 42.74 ± 11.17 | 36.53 ± 8.12 | 27.10 ± 8.29 | 8.819 | 2, 43 | .001** | .291 |
| **STAI-Y2[3]** | 49.63 ± 12.59 | 39.82 ± 11.80 | 31.90 ± 7.52 | 8.485 | 2, 43 | .001** | .283 |

1. Centre for Epidemiological Studies for Depression Scale, 2. State and Trait Anxiety Scale (State), 3. State and Trait Anxiety Scale (Trait); †Welch's F; **$p$<.01; ***$p$<.001;

### 5.1.2. Social Support

Table 5.2 details the normality Z scores for social support. The total score for the scale indicated a normal data distribution for the three groups. Support from family found a slight negative skew for both FMS and OA. Support from friends also indicated negative skew for FMS and OA, OA were also leptokurtotic. Social support from a significant other were negatively skewed for all three groups, and leptokurtotic for FMS and NHC.

One-way analysis of variance was run on the social support scale and its subscales (Table 5.3). Overall the three groups showed a similar level of perceived social support, both in terms of the total score and its subscores. No significant main effects were observed for the three groups.

***Table 5.2. Skewness and Kurtosis Z scores and Levene's test for multidimensional scale of perceived social support between fibromyalgia, osteoarthritis and healthy controls***

| | **FMS Skew** *n=19* | **FMS Kurt** *n=19* | **OA Skew** *n=17* | **OA Kurt** *n=17* | **NHC Skew** *n=10* | **NHC Kurt** *n=10* | **Levene's** ***F, p*** |
|---|---|---|---|---|---|---|---|
| **SS-TOTAL[1]** | -0.96 | -0.86 | -0.97 | -1.17 | -0.30 | -0.81 | 1.54, n.s. |
| **SS-FA[2]** | **-2.42*** | 0.57 | **-2.09*** | 0.78 | -0.34 | -1.20 | .05, n.s. |
| **SS-FR[3]** | **-2.32*** | 0.62 | **-2.66*** | **2.48*** | -1.67 | 0.47 | .49, n.s. |
| **SS-SO[4]** | **-3.11*** | **2.37*** | **-2.68*** | 1.16 | **-2.53*** | **2.16*** | 1.87, n.s. |

1. Multidimensional Scale of Social Support Total, 2. Multidimensional Scale of Social Support Family, 3. Multidimensional Scale of Social Support Friends, 4. Multidimensional Scale of Social Support Significant Other; *±1.96;

***Table 5.3. Means and standard deviations the multidimensional scale of perceived social support in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS (*M* ± *SD*)** *n=19* | **OA (*M* ± *SD*)** *n=17* | **NHC (*M* ± *SD*)** *n=10* | ***F*** | ***df*** | ***p*** | **$\eta^2$** |
|---|---|---|---|---|---|---|---|
| **SS-TOTAL[1]** | 5.71 ± 1.03 | 5.76 ± 1.20 | 5.99 ± 0.78 | .246 | 2, 43 | .783 | .011 |
| **SS-FA[2]** | 5.75 ± 1.50 | 5.66 ± 1.45 | 5.58 ± 1.23 | .051 | 2, 43 | .950 | .002 |
| **SS-FR[3]** | 5.59 ± 1.44 | 5.59 ± 1.63 | 5.95 ± 1.18 | .235 | 2, 43 | .791 | .011 |
| **SS-SO[4]** | 5.79 ± 1.68 | 6.03 ± 1.27 | 6.45 ± 0.82 | .743 | 2, 43 | .482 | .033 |

1. Multidimensional Scale of Social Support Total, 2. Multidimensional Scale of Social Support Family, 3. Multidimensional Scale of Social Support Friends, 4. Multidimensional Scale of Social Support Significant Other;

### 5.1.3. Health Locus of Control

Differences in health locus of control was analysed using one-way independent ANOVA. Table 5.4 presents normality Z scores and Levene's test for the three groups looking at all the health locus of control subscales. For all subscales, the three groups fell within a normal distribution, except for internal locus of control where the NHC group was somewhat leptokurtotic. For homogeneity of variance, Levene's test indicated all the groups in the HLOC scale met equality of variance. Consequently, the standard ANOVA F values were used, in addition to Bonferroni corrections for the post-hoc analysis.

***Table 5.4. Skewness and Kurtosis Z scores and Levene's test for health locus of control between fibromyalgia, osteoarthritis and healthy controls***

| | **FMS Skew** *n=19* | **FMS Kurt** *n=19* | **OA Skew** *n=17* | **OA Kurt** *n=17* | **NHC Skew** *n=10* | **NHC Kurt** *n=10* | **Levene's** ***F, p*** |
|---|---|---|---|---|---|---|---|
| **HLOC-I[1]** | -0.36 | -0.91 | -0.47 | -0.34 | 0.78 | **2.25*** | 2.16, n.s. |
| **HLOC-EO[2]** | -1.20 | -0.64 | 0.02 | 0.00 | -0.14 | -0.91 | .34, n.s. |
| **HLOC-ED[3]** | -0.12 | 0.77 | 0.45 | -0.06 | -1.09 | -0.96 | .91, n.s. |
| **HLOC-C[4]** | -0.92 | 0.29 | -0.51 | -0.97 | -0.58 | 0.20 | .75, n.s. |

1. Health Locus of Control Internal, 2. Health Locus of Control External Others, 3. Health Locus of Control External Doctors, 4. External Health Locus of Control Chance; *±1.96;

Table 5.5 shows the means and standard deviations for the HLOC subscales, in addition to the results of the analysis of variance tests. From the outset, the clinical groups appeared to be less internally located than the NHC group. Inferential tests indicated a significant main effect and difference within the groups. Post-hoc analysis found the clinical groups FMS (*Mdiff*=8.66, $p<.001$) and OA (*Mdiff*=7.69, $p=.001$) were significantly less internally located than the healthy control group. No differences were observed between FMS and OA (*Mdiff*=.97, *p*=n.s.).

For external locus of control, in the 'others' subscale, the NHC group appeared to have a lower external locus of control than the clinical groups. However, an overall main effect was not observed. Looking at external 'doctors' subscale, again we can observe a lower score in the NHC group, with OA having the highest score. Post-hoc analysis indicated a significantly greater external-doctor locus of control for FMS (*Mdiff*=3.67, $p=.007$) and OA (*Mdiff*=5.55, $p<.001$) as compared to NHC. No differences were found between FMS and OA (*Mdiff*=1.88, *p*=n.s.).

The health locus of control for 'chance' showed similar levels of belief between the three groups, however FMS patients showed a slightly higher mean score than both OA and NHC. ANOVA showed no significant main effects between the two groups.

***Table 5.5. Means and standard deviations of health locus of control in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS (*M* ± *SD*)** *n=19* | **OA (*M* ± *SD*)** *n=17* | **NHC (*M* ± *SD*)** *n=10* | ***F*** | ***df*** | ***p*** | **$\eta^2$** |
|---|---|---|---|---|---|---|---|
| **HLOC-I[1]** | 17.74 ± 5.12 | 18.71 ± 5.77 | 26.40 ± 3.50 | 10.317 | 2, 43 | .000*** | .324 |
| **HLOC-EO[2]** | 8.21 ± 2.80 | 9.18 ± 3.61 | 6.30 ± 2.45 | 2.780 | 2, 43 | .073 | .115 |
| **HLOC-ED[3]** | 10.47 ± 2.78 | 12.35 ± 3.20 | 6.80 ± 2.53 | 11.609 | 2, 43 | .000*** | .351 |
| **HLOC-C[4]** | 18.47 ± 5.55 | 17.06 ± 6.44 | 17.60 ± 5.17 | .270 | 2, 43 | .765 | .012 |

1. Health Locus of Control Internal, 2. Health Locus of Control External Others, 3. Health Locus of Control External Doctors, 4. External Health Locus of Control Chance; ****p*<.001;

### 5.1.4. Pain Catastrophizing

Table 5.6 displays the skewness and kurtosis Z scores for normality and the Levene's test for homogeneity of variance. For pain catastrophizing total score and its subscales, both the FMS and OA group showed a normal distribution that fell within the ±1.96 range. However, for the NHC group, on all PCS variables showed a positively skewed distribution. Additionally, Levene's test indicated that all groups were not significantly different in terms of variance.

***Table 5.6. Skewness and Kurtosis Z scores and Levene's test for the pain catastrophizing scale between fibromyalgia, osteoarthritis and healthy controls***

| | **FMS Skew** *n=19* | **FMS Kurt** *n=19* | **OA Skew** *n=17* | **OA Kurt** *n=17* | **NHC Skew** *n=10* | **NHC Kurt** *n=10* | **Levene's** ***F, p*** |
|---|---|---|---|---|---|---|---|
| **PCS-Total**[1] | 1.08 | -0.30 | 0.96 | -0.79 | **2.52*** | 1.62 | .12, n.s. |
| **PCS-R**[2] | 0.73 | -0.68 | 0.65 | -1.41 | **2.23*** | 0.89 | .33, n.s. |
| **PCS-M**[3] | 0.95 | -0.77 | 1.88 | 0.11 | **2.08*** | 1.26 | 1.75, n.s. |
| **PCS-H**[4] | 1.32 | -0.19 | 0.91 | -0.41 | **2.66*** | 1.74 | .51, n.s. |

1. Pain Catastrophizing Scale Total, 2. Pain Catastrophizing Scale Rumination, 3. Pain Catastrophizing Scale Magnification, 4. Pain Catastrophizing Scale Helplessness; *±1.96;

One-way independent ANOVA indicated no significant differences between the groups in terms of the total PCS score, the subscales of rumination or magnification (Table 5.7). However, looking at the mean scores, there appeared to be a numerical gradient trend whereby FMS patients had the highest scores for total PCS, rumination, magnification and helplessness, with the OA patients having the second highest scores, and lowest scores observed in the NHC group. For helplessness, an overall significant effect was observed ($p$=.041). For helplessness, post-hoc analysis with Bonferroni corrections found a significantly higher score for FMS patients as compared to NHC ($Mdiff$=5.73, $p$=.040). However, no differences were found between the clinical groups ($Mdiff$=2.82, $p$=n.s.) or between OA and NHC ($Mdiff$=2.91, $p$=n.s.).

***Table 5.7. Means and standard deviations of the pain catastrophizing scale in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS (*M* ± *SD*)** *n=19* | **OA (*M* ± *SD*)** *n=17* | **NHC (*M* ± *SD*)** *n=10* | ***F*** | ***df*** | ***p*** | **$\eta^2$** |
|---|---|---|---|---|---|---|---|
| **PCS-Total**[1] | 20.63 ± 13.01 | 16.06 ± 11.93 | 10.10 ± 12.81 | 2.328 | 2, 43 | .110 | .098 |
| **PCS-R**[2] | 7.05 ± 4.87 | 6.35 ± 5.26 | 4.60 ± 5.48 | .748 | 2, 43 | .479 | .034 |
| **PCS-M**[3] | 4.05 ± 3.12 | 3.00 ± 2.74 | 1.70 ± 1.95 | 2.410 | 2, 43 | .102 | .101 |
| **PCS-H**[4] | 9.53 ± 6.26 | 6.71 ± 4.86 | 3.80 ± 5.85 | 3.442 | 2, 43 | .041* | .138 |

1. Pain Catastrophizing Scale Total, 2. Pain Catastrophizing Scale Rumination, 3. Pain Catastrophizing Scale Magnification, 4. Pain Catastrophizing Scale Helplessness; *$p$<.05;

### 5.1.5. Personality

Personality was assessed using the Eysenck Personality Questionnaire with four bipolar personality typings analysed (neuroticism, psychoticism, extraversion and lie). Looking at the normal distribution (Table 5.8), all the groups had scores that fell within a normal distribution for neuroticism, extraversion and lie; however, for psychoticism, the OA group appeared to be positively skewed and leptokurtotic. Levene's F test also showed equality of variance in the population groups (Table 5.8).

***Table 5.8. Skewness and Kurtosis Z scores and Levene's test for the Eysenck Personality Questionnaire between fibromyalgia, osteoarthritis and healthy controls***

| | **FMS Skew** *n=19* | **FMS Kurt** *n=19* | **OA Skew** *n=17* | **OA Kurt** *n=17* | **NHC Skew** *n=10* | **NHC Kurt** *n=10* | **Levene's *F, p*** |
|---|---|---|---|---|---|---|---|
| **EPQ-N**[1] | -0.09 | -0.94 | -0.75 | 0.03 | -0.68 | -0.07 | .94, n.s. |
| **EPQ-P**[2] | 1.81 | 1.13 | **2.53*** | **3.09*** | 1.49 | -0.23 | .22, n.s. |
| **EPQ-E**[3] | -1.11 | 0.55 | 0.35 | -0.96 | 0.22 | -0.87 | 1.60, n.s. |
| **EPQ-L**[4] | 0.75 | 0.56 | 0.27 | -0.66 | 1.10 | 0.38 | .45, n.s. |

1. Eysenck Personality Scale Neuroticism, 2. Eysenck Personality Scale Psychoticism, 3. Eysenck Personality Scale Extraversion, 4. Eysenck Personality Scale Lie; *p<.05, *±1.96;

Firstly, looking at neuroticism, the FMS group appeared to have the greatest score on neuroticism, with OA being second highest and lowest in NHC. Analysis of variance also indicated a significant main effect within the groups (Table 5.9). Post-hoc analysis with Bonferroni corrections found the FMS group were significantly more neurotic than the healthy control group (*Mdiff*=6.44, *p*=.009). However, no differences were found between FMS and OA (*Mdiff*=2.27, *p*=n.s.) or OA and NHC (*Mdiff*=4.17, *p*=n.s.).

Psychoticism subscale showed no discernible differences in mean scores between the three groups, however the clinical groups had a lower psychoticism score than the NHC group. ANOVA did not show a significant main effect (Table 5.9).

For the extraversion subscale, the mean scores indicated a greater score for FMS patients, followed by OA and the lowest being NHC. However, no significant main effect was found.

Lastly for the lie scale, the clinical groups seemed to have a greater score than the NHC group. ANOVA showed a significant main effect (Table 5.9; *p*=.014). Post-hoc analysis with Bonferroni corrections found the clinical groups had a significantly greater score on the lie scale than the NHC group with a mean difference of 3.62 (*p*=.036) and 4.12 (*p*=.016) for FMS and OA respectively.

***Table 5.9. Means and standard deviations of the Eysenck Personality Questionnaire in fibromyalgia, osteoarthritis and healthy control participants***

| | **FMS (*M* ± *SD*)** *n=19* | **OA (*M* ± *SD*)** *n=17* | **NHC (*M* ± *SD*)** *n=10* | ***F*** | ***df*** | ***p*** | **$\eta^2$** |
|---|---|---|---|---|---|---|---|
| **EPQ-N[1]** | 15.74 ± 4.36 | 13.47 ± 5.80 | 9.30 ± 5.06 | 5.258 | 2, 43 | .009** | .197 |
| **EPQ-P[2]** | 4.47 ± 3.64 | 3.88 ± 2.47 | 5.80 ± 3.68 | 1.094 | 2, 43 | .344 | .048 |
| **EPQ-E[3]** | 12.16 ± 5.10 | 11.71 ± 6.08 | 10.90 ± 6.56 | .154 | 2, 43 | .858 | .007 |
| **EPQ-L[4]** | 11.32 ± 4.18 | 11.82 ± 2.90 | 7.70 ± 3.13 | 4.753 | 2, 43 | .014* | .181 |

1. Eysenck Personality Scale Neuroticism, 2. Eysenck Personality Scale Psychoticism, 3. Eysenck Personality Scale Extraversion, 4. Eysenck Personality Scale Lie; *p<.05; **p<.01;

Tables 5.1-5.9 show the mean results of the psychometric assessments between fibromyalgia, osteoarthritis and healthy controls. Overall for most of the assessments, the clinical groups record higher values than the control. In addition, the fibromyalgia patients tend to have greater values than those in the osteoarthritis group. There were highly significant differences between the three groups for depression, state and trait anxiety, health locus of control (internal, external-doctor) and neuroticism. There were also significant differences between groups for pain catastrophizing and the EPQ-Lie scale. There were significant differences found between fibromyalgia and osteoarthritis in depression, there were similar differences found in anxiety measures.

There was a trend towards a lower health locus of control in fibromyalgia compared to osteoarthritis. For neuroticism the FMS patients were statistically significant for healthy controls but not for the osteoarthritis group.

Figures 5.1 to 5.5 depict graphically results of the psychological variables in the three different groups.

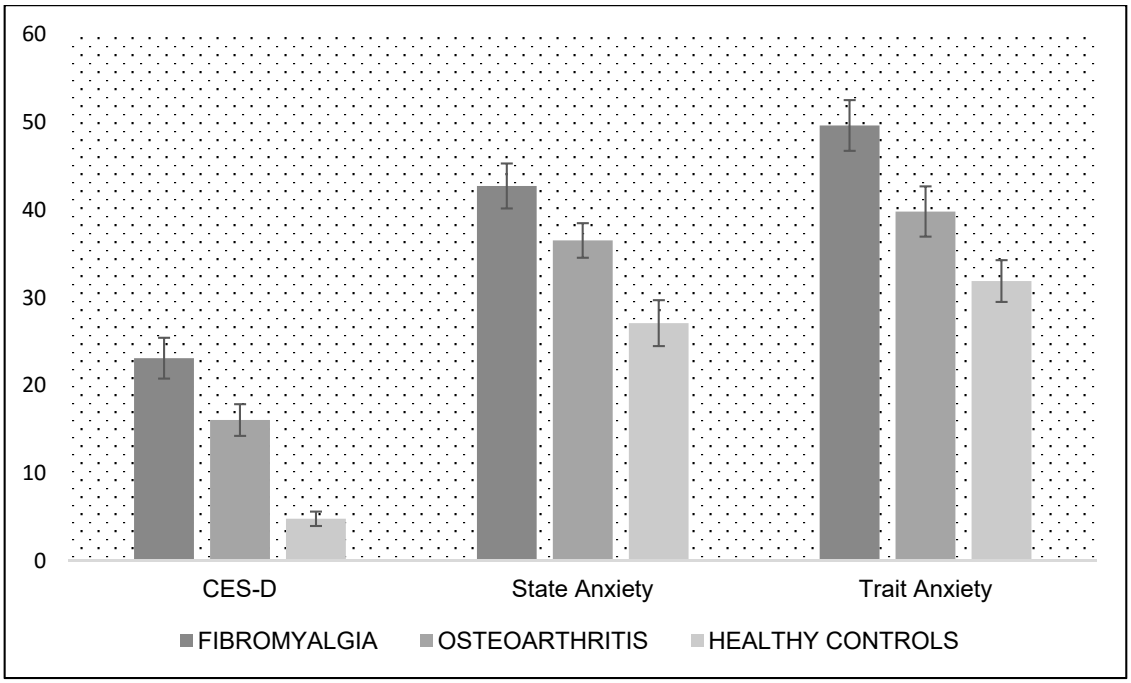



**Figure 5.1.** Bar graph comparing means scores of depression (CES-D), state, and trait anxiety (STAI) between fibromyalgia, osteoarthritis and healthy control participants. Standard error bars are also displayed.

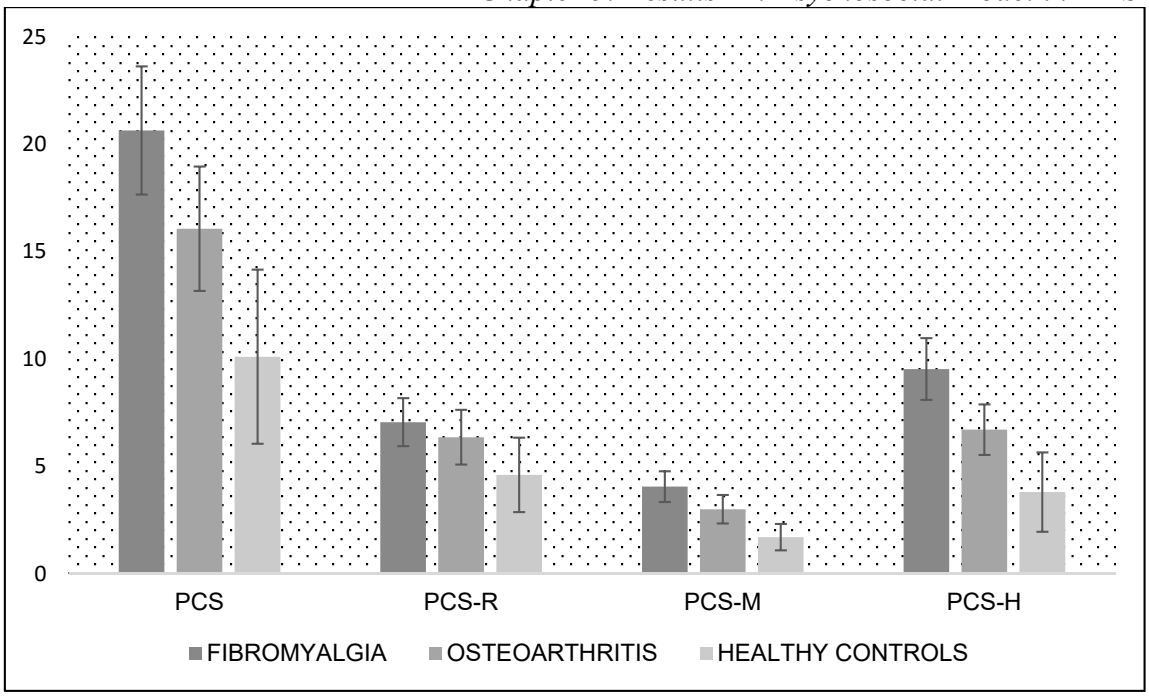



**Figure 5.2.** Bar graph comparing means scores of the pain catastrophizing scale, depicting total, and subscores of rumination, magnification and helplessness, between fibromyalgia, osteoarthritis and healthy control participants. Standard error bars are also displayed.

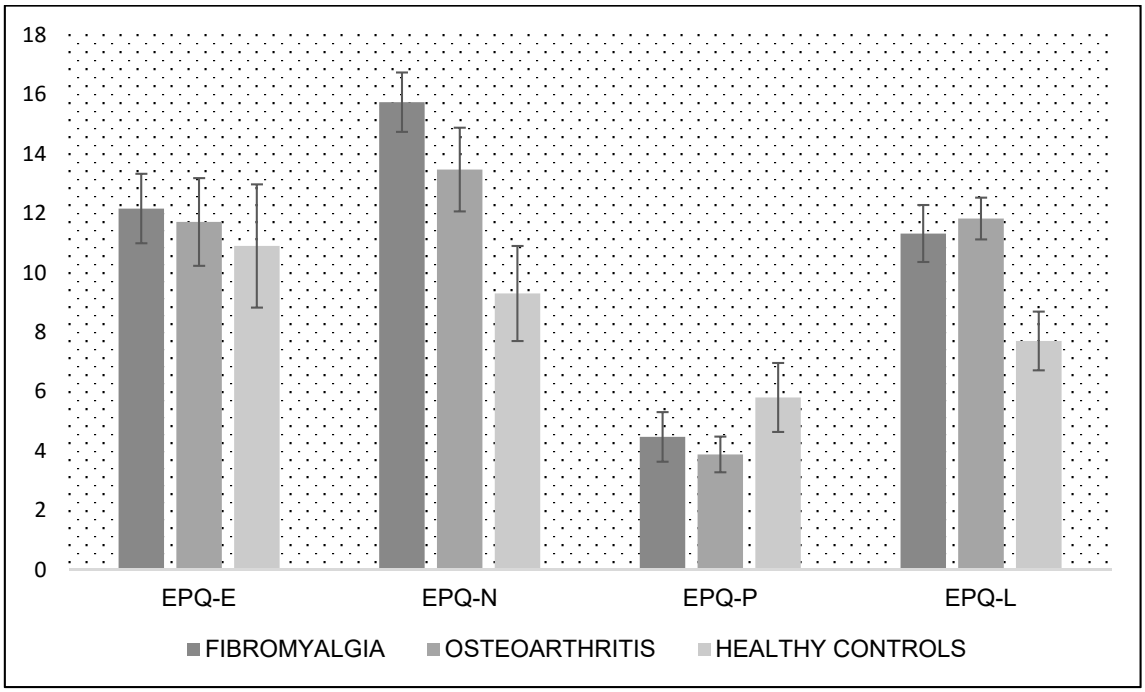



**Figure 5.3.** Bar graph comparing means scores of the Eysenck Personality Questionnaire in scores of extraversion, neuroticism, psychoticism and lying, between fibromyalgia, osteoarthritis and healthy control participants. Standard error bars are also displayed.

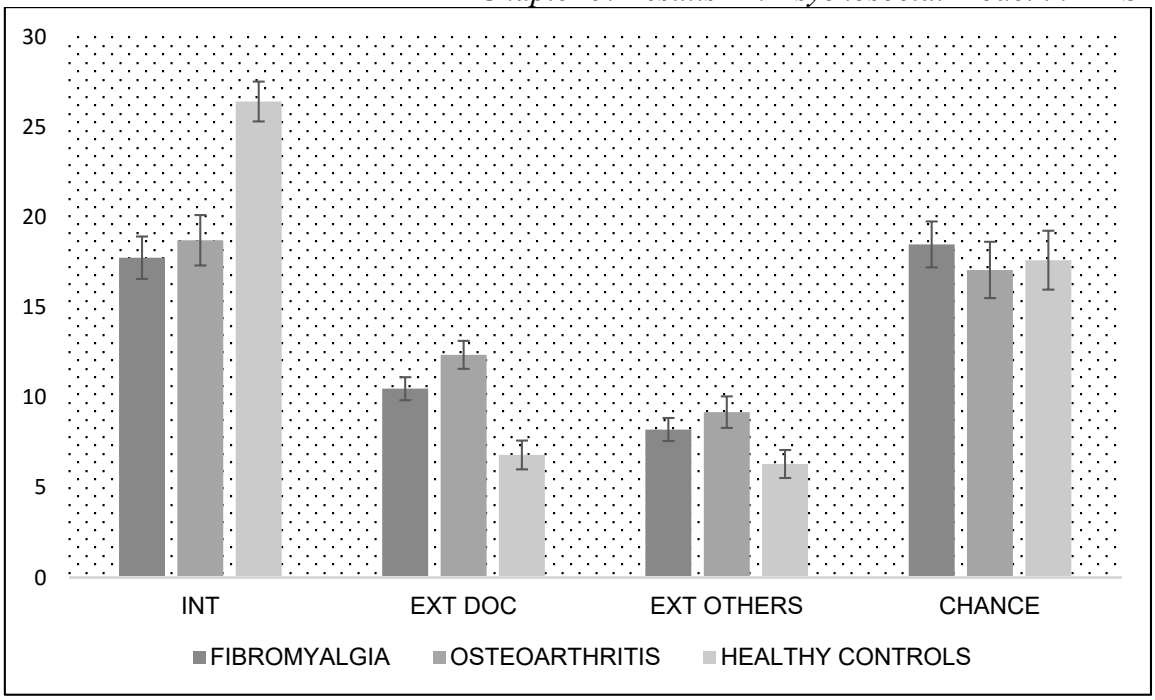



**Figure 5.4.** Bar graph comparing means scores of health locus of control depicting scores of internal, external-doctor, external-other and chance, between fibromyalgia, osteoarthritis and healthy control participants. Standard error bars are also displayed.

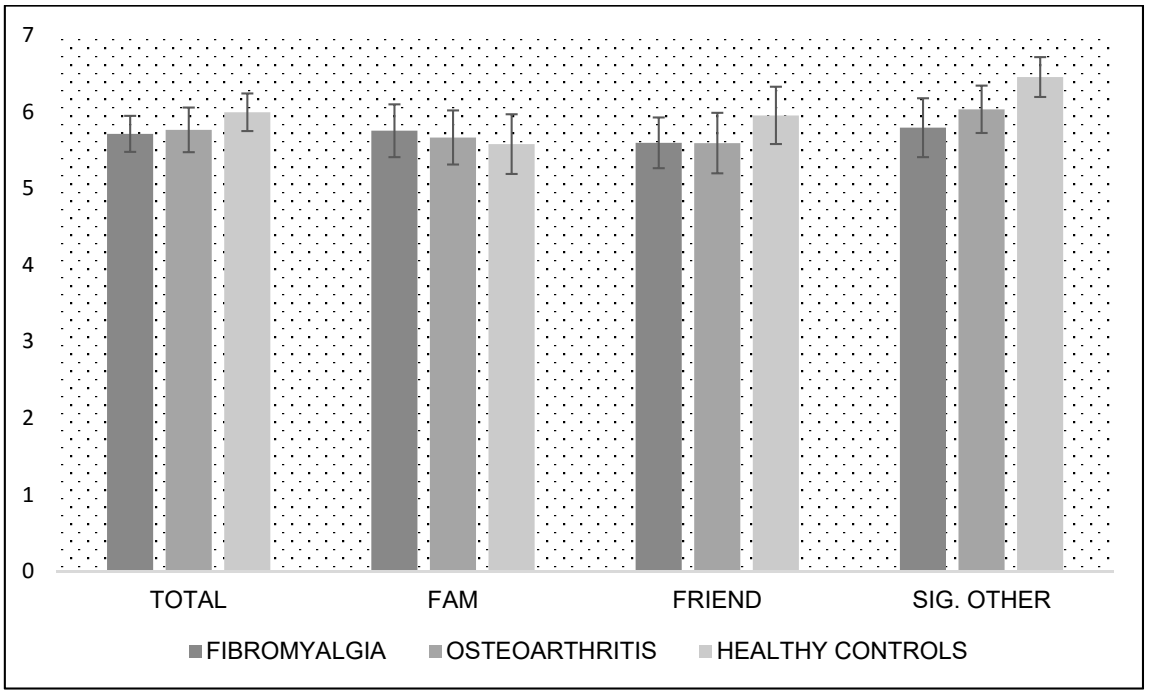



**Figure 5.5.** Bar graph comparing means scores of the multidimensional scale of social support depicting the total social support score and subscores of familial, friend and significant other support. They are compared between fibromyalgia, osteoarthritis and healthy control participants. Standard error bars are also displayed.

# 6. General Discussion

This is the first study to compare the electrophysiological sleep structure, subjective sleep experience, and psychological profiles of FMS patients with both non-FMS chronic pain patients, and healthy normal controls. In recruiting the groups for this study considerable care was taken to ensure: 1) unambiguous and recent diagnoses of fibromyalgia syndrome in the FMS group; 2) similarities in age across the three groups; 3) the presence of significant pain-related sleep disturbance within the OA group (since, unlike FMS, sleep symptoms are not cardinal in arthritic pathology); and 4) in all groups, the appropriate control of extraneous factors likely to introduce confounds into the analyses (drug consumption, menopausal symptoms, comorbidities, etc.). While both clinical (FMS & OA) groups showed PSQI scores in the 'poor sleeper' range of >5 (Buysse et al., 1989) and FSS scores indicative of daytime fatigue at screening, the NHC group showed a sleep profile consistent with their age and health status, with no significant sleep symptoms. Given, then, that the rigorous selection criteria were met by all participants, profiles for the resulting groups of 19 (FMS), 17 (OA) and 10 (HNC) support the view that these individuals are 'representative' of the intended clinical and non-clinical groupings, and provide the basis for robust tests of the study hypotheses.

Fibromyalgia syndrome is a disorder characterised by chronic widespread pain and tenderness, sleep disturbance and fatigue. The aetiology of FMS is largely unknown, but there has been significant interest in the role of alpha wave intrusion in delta wave sleep which was first described by Moldofsky and colleagues (Moldofsky et al., 1975). However, the later findings of 'alpha intrusions' have been inconclusive. It has also remained unclear whether this a primary phenomenon or secondary to sleep disturbance from pain experience.

In order to determine whether sleep abnormalities in the microstructure of sleep are present, and whether they are a result of pain or a secondary phenomenon, this thesis aimed to compare patients with fibromyalgia syndrome, osteoarthritis and healthy controls. They were compared on symptoms of sleep dysfunction (multiple aspects, including subjective and objective) and multiple psychosocial factors. It is understood from literature that patients with FMS, aside from being characterised by chronic widespread pain, also have sleep disturbance as a core symptom that exacerbates their symptomology and degrades quality of life. A comparator group that exhibited sleep dysfunction as a function of chronic pain was a necessity to determine whether sleep

disturbance was fundamental to the development of FMS or a consequence of FMS advancement, especially the well documented alpha-delta anomaly.

Objective sleep was examined from both a macrostructure and microstructure perspective in order to understand the differences of sleep architecture in a more thorough approach. In addition to sleep disturbances, many psychological and psychosocial constructs have been found to be associated with this condition. Consequently, selected psychosocial variables were also measured in order to explore, and better define, the psychological phenotype in FMS.

To reiterate the aims of the study, a series of controlled analyses were designed to address the following key research questions:

1. When scored according to AASM criteria, does the polysomnographic sleep of FMS, OA, and healthy control participants show significant differences on measures of: total sleep time; sleep onset latency; sleep efficiency; wake after sleep onset; and the percentage of time spent in each stage of sleep?
2. Through spectral analysis, do FMS patients exhibit a significantly greater frequency and power of alpha-delta sleep than OA patients or healthy controls?
3. Through spectral analysis, do FMS patients exhibit significant differences in the microstructure of sleep across the standard frequency range for sleep PSG than OA patients or healthy controls?
4. Do FMS, OA, or healthy control participants show significant differences on objective (PSG and Actigraphy) and subjective (PSQI, ESS and FSS) measures of sleep disturbance and quality?
5. Do measures of total sleep time, sleep onset latency, wake after sleep onset and sleep efficiency correlate between polysomnography and actigraphy across the groups?
6. In comparisons of mean values, do FMS, OA and healthy control participants show differences on psychometric assessments of: pain, depression, anxiety, ‘perceived social support’, ‘health locus of control’, ‘pain catastrophizing’ and personality?

### 6.1. Participant Selection

A vital part of this study was to obtain appropriately constituted and, on key variables (e.g. pain), comparable patient groups. From the outset, all the patients and participants were age and sex matched. In terms of age, all three of the groups did not exhibit any differences or variability. In order to exclude any inter-gender variation in sleep, all the

cohort selected were female. We had also measured height and weight to determine body mass index. Although the OA group had a significantly greater BMI than the NHC group, it was not deemed problematic; it is important for this study that sleep architecture is not disrupted due to factors other than pain experience, thus it was required to take into consideration risk factors for certain conditions that may occur such as sleep apnoea. In terms of a risk of obstructive sleep apnoea (OSA) in the patients, they were screened out for medically diagnosed sleeping problems, in addition the prevalence of obstructive sleep apnoea for example are found to be more common in males. Although there have been past studies that have found a relationship between greater BMI to an increase in OSA prevalence (Wall, Smith, & Hubbard, 2012), these have mostly been found in patients with a BMI greater than 30, whilst the patient set did not exceed these values.

It was important that the FMS patients were newly diagnosed and originating from a single site. Newly diagnosed patients are less likely to have been subjected to pharmacological therapy prior to recruitment, and therefore their sleep architecture is less likely to have been altered due to drug therapy; as certain medications have been shown to affect sleep architecture such as tricyclic antidepressants and other opioids (e.g. Dimsdale, Norman, D, & Wallace, 2007). This paradigm allowed us to observe FMS patients from the onset of diagnosis to obtain a better valid representation and decreased the need to conduct 'washout' periods, although in some cases this was unavoidable.

In addition to newly diagnosed patients, all the patients were diagnosed using the ACR 1990 criteria and their FIQ result indicated a similar severe level of daytime impact for the FMS patients. In terms of demographics, the majority of the participants were Caucasian, previous research has indicated inconclusive evidence in the differences in sleep architecture between ethnicities (e.g. Jean-Louis et al., 2001; Rao et al., 1999; Stepnowsky, Moore, & Dimsdale, 2003), although there may be scope to explore this further.

The OA patients, were perhaps the most important for selection in this process. They were recruited from an orthopaedic waiting list and were awaiting surgery for knee, hip and shoulder operations. It was important that they exhibited a mainly localized chronic pain, but also were sleep disturbed due to pain. Thus the screening for these variables were highly stringent, and achieved by consultations with a rheumatologist for their pain condition and also rigorous screening using various sleep related questionnaires prior to recruiting the patient into the study. Additional to their pain, it was vital that they were free from pharmacological treatment that may affect their sleep; this point was also conducted smoothly via set agreed 'washout' periods.

It was important when recruiting these participants and analysing the results that they did not differ in certain areas. The clinical patients were required to exhibit similar levels of pain, although, because the two clinical groups had different diseases, it was not possible to control for pain; assessments using the BPI helped to ensure that both clinical groups were similar in terms of pain severity, pain interference and also on a basic visual analogue scale. We achieved this effectively, whilst the healthy control group were free from pain and pain interference using the same method. In terms of sleep quality as measured using the PSQI, we required that they exhibited clinical significance in terms of sleep disturbance. Both groups had scored highly on the global PSQI, which resulted in severely disturbed sleep, in contrast to a low sleep score obtained from the NHC group.

Additionally, FMS patients were found to have a much greater level of fatigue and sleepiness than both the OA and NHC group; and there were similar statistically significant differences between OA and NHC; these large and significant differences between the three groups could perhaps be due to an alteration in terms of the micro/macrostructure of sleep.

### 6.2. Do FMS, OA and NHC participants show a difference on measures of objective sleep variables?

PSG was recorded over two nights, however only the second night was used for all subsequent analyses for reliability purposes. They were scored according to the AASM guidelines. We failed to observe any differences between the three groups in TST, SOL, and WASO; they appeared to spend similar amounts of time sleeping, similar amounts of time getting to sleep and similar amounts of wake time during the night. However these findings do not replicate or reach a consensus with what is typically observed, whereby FMS patients characteristically have been found to sleep less, have prolonged sleep latencies and have increased night time awakenings (Roizenblatt et al., 2001). However, the mean trends for wake after sleep onset have found the greatest amount of wake time in the FMS patients, followed by the OA and the lowest being the healthy group, there was a greater standard deviation with the FMS group which may contribute to a non-significant model, which highlights the greater range of variability in FMS patients, or the FM syndrome as a whole.

Though the FMS patients did have a significantly lower sleep efficiency than the NHC group, but there were no differences between the clinical groups (FMS & OA) or between OA and NHC. This outcome agrees with what has been previously found (e.g. Wittig, Zorick, Blumer, Heilbronn, & Roth, 1982); although there were no differences

between the clinical groups nor between the OA and NHC groups, the mean values indicated a trend whereby FMS patients on average had a lower sleep efficiency than OA, however this was marginal (difference of 0.86) and non-significant, and the highest sleep efficiency with the healthy controls which was only significant between the FMS group. This implies that the FMS group had less variability in their sleep efficiency than the OA group. This result may also be possible due to a mediation effect of pain and sleep, since the FMS and OA groups' exhibit two different diseases, a third mediating factor may be at play affecting the severity of sleep dysfunction which may relate to other physiological or psychological differences.

Sleep was staged according to AASM guidelines; no differences were observed between the three groups in terms of the percentage amount of time spent in each stage of sleep. They appeared to be equal in the amounts of time spent in N1, N2, N3 and REM sleep, with their mean differences to be negligible. Typically, FMS patients have been found to have increases in N1 and N2 sleep and reductions in N3 (Harding, 1998) as compared to a healthy comparator group. However, this was not observed here. The present study has a methodologically robust research design, more so than previous research; employing a pain and healthy comparator group; conducting at-home recordings rather than in a lab; and evaluating psychometric factors. At this point, there may be indications that FMS irregularities in sleep dysfunction may be an abnormality of perception rather than reality.

The question is now posed, whether these patients have greater amounts of awakenings or arousals? From the analyses, we did not find significant differences, they had similar amounts of awakenings and PSG arousals during the night, although the clinical groups did have greater mean numbers than the healthy controls for both awakenings and arousals, there was also a greater variability in the clinical groups, which further highlights the individual differences or even greater variability of sleep of the conditions as a whole. There was a trend however, where FMS patients had a greater, though not significant, amount of PSG arousals than the OA and NHC groups.

Subjectively the FMS patients have already shown they are significantly more sleep disturbed, they are more fatigued and they have greater sleepiness than both the pain control group and the healthy control group, but they appear from the outset to have a similar sleep architecture on the macro level. In order to obtain a comprehensive picture, it was necessary to tease apart whether the sleep of the clinical groups was more fragmented than the NHC group. To do this we analysed the number of sleep stage transitions each participant group had; the greater the amount of sleep transitions, the

more fragmented we reasoned their sleep would be; sleep stage transitions are a measure of the frequency or number of transitions from one sleep stage to the next, an increase in the number of sleep stage transitions especially in a short period of time indicates a much poorer sleep quality. In addition to sleep stage transitions for the whole night, we also analysed the number of transitions per hour of sleep. The results showed that indeed the clinical groups exhibited a significantly greater amount of sleep stage transitions than did the healthy controls, both for the whole night of sleep and also particularly during each hour of sleep. However, we did not observe a difference between FMS and OA. This may help clarify the differences in subjective differences between the clinical groups and the healthy control group, perhaps it is not surprising that patients will develop symptoms of fatigue and sleepiness, if pain causes interruption in the pattern of sleep. However, the FMS patients still had significantly worse perceived sleep quality, perceived fatigue and perceived sleepiness than the pain control group (OA group).

Having also run actigraphy for two weeks, the idea was to obtain a general measure of their sleep across a small period of time. The results of the actigraphy analysis also indicated that there were no differences in sleep quality between any of the three groups. The use of actigraphy is perhaps a secondary measure to aide in validation of the objective sleep or PSG recordings. The question that should be asked now, is why patients with FMS and OA have a greater subjective impairment in sleep quality with increased fatigue and sleepiness when their objective measures of PSG and actigraphy appear to be similar to a healthy comparator group? What then is driving this perceived sleep impairment?

### 6.3. Do sleep variables for polysomnography and actigraphy correlate across the groups?

Actigraphy was included as an additional measure of objective sleep, both due to the need for a general picture of an individual's sleep, but also as an exploration into the comparisons between one night of PSG and a measurement of sleep over a longer period. Pearson correlations between actigraphy and polysomnography on measures of TST, SOL, WASO and SE were conducted on all the groups together. Measures of SOL, WASO and SE, were all significantly correlated with each other. However, for TST, a weaker non-significant correlation resulted. It was reasoned that the more accurate and highly specific measure of PSG in determining sleep and wake times may have a part to play in a weaker relationship.

Due to the nature of actigraphy by use of preset algorithms on motion data for detecting sleep-wake status, there have been studies which have shown a lower specificity for this methodology. Studies have shown that actigraphy tends to overestimate certain measures such as sleep latency, total sleep time and sleep efficiency and underestimating awakenings (de Souza et al., 2003; Marino et al., 2013). Looking at data trends of the present study, the mean values appear to show actigraphy underestimating TST, SOL and SE, opposite to what previous studies have described; and overestimating WASO and awakenings. The use of actigraphy in certain populations are still relatively unknown, especially in two different chronic pain groups, this may be of worth to note when conducting future studies using this technology with other population groups.

### 6.4. Are there differences between subjective and objective measures of sleep for FMS, OA and NHC?

From the PSQI component measures of TST, SOL and SE were obtained. These subjectively obtained values were compared with objectively obtained values from PSG for all three groups. We found that the clinical groups had significantly underestimated the amount of sleep they had, and in turn underestimated their sleep efficiency. In comparison, the healthy control group did not exhibit differences in their subjectively perceived sleep times and objectively measured sleep times. This further points to a fault in the perception of the amount of sleep reported by these participants. The same result was found for both clinical groups (FMS and OA). This agrees with previous research, which found common misperceptions of sleep in FMS patients (Okifuji & Hare, 2011b). However, both pain groups had an error in sleep estimation, which was further explored by calculating the magnitude of difference (TST and SE) for both FMS and OA groups and then comparing the differences in magnitude between the two groups. It was found that that FMS patients had a significantly greater magnitude of difference from subjective to objective, than did OA patients. This may imply pain perception has a role to play in sleep misperception; however, this irregularity is much greater in FMS patients, which concurs with past research. However, pain may not be the only factor in deciding this, due to a greater misperception in FMS patients, further factors may play a role in exacerbating this phenomenon, which may relate to physiological or psychological functions.

### 6.5. The Microstructure of Sleep

The main focus/hypothesis of this study was to investigate the microstructure of sleep, and explore differences in various EEG frequencies during different stages of sleep and

during different times of the night between FMS, OA and NHC. This was to answer the general question of whether patients with FMS have differences/anomalies in their sleep EEG which may contribute to their symptomology and (relative to OA patients and a healthy control group). This was achieved through a thorough spectral analysis of the EEG channels of the PSG. Through this multiple points of note were found.

### 6.5.1. The Alpha-Delta Anomaly

One of the main focuses of this study was to evaluate the alpha-delta sleep anomaly. The patients with osteoarthritis were selected only if they had sleep that was disturbed by pain. Multiple studies have documented greater alpha-wave intrusions during slow wave sleep in patients with FMS. These studies have been inconsistent in their findings and none have utilised a well selected and screened pain control group. Spectral analysis was utilised to decompose the wave and investigate the alpha-wave anomaly in its entirety. Initially the alpha frequency was explored for N3 for the whole night of sleep. Additionally, analyses were also carried out for the first three cycles of sleep that consisted of N3; a cycle by cycle examination was conducted as the literature has consistently demonstrated the first cycles of sleep as having the strongest signal before stepping down after each cycle (Besteiro González et al., 2011).

The findings demonstrated that between the three groups, no discernible differences were found for the power of the alpha frequency signal during N3 sleep. This may arise due to several reasons, the main one being that generally, not everybody exhibits the same amount of N3 sleep across the entire night, in some cases patients may only exhibit less than 5% of N3 across the whole night in the patient groups, where for a typical sleeper it is around 30%. However, these findings do not support the hypothesis that alpha-wave intrusion is a primary abnormality found in fibromyalgia. Moreover, the patient groups did not exhibit differences in pain measures, but the results showed a consistent trend towards an increase in alpha power in the FMS patients compared with OA, and both clinical groups had a numerically greater alpha power than the healthy controls that was consistent throughout the night. This may indicate that the present study could be lacking power in order to produce a significant finding; it should be noted that the study failed to recruit the necessary numbers (20 per group) produced by the power calculation specified earlier. The trend toward an increase in alpha-wave intrusion in the clinical groups, questions whether alpha-waves are a function of sleep disturbed by pain rather than specific to FMS, there is thus still scope to explore this further.

In addition to slow wave sleep, numerically on average, alpha power was generally stronger in FMS patients, with OA having the second greatest alpha power and lowest strength in the healthy control group. This has been observed to be true for both NREM and N2 separated, in addition to the first three cycles of sleep. The lack of significant findings is perhaps due to a greater variability in the FMS patients, as they consistently had greater standard deviations for alpha. This agrees with past research that have found inconsistent alpha power within FMS patient groups where some exhibit a greater amount than others. This highlights the greater variability in FMS patients and perhaps is mediated by psychosocial factors such as anxiety and depression.

### 6.5.2. Specific findings in the micro-structure of sleep

Although no differences were found in alpha power, some differences were observed in spectral power at other frequencies, which may bear some significance. The results of the spectral analysis demonstrated significant differences in the averaged power of the sigma-2 frequency in NREM sleep merged, N2 and N3. The greatest numerically observed power was found in the FMS group, followed by OA, with the NHC group having the lowest averaged power. However, only the osteoarthritis group exhibited a significantly greater amount of sigma-2 power than the NHC group for all three sleep stage groupings. This was again due to greater inconsistencies in the results of the FMS patients, where they had a larger standard deviation than the other groups.

Sigma related activity can be clarified as relating to sleep spindle activity, the greater power observed in the sigma range may indicate a greater amount of sleep spindle activity; spindle activity is typically described as sinusoidal oscillations that fall within the 11-16 Hz range. Moreover spectral analysis has been consistently shown to be the most robust and reliable method of ascertaining spindle rate (Knoblauch et al., 2003). The sigma-2 frequency sits at 14-16 Hz, and reflects the frequency of faster spindles (13-15 Hz) than the typically slower spindles that occur in the 11-13 Hz range (Mölle, Bergmann, Marshall, & Born, 2011). No differences were observed between the FMS group and healthy control group, which suggests they exhibited a similar level of spindle activity, however FMS patients have consistently shown numerically greater sigma-2 power as opposed to NHC, previous research however has found inconclusive results where FMS patients may display decreased sleep spindles compared to controls (e.g. Landis et al., 2004) or they may have an increase in N2 sleep, which by default would see an increase in spindle activity, but these research studies have mainly used a manual method of computing the number of spindles, rather than investigating the spectral

component of spindle activity, which can be less reliable due to human error. Additionally, again much greater variability was observed in FMS patients, which lead to possible non-significant findings in this respect. Moreover, a greater sigma-2 power was observed in the OA pain control group as compared to the NHC group, which further proposes pain as a function of increased spindle activity. There is, however, research that indicates a possible link between 'fast' spindles and depressed mood (Plante et al., 2013), so there may be merit here for future areas of investigation.

In addition to sigma-2 activity, some variations in slow wave sleep were also observed. The groups showed significant differences in extreme slow wave activity in the delta-1 range (0.1-1 Hz). The OA group were found to have significantly lower delta-1 power than both FMS and NHC groups in N3 sleep, these results appeared consistent throughout the night, where the FMS and NHC group showed no differences in delta-1 power. This is an interesting finding, and leads one to reason that FMS is not a typical chronic pain condition, where OA exhibits a modified sleep structure akin to that of a characteristic chronic pain group, FMS do not, at least not entirely. This observation however, does not support the findings from previous research which described FMS patients as having less slow wave sleep than healthy baseline controls (Drewes et al., 1995), in fact in the present study they appeared to exhibit the same amount of slow wave activity as the healthy control group; however, delta power across these groups have not been frequently explored.

Overall a general consensus for most of what was observed with the spectral analysis relates to the greater variability in FMS patients in terms of the microstructure of their sleep, as observations generally show greater power in the FMS patients but a greater deviation from the mean. This may imply that FMS patients are highly varied individuals, and two patients may exhibit very different symptom severities. This should be taken into account with future research directions. However, it must also be considered that these patients are newly diagnosed; long-term diagnoses may gradually lead FMS patients to develop or *fall into* typical sleep characteristics found in previous studies such as increased alpha-delta sleep or decreased slow wave sleep, these in turn may be moderated by a third factor, perhaps relating to their psychosocial profile.

### 6.6. Psychosocial Analysis

Several psychosocial factors have previously been found to be different in fibromyalgia sufferers compared to healthy controls. Some of these include a greater level of depression and anxiety, decreased social support, a greater external health locus of

control, increased pain catastrophizing and a more prevalent neurotic personality type. These were all analysed in this study in an attempt to explore and build a possible psychosocial profile of these particular patients.

Although there were little differences in demographic analysis and sleep parameters between patients with fibromyalgia and those with osteoarthritis, there were significant differences in a number of their psychological parameters. Between the three groups, both clinical groups were significantly more depressed than the healthy control group, however the difference between FMS and OA did not reach significance, although this was close at .057. It is already known that FMS patients are more depressed than a healthy control group (Thieme et al., 2004), however FMS patients appeared to be similar to a matched pain control group. Although there appeared to be a trend where FMS patients had a greater depression mean score. FMS patients also had a greater standard deviation in terms of depression than both OA and NHC, further reinforcing individual differences within an FMS population, moreover the *p* values were close to reaching significance, and as a point of note, prior to corrections for multiple comparisons the test reached clinical significance.

Furthermore, the models for state and trait anxiety found significant group differences. The FMS patients had numerically the greatest state and trait anxiety mean scores, with the OA group having the second highest, and lowest being the NHC group. Nonetheless, the only *significant* difference observed for *state* anxiety was between FMS and NHC. This indicated a greater severity in state anxiety in the FMS patients compared with healthy controls. Conversely with *trait* (general) anxiety, FMS patients exhibited a *significantly* much greater level of trait anxiety than both OA and NHC; this supports previous research implying a greater anxiety in FMS patients than with healthy controls, however we have also found the same to be true for a comparative pain control group, which may point to this being specific to FMS and part of their psychosocial profile.

FMS patients have been shown to exhibit a decrease in perceived social support in previous research (Shuster et al., 2009). In the current study using the Multidimensional Scale of Perceived Social Support, we did not find any differences either in the total score, or the sub-scales between any of the groups. This did not agree with previous findings; however, it may point to the increased likelihood of heterogeneity in FMS patients. The newly diagnosed nature of FMS patients in the present study could account for the heterogeneity of the patients; social support is not a constant, and over time it may decrease, perhaps even due to FMS patients gradually developing into a more typical FMS profile with higher anxiety and greater depression. Moreover, cultural influences

should be taken into account when looking at social support, as some cultures promote support better than others.

Health locus of control is well studied in the past; it is an individuals' belief that one's health is dependent upon either internal or external factors. For FMS, they have previously been shown to be more externally located, in other words they expect their health to be outside of their own control (Gustafsson & Gaston-Johansson, 1996). However, they have not been directly compared to a pain control group (OA). The clinical groups were less internally located than the healthy control group, moreover, they were more externally located particularly in the doctor subscale; this means that their beliefs of their health outcome is in their doctors' hands. This result not only supports previous findings, but it also extends previous findings by including a pain control group. The findings in this facet of psychology implies that external health locus of control beliefs may be more likely with clinical patients, and are not particularly specific to FMS.

FMS sufferers have also been found to be greater pain catastrophizers than healthy control groups (Carol S Burckhardt et al., 1997; Hassett et al., 2000). The results showed a general trend towards a greater pain catastrophization total score and subscores in FMS patients, followed by OA and the lowest scores in the healthy control group. Though FMS patients were only found to be more *significant* pain catastrophizers in terms of helplessness in comparison to the NHC group, with no differences found in the other subscales of rumination or magnification. Additionally, no differences were observed between FMS and OA patients. Helplessness has been previously identified as a potential mediator of health status in FMS patients, partial mediation of pain and disability through depression, and full mediation of pain effects through self-reported pain behaviour (Nicassio, Schuman, Radojevic, & Weisman, 1999). In order to investigate this further, a larger participant sample size would be required to find possible mediators/moderators of FMS symptoms through psychosocial variables.

The last psychological variable explored was the aspect of personality. FMS has been explored as a potential manifestation of neuroticism (Netter & Hennig, 1998). More recently however, personality traits were examined in FMS patients to seek associations with key psychological processes and clinical symptoms; a significant association between the level of neuroticism and pain, sleep, fatigue, depression, anxiety and stress. It was concluded personality was a significant modulator of clinical symptoms in FMS (Malin & Littlejohn, 2012). In the present study, the EPQ-R was used as a personality measure which was robust in terms of reliability and validity. The findings indicated a difference in neuroticism scores within the three groups, and trends showed the FMS

group had the highest score on neuroticism, with the OA group being second, and the NHC group the lowest scoring on the neuroticism sub-scale. Nonetheless, only the FMS group reached clinical significance when compared to the healthy controls. This factor supports previous research whereby FMS were found to have a more neurotic personality type than a healthy control group; however, compared to osteoarthritis, no differences were found. Concurring with Malin & Littlejohn (2012), there are perhaps unexplored relationships relating to neuroticism and factors such as pain, sleep, fatigue etc. which should be taken into consideration for future research. There is a need to explore how a neurotic personality type interacts with variables such as pain perception, depression, and anxiety etc. to understand whether FMS could be a manifestation of neuroticism or perhaps its main symptomology is mediated by neuroticism.

Additional to neuroticism, the lie scale within the EPQ-R was also explore, the analyses indicated that the clinical groups had a greater lie personality score than the healthy counterpart. It could suggest a specific personality trait linked to chronic pain patients, and this area needs to be investigated further.

### 6.7. Fatigue and Sleepiness

One of the more noteworthy results from this study is the differences in subjective sleep related measures. Objective sleep measures found little differences between the clinical groups, most of the objectively observed sleep variables were similar between FMS and OA patients. The question is thus raised as to why FMS patients feel significantly more fatigued and have greater amounts of sleepiness than the OA patients. FMS patients are expected to be more fatigued and sleepy than healthy groups, but they are also seemingly different from OA, with which they share similar objective sleep characteristics. It seems to point to a more psychosocial effect rather than physiological, which may in turn exacerbate FMS symptom severity. Investigating relationships between fatigue, sleep and other psychosocial constructs are essential to understand this problem.

### 6.8. Limitations

This study was important in addressing unanswered question behind the alpha-delta sleep anomaly and FMS. Nevertheless, limitations in the methodology, and constraints on the analyses must be recognised. The PSG methodology focussed only on the EEG, EOG and SMG signals adequate to investigate the proposed hypotheses. However, the opportunity was not exploited to simultaneously incorporate channels which measured oxygen saturation (which could have provided a more precise indication of possible sleep-related respiratory disturbances), or further EMG channels for help in detecting possible

undiagnosed sleep related motor conditions like periodic limb movements. Although participants were screened for these conditions using symptom questionnaires, the possibility of undetected sleep pathology remains present. In mitigation, it should also be pointed out, however, that the selection and screening of the present sample equates with best practice in this research area and, in combination with the diagnostic standardisation utilised here, delivered a methodology superior to that reported in many reported studies. It should also be recognised that, in conducting domiciliary recordings, the comfort of the participants was a priority, and time constraints in setting up additional channels would have been difficult.

Finally, it is recognised that the present analyses have focussed narrowly on those comparisons required by the research questions set out at the start of the study. However, there are clearly some areas (only indirectly related to the stated research questions) that are certainly worth exploring within this dataset using additional multivariate analyses: 1) to assess possible mediating or moderating factors influencing pain-sleep relationships; and 2) selected controlled comparisons of sleep variables within the existing groups using ANCOVA models to adjust for psychological status. The present n-sizes were sufficient to deliver adequate power for the tests reported here; care would need to be exercised in developing more complex multivariate models. Nevertheless, it is fully acknowledged that the potential of the present database has not been fully exploited in the present, focussed analyses.

### 6.9. Future directions

This research was a key study into FMS, not only did we incorporate a similarly matched pain control group and healthy baseline group; we also incorporated multiple subjective and objective measures of sleep dysfunction and quality additional to numerous psychosocial measures in order to understand the relationships between these variables.

Future directions of research would perhaps point to a more in-depth analyses of how psychosocial variables interact with sleep measures. In order to produce predictive models that explore these relationships, a much larger scale study would then be warranted.

Additionally, the hope to investigate aspects of heterogeneity in FMS patients would be beneficial, as previous research and the current study has shown, FMS patients may be less homogeneous than we first thought, both in terms of psychological and physiological characteristics.

### 6.10. Implications for future research

The present study attempted to not only examine FMS in an entirely comprehensive manner, but also to categorically define FMS in a way that has not been done before. The research design aimed to conclusively examine sleep from all relevant aspects, using multiple measures and psychometric instruments; to both conclude several observations made by previous studies, but also to investigate possible avenues that may be relevant for FM syndrome.

The hope for these findings is to lead future research directions in FMS. The direction that is implied from the findings is to explore psychosocial aspects in greater detail, but also to explore their relationships with physiological measures and how they may affect each other. In doing this, future therapies and treatments for FMS could be tailored to incorporate behavioral interventions in current treatments of FMS.

**Conclusion**

FMS is not a homogeneous diagnosis, but shows varying proportions of comorbid anxiety and depression dependent on psychosocial characteristics of the patients (Thieme et al., 2004). Previous studies have rarely utilised newly diagnosed patients, conducted at home recordings, whilst conducting psychometric testing as well; these methodological differences may account for much of what was observed. These patients may be more heterogeneous, as long-term diagnosed FMS patients over time may gradually develop into a typical FMS sufferer, fitting a specific profile, with high anxiety, depression, modified sleep structure; whereby newly diagnosed patients are not yet at that stage. Additionally, differences or lack thereof found in psychosocial factors may be simply due to a factor of time; for example, perceived social support may decrease over time post-diagnosis.

The results of this study helped to identify the clinical features of fibromyalgia. Patients with fibromyalgia have pain which is more severe than patients with osteoarthritis requiring surgery, more psychological symptoms and worse subjective symptoms of sleep, fatigue and sleepiness. In comparison, disturbed sleep is evidenced by sleep stage transitions, which is similar to patients with osteoarthritis, but their total sleep time is similar to healthy controls.

Is the reduction in sleep quality in fibromyalgia, simply a function of their psychological phenotype? The results of this study, do suggest that there may be certain abnormalities of sleep that are different. Although, I have shown that alpha-wave

intrusion is not specific to fibromyalgia, the increase in sigma-2 which possibly relates to faster spindles (spindles of a higher frequency) may reflect some very subtle differences in sleep pathology that cannot be explained by sleep that is disturbed from pain. It is increasingly recognised that the pain in fibromyalgia, can be explained by abnormalities of neural connectivity, and it is interesting to hypothesise that an interaction between psychological phenotypes and sleep abnormality may lead to the development of neural networks to pain pathways.

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# 8. Appendices

**APPENDIX A – ETHICAL APPROVAL**

- **ORIGINAL ETHICS APPROVAL (20-09-2005)**
- **ETHICS MINOR AMENDMENT (22-06-2011)**
- **BASELINE STUDY ETHICS APPROVAL (17-01-2013)**

**APPENDIX B – SCREENING QUESTIONNAIRES**

- **OSTEOARTHRITIS**
- **HEALTHY CONTROLS**

**APPENDIX C – HEALTHY CONTROLS ADVERT**

**APPENDIX D – ACTIGRAPHY**

- **ACTIWATCH INFORMATION SHEET**
- **SLEEP DIARY**

**APPENDIX E – PSYCHOMETRIC QUESTIONNAIRES**

**APPENDIX F – PARTICIPANT INFORMATION SHEETS**

- **CLINICAL PATIENT INFORMATION SHEET**
- **HEALTHY CONTROLS PARTICIPANT INFORMATION SHEET**

**APPENDIX G – CONSENT FORMS**

- **CLINICAL CONSENT FORM**
- **HEALTHY CONTROLS CONSENT FORM**

**APPENDIX H – PAIN MANIKINS FROM THE BPI**

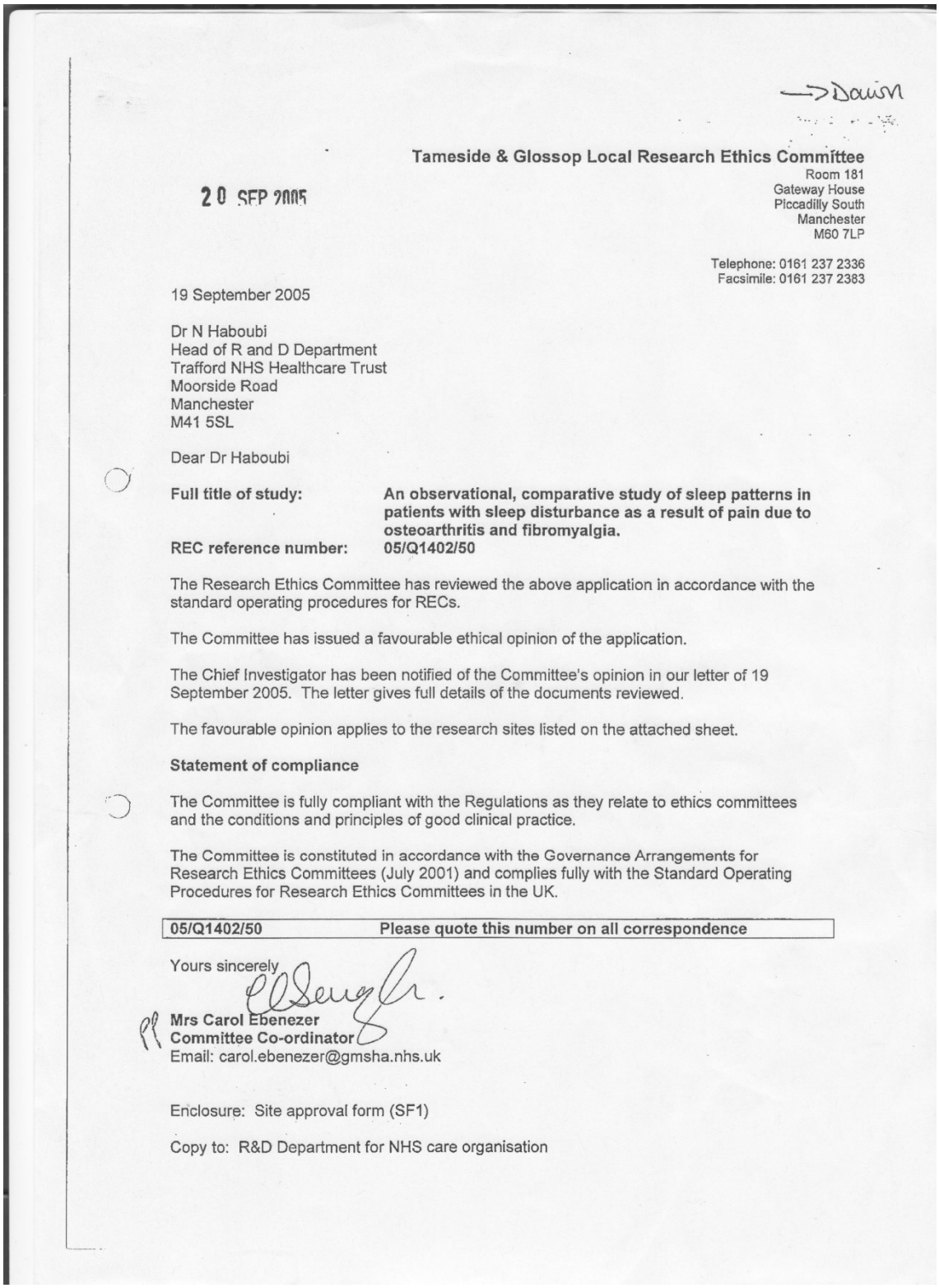
- **FIBROMYALGIA**
- **OSTEOARTHRITIS**

**APPENDIX I – HYPNOGRAMS FROM POLYSOMNOGRAPHY**

**APPENDIX J – EXAMPLE ACTIGRAPHS FROM ACTIGRAPHY**

# APPENDIX A

## ORIGINAL ETHICS APPROVAL (20-09-2005)



→Dawn

**Tameside & Glossop Local Research Ethics Committee**
Room 181
Gateway House
Piccadilly South
Manchester
M60 7LP

Telephone: 0161 237 2336
Facsimile: 0161 237 2383

20 SEP 2005

19 September 2005

Dr N Haboubi
Head of R and D Department
Trafford NHS Healthcare Trust
Moorside Road
Manchester
M41 5SL

Dear Dr Haboubi

**Full title of study:** **An observational, comparative study of sleep patterns in patients with sleep disturbance as a result of pain due to osteoarthritis and fibromyalgia.**

**REC reference number:** **05/Q1402/50**

The Research Ethics Committee has reviewed the above application in accordance with the standard operating procedures for RECs.

The Committee has issued a favourable ethical opinion of the application.

The Chief Investigator has been notified of the Committee's opinion in our letter of 19 September 2005. The letter gives full details of the documents reviewed.

The favourable opinion applies to the research sites listed on the attached sheet.

**Statement of compliance**

The Committee is fully compliant with the Regulations as they relate to ethics committees and the conditions and principles of good clinical practice.

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

| 05/Q1402/50 | Please quote this number on all correspondence |
|---|---|

Yours sincerely

pp **Mrs Carol Ebenezer**
**Committee Co-ordinator**
Email: carol.ebenezer@gmsha.nhs.uk

Enclosure: Site approval form (SF1)

Copy to: R&D Department for NHS care organisation

**Tameside & Glossop Local Research Ethics Committee**

**LIST OF SITES WITH A FAVOURABLE ETHICAL OPINION**

*For all studies requiring site-specific assessment, this form is issued by the main REC to the Chief Investigator and sponsor with the favourable opinion letter and following subsequent notifications from site assessors. For issue 2 onwards, all sites with a favourable opinion are listed, adding the new sites approved.*

| | | | | | |
|---|---|---|---|---|---|
| **REC reference number:** | 05/Q1402/50 | **Issue number:** | 1 | **Date of issue:** | 19 September 2005 |
| **Chief Investigator:** | Dr Frank McKenna | | | | |
| **Full title of study:** | An observational, comparative study of sleep patterns in patients with sleep disturbance as a result of pain due to osteoarthritis and fibromyalgia. | | | | |

*This study was given a favourable ethical opinion by Tameside & Glossop Local Research Ethics Committee on 19 September 2005. The favourable opinion is extended to each of the sites listed below. The research may commence at each NHS site when management approval from the relevant NHS care organisation has been confirmed.*

| *Principal Investigator* | *Post* | *Research site* | *Site assessor* | *Date of favourable opinion for this site* | *Notes (1)* |
|---|---|---|---|---|---|
| Dr Frank McKenna | Consultant Physician and Rheumatologist | Trafford Healthcare NHS Trust<br>Manchester<br>M41 5SL | Salford & Trafford Local Research Ethics Committee | 19/09/2005 | |

Approved by the Chair on behalf of the REC:

..... (Signature of Chair/Administrator)

(delete as applicable)

C. BROWNLEER ..... (Name)

## ETHICS MINOR AMENDMENT (22-06-2011)

NHS
National Research Ethics Service
NRES Committee North West - Greater Manchester East

3rd Floor, Barlow House
4 Minshull Street
Manchester
M1 3DZ

Tel: 0161 625 7830

22 June 2011

Dr Frank Mckenna
Consultant Physician and Rheumatologist
Trafford NHS Healthcare Trust
Rheumatic Diseases Unit
Trafford NHS Healthcare Trust
Manchester
M41 5SL

Dear Dr Mckenna

| | |
|---|---|
| **Study title:** | **An observational, comparative study of sleep patterns in patients with sleep disturbance as a result of pain due to osteoarthritis and fibromyalgia.** |
| **REC reference:** | **05/Q1402/50** |
| **Protocol number:** | **N/A** |
| **Amendment number:** | **01** |
| **Amendment date:** | **07 June 2011** |

**Overview of Amendment**

- Addition of two new investigators into study and addition of nine additional questionnaires/scales.

The above amendment was reviewed at the meeting of the Sub-Committee held on 21 June 2011.

**Ethical opinion**

The members of the Committee taking part in the review gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

**Approved documents**

The documents reviewed and approved at the meeting were:

| Document | Version | Date |
|---|---|---|
| CV for Kevin Morgan | | |
| CV for Wai Kent Yeung | | 11 May 2011 |
| Questionnaire: Adult EPQ-R | | |
| Questionnaire: Pain catastrophizing scale | | |
| Questionnaire: Multidimensional health locus of control | | |
| Questionnaire: Brief pain inventory - short form | | |

This Research Ethics Committee is an advisory committee to the North West Strategic Health Authority
*The National Research Ethics Service (NRES) represents the NRES Directorate within the National Patient Safety Agency and Research Ethics Committees in England*

| | | |
|---|---|---|
| Questionnaire: Fatigue severity scale | | |
| Notice of Substantial Amendment (non-CTIMPs) | 01 | 07 June 2011 |
| Covering Letter | | 07 June 2011 |
| List of changes to protocol | 1.1 | 07 June 2011 |
| Questionnaire: Multidimensional scale of perceived social support | | |
| Questionnaire: Self evaluation questionnaire | | |
| Questionnaire: CES-D | | |
| Questionnaire: Restless leg syndrome screening | | |

**Membership of the Committee**

The members of the Committee who took part in the review are listed on the attached sheet.

**R&D approval**

All investigators and research collaborators in the NHS should notify the R&D office for the relevant NHS care organisation of this amendment and check whether it affects R&D approval of the research.

**Statement of compliance**

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

| | |
|---|---|
| **05/Q1402/50:** | **Please quote this number on all correspondence** |

Yours sincerely

pp

**Mr Francis Chan**
**Chair**

E-mail: rowen.callaghan@northwest.nhs.uk

*Enclosures:* *List of names and professions of members who took part in the review*

*Copy to:* *R & D Department – Trafford NHS Healthcare Trust*

**NRES Committee North West - Greater Manchester East**

**Attendance at Sub-Committee of the REC meeting on 21 June 2011**

| *Name* | *Profession* | *Capacity* |
|---|---|---|
| Mr Francis Chan | Consultant Orthopaedic Surgeon | Expert |
| Dr Michael Hollingsworth | Retired Senior Lecturer in Pharmacology | Lay |

# BASELINE STUDY ETHICS APPROVAL (17-01-2013)

**Wai Yeung**

**From:** Zoe Stockdale
**Sent:** 17 January 2013 15:43
**To:** Wai Yeung
**Cc:** Kevin Morgan; Adrian Brindley
**Subject:** RE: HPSC Research Proposal R12-P179 - final reminder

Dear Wai,

Many thanks for your response to the Sub-Committee's comments. I can confirm that you have responded to all of the comments, and that your study now has full ethical approval.

If, in the future, you wish to make any amendments to the study, you should contact me in the first instance.

Kind Regards,

Zoe

---

**From:** Wai Yeung
**Sent:** 16 January 2013 18:11
**To:** Zoe Stockdale
**Cc:** Kevin Morgan; Adrian Brindley
**Subject:** RE: HPSC Research Proposal R12-P179 - final reminder

Dear Zoe,

Apologies for the delay. Response is attached.

Kind Regards

Wai Kent Yeung

---

**From:** Zoe Stockdale
**Sent:** 16 January 2013 14:31
**To:** Kevin Morgan; Wai Yeung
**Cc:** Adrian Brindley
**Subject:** HPSC Research Proposal R12-P179 - final reminder
**Importance:** High

Research Proposal: A community based study of sleeping patterns and psychological constructs in individuals with osteoarthritis
Proposal Number: R12-P179

I have not yet received a response to the Sub-Committee's clearance notification. The deadline for this response was the 16th January 2013. If I have not received a response to the notification by next Wednesday (**23rd January 2013**), the conditional approval will be **withdrawn** and you will **need to re-apply for ethical approval**.

Regards,

Zoë

1

# APPENDIX B

## HEALTH SCREENING QUESTIONNAIRE FOR OA

Name/Number .....

### Health Screening Questionnaire for Study Volunteers

As a volunteer participating in a research study, it is important that you are currently in good health and have had no significant medical problems in the past. This is (i) to ensure your own continuing well-being and (ii) to avoid the possibility of individual health issues confounding study outcomes.

**Please complete this brief questionnaire to confirm your fitness to participate:**

**Personal Details**

| Your Name: | | Telephone(s): | Date of birth: Age: |
|---|---|---|---|
| Height | Weight | | |
| Address: | | | |

**1.** **At present,** do you have any health problem for which you are:

| | | | | |
|---|---|---|---|---|
| (a) | on medication, prescribed or otherwise ..... | Yes ☐ | No ☐ |
| (b) | attending your general practitioner ..... | Yes ☐ | No ☐ |
| (c) | on a hospital waiting list ..... | Yes ☐ | No ☐ |

**If YES to any,** please give details (e.g. name of medication, for how long have you been taking medication etc.):

.....

.....

.....

**2.** **Have you ever** had any of the following:

| | | | | |
|---|---|---|---|---|
| (a) | **Convulsions/epilepsy** ..... | Yes ☐ | No ☐ |
| (b) | **Asthma** ..... | Yes ☐ | No ☐ |
| (c) | **Eczema** ..... | Yes ☐ | No ☐ |
| (d) | **Diabetes** ..... | Yes ☐ | No ☐ |
| (e) | **A blood disorder** ..... | Yes ☐ | No ☐ |
| (f) | **Head injury** ..... | Yes ☐ | No ☐ |
| (g) | **Digestive problems** ..... | Yes ☐ | No ☐ |
| (h) | **Heart problems** ..... | Yes ☐ | No ☐ |
| (i) | **Problems with bones or joints** ..... | Yes ☐ | No ☐ |

| | | | |
|---|---|---|---|
| (j) | Disturbance of balance/coordination ..... | Yes ☐ | No ☐ |
| (k) | Numbness in hands or feet ..... | Yes ☐ | No ☐ |
| (l) | Disturbance of vision ..... | Yes ☐ | No ☐ |
| (m) | Ear / hearing problems ..... | Yes ☐ | No ☐ |
| (n) | Thyroid problems ..... | Yes ☐ | No ☐ |
| (o) | Kidney or liver problems ..... | Yes ☐ | No ☐ |
| (p) | Allergy to nuts ..... | Yes ☐ | No ☐ |

**3. Have you ever** had any of the following:

| | | | |
|---|---|---|---|
| (a) | Anxiety disorder ..... | Yes ☐ | No ☐ |
| (b) | Bipolar disorder ..... | Yes ☐ | No ☐ |
| (c) | Delirium ..... | Yes ☐ | No ☐ |
| (d) | Dementia ..... | Yes ☐ | No ☐ |
| (e) | Depression, dysthymia ..... | Yes ☐ | No ☐ |
| (f) | Schizophrenia ..... | Yes ☐ | No ☐ |
| (g) | Substance abuse ..... | Yes ☐ | No ☐ |

**If YES to** any question, please describe briefly if you wish (e.g. to confirm problem was/is short-lived, insignificant or well controlled.)

.....

.....

.....

**4. Do you** regularly consume:

| | | | | How much/day? |
|---|---|---|---|---|
| (a) | Caffeine ..... | Yes ☐ | No ☐ | |
| (b) | Alcohol ..... | Yes ☐ | No ☐ | |
| (c) | Nicotine ..... | Yes ☐ | No ☐ | |
| (d) | Excessive fluid in the evening ..... | Yes ☐ | No ☐ | |

**5.** Please information on any allergies that you may have:

.....

.....

**6.** Additional questions for female participants

(a) Are your periods normal/regular? ..... Yes ☐ No ☐

(b) Are you on "the pill"? ..... Yes ☐ No ☐

(c) Could you be pregnant? ..... Yes ☐ No ☐

(d) Are you taking hormone replacement therapy (HRT)? Yes ☐ No ☐

**If YES,** please give details (e.g. state when you commenced HRT):

.....

.....

## Sleep problems

Q1. Have you been told that you have a sleep problem/condition by your GP or another healthcare professional? ..... Yes ☐ No ☐

**If YES**, please describe the diagnosis

.....

Q2. Are you currently taking medication/any other treatment for this condition? ..... Yes ☐ No ☐

**If YES**, please provide details – what medication/treatment are you taking, when have you started

.....

.....

## Sleep Quality Questionnaire

The following questions relate to your usual sleep habits during the past month. Your answers should indicate the most accurate reply for the *majority* of days and nights in the past month.

1. During the past month, what time have you usually gone to bed at night?

   BED TIME_____

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

   NUMBER OF MINUTES_____

3. During the past month, what time have you usually woken up in the morning?

   GETTING UP TIME_____

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

HOURS OF SLEEP PER NIGHT_____

***For each of the remaining questions, check the one best response. Please answer all questions.***

5. During the past month, how often have you had trouble sleeping because you...

a) Cannot get to sleep within 30 minutes

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

b) Wake up in the middle of the night or early morning

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

c) Have to get up to use the bathroom

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

d) Cannot breathe comfortably

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

e) Cough or snore loudly

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

f) Feel too cold

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

g) Feel too hot

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

h) Had bad dreams

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

i) Have pain

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

j) Other reason(s), please describe

_____

_____

_____

_____

How often during the past month have you had trouble sleeping because of this?

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

6. During the past month, how would you rate your sleep quality overall?

| Very Good | Fairly Good | Fairly Bad | Very Bad |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

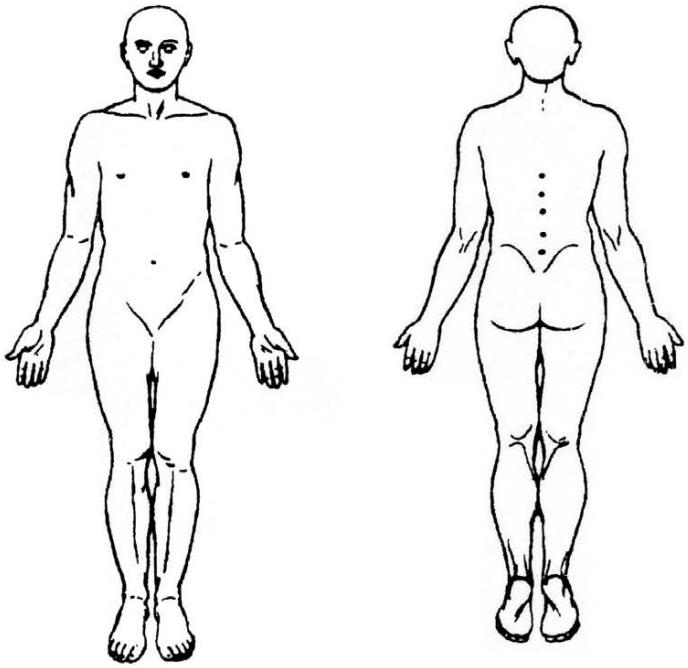
| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

| No problem at all | Only a very slight problem | Somewhat of a big problem | A very big problem |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

## Pain diagram

Which joints or parts of the body are painful?
(Mark with one or more crosses where you have pain)



**THANK YOU FOR COMPLETING ALL QUESTIONS**

**PLEASE RETURN THE SCREENING QUESTIONNAIRE IN THE ENVELOPE PROVIDED**

# HEALTH SCREENING QUESTIONNAIRE FOR NHC

Name/Number .....

## Health Screen Questionnaire for Study Volunteers

As a volunteer participating in a research study, it is important that you are currently in good health and have had no significant medical problems in the past. This is (i) to ensure your own continuing well-being and (ii) to avoid the possibility of individual health issues confounding study outcomes.

**Please complete this brief questionnaire to confirm your fitness to participate:**

| How did you find out about the study? (e.g. advert in the library) | |
|---|---|

**Personal Details**

| Your Name: | Telephone(s): | Date of birth: Age: | |
|---|---|---|---|
| Address: | | Height: | Weight: |

1. **At present,** do you have any health problem for which you are:

| | | | | |
|---|---|---|---|---|
| (a) | on medication, prescribed or otherwise ..... | Yes ☐ | No ☐ |
| (b) | attending your general practitioner ..... | Yes ☐ | No ☐ |
| (c) | on a hospital waiting list ..... | Yes ☐ | No ☐ |

**If YES to any,** please give details (e.g. name of medication, for how long have you been taking medication etc.):

.....

.....

.....

2. **Have you ever** had any of the following:

| | | | | |
|---|---|---|---|---|
| (a) | Convulsions/epilepsy ..... | Yes ☐ | No ☐ |
| (b) | Asthma ..... | Yes ☐ | No ☐ |
| (c) | Eczema ..... | Yes ☐ | No ☐ |
| (d) | Diabetes ..... | Yes ☐ | No ☐ |
| (e) | A blood disorder ..... | Yes ☐ | No ☐ |
| (f) | Head injury ..... | Yes ☐ | No ☐ |
| (g) | Digestive problems ..... | Yes ☐ | No ☐ |
| (h) | Heart problems ..... | Yes ☐ | No ☐ |

| | | | | | |
|---|---|---|---|---|---|
| (i) | Problems with bones or joints ..... | Yes | | No | |
| (j) | Disturbance of balance/coordination ..... | Yes | | No | |
| (k) | Numbness in hands or feet ..... | Yes | | No | |
| (l) | Disturbance of vision ..... | Yes | | No | |
| (m) | Ear / hearing problems ..... | Yes | | No | |
| (n) | Thyroid problems ..... | Yes | | No | |
| (o) | Kidney or liver problems ..... | Yes | | No | |
| (p) | Allergy to nuts ..... | Yes | | No | |

**3.** **Have you ever** had any of the following:

| | | | | | |
|---|---|---|---|---|---|
| (a) | Anxiety disorder ..... | Yes | | No | |
| (b) | Bipolar disorder ..... | Yes | | No | |
| (c) | Delirium ..... | Yes | | No | |
| (d) | Dementia ..... | Yes | | No | |
| (e) | Depression, dysthymia ..... | Yes | | No | |
| (f) | Schizophrenia ..... | Yes | | No | |
| (g) | Substance abuse ..... | Yes | | No | |

**If YES to** any question, please describe briefly if you wish (e.g. to confirm problem was/is short-lived, insignificant or well controlled.)

.....

.....

.....

**4.** **Do you** regularly consume:

| | | | | | How much/day? |
|---|---|---|---|---|---|
| (a) | Caffeine ..... | Yes | | No | |
| (b) | Alcohol ..... | Yes | | No | |
| (c) | Nicotine ..... | Yes | | No | |
| (d) | Excessive fluid in the evening ..... | Yes | | No | |

**5.** Allergy Information

| | | | | | |
|---|---|---|---|---|---|
| (a) | Are you allergic to any food products? | Yes | | No | |
| (b) | Are you allergic to any medicines? | Yes | | No | |
| (c) | Are you allergic to plasters? | Yes | | No | |

**If YES** to any of question 5 please provide additional information on the allergy:

.....

.....

**6.** Additional questions for female participants

| | | | | | |
|---|---|---|---|---|---|
| (a) | Are your periods normal/regular? ..... | Yes | ☐ | No | ☐ |
| (b) | Are you on "the pill"? ..... | Yes | ☐ | No | ☐ |
| (c) | Could you be pregnant? ..... | Yes | ☐ | No | ☐ |
| (d) | Are you taking hormone replacement therapy (HRT)? | Yes | ☐ | No | ☐ |

**If YES,** please give details (e.g. state when you commenced HRT):

.....

.....

**7.** Are you currently involved in any other research studies at the University or elsewhere?

Yes ☐ No ☐

If yes, please provide details of the study

.....

.....

## Sleep problems

Q1. Have you been told that you have a sleep problem/condition by your GP or another healthcare professional? ..... Yes ☐ No ☐

**If YES**, please describe the diagnosis

.....

Q2. a. Please tell us when you were diagnosed

.....

Q2. b. Are you currently taking medication/any other treatment for this condition? ..... Yes ☐ No ☐

**If YES**, please provide details – what medication/treatment are you taking, when have you started

.....

.....

**THANK YOU FOR COMPLETING ALL QUESTIONS**

**PLEASE RETURN THE SCREENING QUESTIONNAIRE IN THE ENVELOPE PROVIDED**

**Or alternatively if you completed an electronic copy, please return it by e-mail to w.k.yeung@lboro.ac.uk**

# APPENDIX C

**ADVERT FOR HEALTHY CONTROLS**

**Participants aged 40-65 required for study into psychology and sleep.**

You will be required to have two nights of polysomnography recordings in your own home and also two weeks of activity monitoring.

If you are interested, please contact Wai Kent Yeung

w.k.yeung@lboro.ac.uk

(01509) 228163

Version 1.1

# APPENDIX D

## ACTIWATCH INFORMATION SHEET

### Sleep Monitoring: Information Sheet

In order to monitor your sleeping patterns we would like you to wear a small device called an Actiwatch. This device records information about your body movements, and stores the information for several weeks. Because people tend to move most when they are awake, and least when they are asleep, we can use this information to see how well someone is sleeping.

**About the Actiwatch**

1. The Actiwatch should be worn like a wrist-watch (sufficiently tight to avoid excessive movement, but sufficiently loose to avoid discomfort). If you already wear a wristwatch, then wear the Actiwatch on the opposite wrist.

2. The Actiwatch should be worn at <u>all</u> times day and night, but should be removed for washing, bathing and swimming.

3. The Actiwatch is quite tough, so don't worry if it accidentally gets dropped, or wet. It would be best, however, to avoid immersing the device in water.

4. Please complete the information on the attached diary for each day you wear the Actiwatch.

**SLEEP DIARY**

## Bedtime Diary

In order to interpret the Actiwatch information, we need to know when you go to bed and get up. Please record the time you go to bed, and the time you get up for each day. Remember to specify AM or PM, or use 24 hour clock notation.

| ID | Time you went to bed | Time you got up |
|---|---|---|
| Day 1<br>Date: | | |
| Day 2<br>Date: | | |
| Day 3<br>Date: | | |
| Day 4<br>Date: | | |
| Day 5<br>Date: | | |
| Day 6<br>Date: | | |
| Day 7<br>Date: | | |
| Day 8<br>Date: | | |
| Day 9<br>Date: | | |
| Day 10<br>Date: | | |
| Day 11<br>Date: | | |
| Day 12<br>Date: | | |
| Day 13<br>Date: | | |
| Day 14<br>Date: | | |

# APPENDIX E

## PSYCHOMETRIC QUESTIONNAIRES

Trafford Healthcare NHS
NHS Trust

**An observational comparative study of sleep patterns in patients with sleep disturbance as a result of chronic pain due to fibromyalgia and osteoarthritis**

**QUESTIONNAIRE PACK**

**Please complete ALL questions**

**THANK YOU**

Loughborough University

Loughborough Sleep Research Centre

Participant ID:

Loughborough University

# About you

Please tick (✓) the appropriate boxes where indicated:

| **Last Name:** | **First Name:** |
|---|---|
| **Age:** | **Date:** |

**Gender:** Male ☐ Female ☐

**Marital Status:**

- Single ☐
- Married ☐
- Cohabiting ☐
- Separated ☐
- Divorced ☐
- Widowed ☐

**What is your ethnic background?**

- White – British, Irish, other white background ☐
- Black or Black British – Caribbean, African, other Black background ☐
- Mixed – white and black Caribbean, white and black African, white and Asian, other mixed background ☐
- Chinese or other ethnic group – Chinese, any other ☐
- Asian or Asian British- Indian, Pakistani, Bangladeshi, other Asian background ☐

**Would you describe your work as:**

- Day time work (e.g. 9am – 5pm) ☐
- Shift work – including nights ☐
- Shift work – day time only ☐
- I am currently unemployed/retired ☐

Participant ID:

Loughborough University

**Please tick your highest qualification:**

| | | | |
|---|---|---|---|
| No formal qualification | ☐ | Degree or equivalent | ☐ |
| O-level/CSE or equivalent/GCSE | ☐ | Postgraduate degree or equivalent | ☐ |
| AS/A-level or equivalent | ☐ | Vocational qualifications | ☐ |

**Your condition:**

Duration of **FM** symptoms (years):

Years since diagnosis of **FM**:

Participant ID:

Loughborough University

# Fibromyalgia Impact Questionnaire

**Directions:** For questions 1 through 11, please check the number that best describes how you did overall for the *past week*. If you don't normally do something that is asked, place an 'X' in the 'Not Applicable' box

| **Were you able to:** | **Always** | **Most** | **Occasionally** | **Never** | **Not Applicable** |
|---|---|---|---|---|---|
| 1. Do shopping | 0 | 1 | 2 | 3 | |
| 2. Do laundry with washer and dryer? | 0 | 1 | 2 | 3 | |
| 3. Prepare meals? | 0 | 1 | 2 | 3 | |
| 4. Wash dishes / cooking utensils by hand? | 0 | 1 | 2 | 3 | |
| 5. Vacuum a rug? | 0 | 1 | 2 | 3 | |
| 6. Make beds? | 0 | 1 | 2 | 3 | |
| 7. Walk several streets? | 0 | 1 | 2 | 3 | |
| 8. Visit friends or relatives? | 0 | 1 | 2 | 3 | |
| 9. Do gardening/garden work? | 0 | 1 | 2 | 3 | |
| 10. Drive a car? | 0 | 1 | 2 | 3 | |
| 11. Climb stairs? | 0 | 1 | 2 | 3 | |
| **Sub-total scores *(for internal use only)*** | | | | | |
| **Total score *(for internal use only)*** | | | | | |

| 12. Of the 7 days in the past week, how many days did you feel good? | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 13. How many days last week did you miss work, including housework, because of fibromyalgia? | | | | | | |

Participant ID:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|

**Directions:** For the remaining items, mark the point on the line that best indicates how you felt overall for the past week.

**14. When you worked how much did pain or other symptoms of your fibromyalgia interfere with your ability to do your work, including housework?**

No problem with work ——— Great difficulty with work

**15. How bad has your pain been?**

No pain ——— Very severe pain

**16. How tired have you been?**

No tiredness ——— Very tired

**17. How have you felt when you get up in the morning?**

Awoke well rested ——— Awoke very tired

**18. How bad has your stiffness been?**

No stiffness ——— Very stiff

**19. How nervous or anxious have you felt?**

Not anxious ——— Very anxious

**20. How depressed or blue have you felt?**

Not depressed ——— Very depressed

Participant ID:

Loughborough University

# Pittsburgh Sleep Quality Index

The following questions relate to your usual sleep habits during the past month. Your answers should indicate the most accurate reply for the *majority* of days and nights in the past month.

1. During the past month, what time have you usually gone to bed at night?

BED TIME_____

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

NUMBER OF MINUTES_____

3. During the past month, what time have you usually woken up in the morning?

GETTING UP TIME_____

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

HOURS OF SLEEP PER NIGHT_____

***For each of the remaining questions, check the one best response. Please answer all questions.***

5. During the past month, how often have you had trouble sleeping because you...

a) Cannot get to sleep within 30 minutes

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

b) Wake up in the middle of the night or early morning

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

c) Have to get up to use the bathroom

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

Participant ID:

Loughborough University

d) Cannot breathe comfortably

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

e) Cough or snore loudly

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

f) Feel too cold

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

g) Feel too hot

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

h) Had bad dreams

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

i) Have pain

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

j) Other reason(s), please describe

_____

_____

_____

_____

Participant ID:

How often during the past month have you had trouble sleeping because of this?

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

6. During the past month, how would you rate your sleep quality overall?

| Very Good | Fairly Good | Fairly Bad | Very Bad |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

| No problem at all | Only a very slight problem | Somewhat of a big problem | A very big problem |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

10. Do you have a bed partner or roommate?

| No bed partner or roommate | Partner/roommate in other room | Partner in same room, but not same bed | Partner in same bed |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

If you have a roommate or bed partner, ask him/her how often in the past month you have had. . .

a) Loud snoring

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

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b) Long pauses between breaths while asleep

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

c) Legs twitching or jerking while you sleep

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

d) Episodes of disorientation or confusion during sleep

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

e) Other restlessness while you sleep, please describe:

_____

_____

_____

_____

| Not During the Past Month | Less than Once a Week | Once or Twice a Week | Three or More Times a Week |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

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# Epworth Sleepiness Scale

How likely are you to doze off or fall asleep in the situations described below, in contrast to feeling just tired?

This refers to your usual way of life in the last 6 months.

Even if you haven't done some of these things recently try to work out how they would have affected you.

Use the following scale to choose the most appropriate number for each situation:-

0 = would never doze

1 = slight chance of dozing

2 = moderate chance of dozing

3 = high chance of dozing

| **Situation** | **Chance of Dozing** |
|---|---|
| Sitting and reading..... | |
| Watching TV..... | |
| Sitting, inactive in a public place (e.g. a theatre or a meeting)..... | |
| As a passenger in a car for an hour without a break..... | |
| Lying down to rest in the afternoon when circumstances permit..... | |
| Sitting and talking to someone..... | |
| Sitting quietly after lunch without alcohol..... | |
| In a car, while stopped for a few minutes in the traffic..... | |

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# Fatigue Severity Scale

This questionnaire contains nine statements that rate the severity of your fatigue symptoms. Read each statement and circle a number from 1 to 7, based on how accurately it reflects your condition during the past week and the extent to which you agree or disagree that the statement applies to you.

***A low value (e.g. 1) indicates strong disagreement with the statement, whereas a high value (e.g. 7) indicates strong agreement.

| ***During the past week I have found that:*** | Disagree ⟷ Agree | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. My motivation is lower when I am fatigued. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2. Exercise brings on my fatigue. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 3. I am easily fatigued. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 4. Fatigue interferes with my physical functioning. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 5. Fatigue causes frequent problems for me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 6. My fatigue prevents sustained physical functioning. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 7. Fatigue interferes with carrying out certain duties and responsibilities. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8. Fatigue is among my three most disabling symptoms. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 9. Fatigue interferes with my work, family or social life. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

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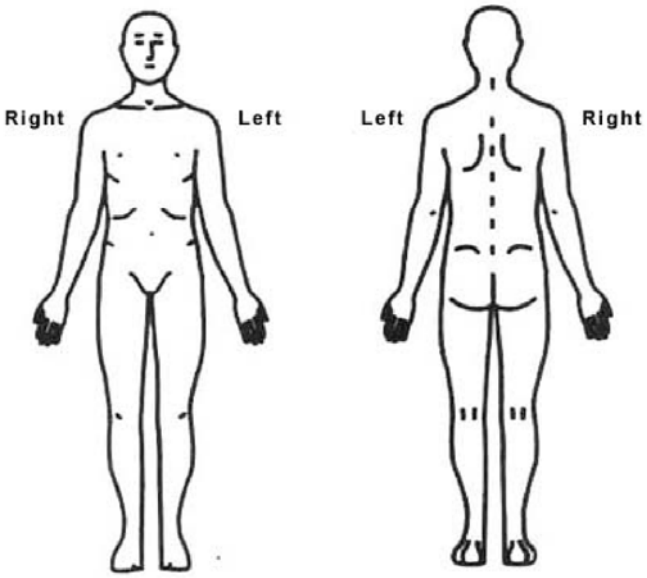
# Brief Pain Index

Please mark the most appropriate responses to the questions below. Please answer **all** questions.

1. Throughout our lives, most of us have had pain from time to time (such as minor headaches, sprains and toothaches). Have you had other pain than these everyday kinds of pain today?

   Yes ☐ No ☐

2. On the diagram, shade in the areas where you feel pain. Put an **X** on the area that hurts the most




3. Please rate your pain by **marking one box** below the number that best describes your pain at its **worst** in the last 24 hours

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

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4. Please rate your pain by **marking one box** below the number that best describes your pain at its least in the last 24 hours

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

5. Please rate your pain by **marking one box** below the number that best describes your pain on average

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

6. Please rate your pain by **marking one box** below the number that tells how much pain you have **right now**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

7. What treatments or medication are you receiving for your pain?

_____

_____

_____

_____

8. In the last 24 hours, how much pain relief have pain treatments or medications provided? Please **mark one box** below the percentage that shows how much **relief** you have received

| 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Relief — Complete Relief

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9. **Mark one box** below the number that best describes how, during the past 24 hours, pain has interfered with your:

**A. General Activity**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Does not interfere — Completely interferes

**B. Mood**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

**C. Walking Ability**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

**D. Normal Work** (Includes both work outside the home and housework)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

**E. Relations with other people**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

**F. Sleep**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

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**G. Enjoyment of Life**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

No Pain — Pain as bad as you can imagine

10. How much pain have you had because of your illness in the past week?

No pain ——————————— Very severe pain

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# NIH-Restless Legs Screening Tool

**Please answer all questions**

1. Have you ever had unpleasant sensations in your legs combined with an urge or need to move your legs?

   Yes ☐ No ☐

2. Do/did these feelings occur mainly or only at rest and do/did they improve with movement?

   Yes ☐ No ☐

3. Are/were these feelings worse in the evening or night than in the morning?

   Yes ☐ No ☐

4. How often do/did these feelings occur?

   | | |
   |---|---|
   | Less than one time per year | ☐ |
   | At least one time a year but less than one time/month | ☐ |
   | 2–4 times per month | ☐ |
   | 2–3 times per week | ☐ |
   | 4–5 times per week | ☐ |
   | 6–7 times per week | ☐ |

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# Centre for Epidemiologic Studies Depression Scale

Below is a list of the ways you might have felt or behaved. Please tell me how often you have felt this way during the past week.

**During the Past Week**

| | Rarely or none of the time (less than 1 day) | Some or a little of the time (1-2 days) | Occasionally or a moderate amount of time (3-4 days) | Most or all of the time (5-7 days) |
|---|---|---|---|---|
| 1. I was bothered by things that usually don't bother me. | ☐ | ☐ | ☐ | ☐ |
| 2. I did not feel like eating; my appetite was poor. | ☐ | ☐ | ☐ | ☐ |
| 3. I felt that I could not shake off the blues even with help from my family or friends. | ☐ | ☐ | ☐ | ☐ |
| 4. I felt I was just as good as other people. | ☐ | ☐ | ☐ | ☐ |
| 5. I had trouble keeping my mind on what I was doing. | ☐ | ☐ | ☐ | ☐ |
| 6. I felt depressed. | ☐ | ☐ | ☐ | ☐ |
| 7. I felt that everything I did was an effort. | ☐ | ☐ | ☐ | ☐ |
| 8. I felt hopeful about the future. | ☐ | ☐ | ☐ | ☐ |
| 9. I thought my life had been a failure. | ☐ | ☐ | ☐ | ☐ |

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| | | | | |
|---|---|---|---|---|
| 10. I felt fearful. | ☐ | ☐ | ☐ | ☐ |
| 11. My sleep was restless. | ☐ | ☐ | ☐ | ☐ |
| 12. I was happy. | ☐ | ☐ | ☐ | ☐ |
| 13. I talked less than usual. | ☐ | ☐ | ☐ | ☐ |
| 14. I felt lonely. | ☐ | ☐ | ☐ | ☐ |
| 15. People were unfriendly. | ☐ | ☐ | ☐ | ☐ |
| 16. I enjoyed life. | ☐ | ☐ | ☐ | ☐ |
| 17. I had crying spells. | ☐ | ☐ | ☐ | ☐ |
| 18. I felt sad. | ☐ | ☐ | ☐ | ☐ |
| 19. I felt that people dislike me. | ☐ | ☐ | ☐ | ☐ |
| 20. I could not "get going." | ☐ | ☐ | ☐ | ☐ |

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# State and Trait Anxiety Scale

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel **right now, that is, at this moment**. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

| | Not at all | Somewhat | Moderately so | Very much so |
|---|---|---|---|---|
| 1. I feel calm | 1 | 2 | 3 | 4 |
| 2. I feel secure | 1 | 2 | 3 | 4 |
| 3. I am tense | 1 | 2 | 3 | 4 |
| 4. I feel strained | 1 | 2 | 3 | 4 |
| 5. I feel at ease | 1 | 2 | 3 | 4 |
| 6. I feel upset | 1 | 2 | 3 | 4 |
| 7. I am presently worrying over possible misfortunes | 1 | 2 | 3 | 4 |
| 8. I feel satisfied | 1 | 2 | 3 | 4 |
| 9. I feel frightened | 1 | 2 | 3 | 4 |
| 10. I feel comfortable | 1 | 2 | 3 | 4 |
| 11. I feel self-confident | 1 | 2 | 3 | 4 |
| 12. I feel nervous | 1 | 2 | 3 | 4 |
| 13. I am jittery | 1 | 2 | 3 | 4 |
| 14. I feel indecisive | 1 | 2 | 3 | 4 |
| 15. I am relaxed | 1 | 2 | 3 | 4 |
| 16. I feel content | 1 | 2 | 3 | 4 |
| 17. I am worried | 1 | 2 | 3 | 4 |
| 18. I feel confused | 1 | 2 | 3 | 4 |
| 19. I feel steady | 1 | 2 | 3 | 4 |
| 20. I feel pleasant | 1 | 2 | 3 | 4 |

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A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you **generally** feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

| | Not at all | Somewhat | Moderately so | Very much so |
|---|---|---|---|---|
| 21. I feel pleasant | 1 | 2 | 3 | 4 |
| 22. I feel nervous and restless | 1 | 2 | 3 | 4 |
| 23. I feel satisfied with myself | 1 | 2 | 3 | 4 |
| 24. I wish I could be as happy as others seem to be | 1 | 2 | 3 | 4 |
| 25. I feel like a failure | 1 | 2 | 3 | 4 |
| 26. I feel rested | 1 | 2 | 3 | 4 |
| 27. I am "calm, cool, and collected" | 1 | 2 | 3 | 4 |
| 28. I feel that difficulties are piling up so that I cannot overcome them | 1 | 2 | 3 | 4 |
| 29. I worry too much over something that really doesn't matter | 1 | 2 | 3 | 4 |
| 30. I am happy | 1 | 2 | 3 | 4 |
| 31. I have disturbing thoughts | 1 | 2 | 3 | 4 |
| 32. I lack self-confidence | 1 | 2 | 3 | 4 |
| 33. I feel secure | 1 | 2 | 3 | 4 |
| 34. I make decisions easily | 1 | 2 | 3 | 4 |
| 35. I feel inadequate | 1 | 2 | 3 | 4 |
| 36. I am content | 1 | 2 | 3 | 4 |
| 37. Some unimportant thought runs through my mind and bothers me | 1 | 2 | 3 | 4 |
| 38. I take disappointments so keenly that I can't put them out of my mind | 1 | 2 | 3 | 4 |
| 39. I am a steady person | 1 | 2 | 3 | 4 |
| 40. I get in a state of tension or turmoil as I think over the recent concerns and interests | 1 | 2 | 3 | 4 |

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# Multidimensional Scale of Perceived Social Support

We are interested in how you feel about the following statements. Read each statement carefully. Indicate how you feel about each statement.

| | Very Strongly Disagree | Strongly Disagree | Mildly Disagree | Neutral | Mildly Agree | Strongly Agree | Very Strongly Agree |
|---|---|---|---|---|---|---|---|
| 1. There is a special person who is around when I am in need. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2. There is a special person with whom I can share my joys and sorrows. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 3. My family really tries to help me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 4. I get the emotional help and support I need from my family. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 5. I have a special person who is a real source of comfort to me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 6. My friends really try to help me. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 7. I can count on my friends when things go wrong. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8. I can talk about my problems with my family. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 9. I have friends with whom I can share my joys and sorrows. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 10. There is a special person in my life who cares about my feelings. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 11. My family is willing to help me make decisions. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12. I can talk about my problems with my friends. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

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# Multidimensional Health Locus of Control Scale

Each item below is a belief statement about your medical condition with which you may agree or disagree. Beside each statement is a scale which ranges from strongly disagree (1) to strongly agree (6). For each item we would like you to circle the number that represents the extent to which you agree or disagree with that statement. The more you agree with a statement, the higher will be the number you circle. The more you disagree with a statement; the lower will be the number you circle. Please make sure that you answer **EVERY ITEM** and that you circle **ONLY ONE** number per item. This is a measure of your personal beliefs; obviously, there are no right or wrong answers.

| | | Strongly Disagree | Mildly Disagree | Disagree | Agree | Mildly Agree | Strongly Agree |
|---|---|---|---|---|---|---|---|
| 1 | If my condition worsens, it is my own behaviour which determines how soon I will feel better again. | 1 | 2 | 3 | 4 | 5 | 6 |
| 2 | As to my condition, what will be will be | 1 | 2 | 3 | 4 | 5 | 6 |
| 3 | If I see my doctor regularly, I am less likely to have problems with my condition. | 1 | 2 | 3 | 4 | 5 | 6 |
| 4 | Most things that affect my condition happen to me by chance. | 1 | 2 | 3 | 4 | 5 | 6 |
| 5 | Whenever my condition worsens, I should consult a medically trained professional. | 1 | 2 | 3 | 4 | 5 | 6 |
| 6 | I am directly responsible for my condition getting better or worse. | 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | Other people play a big role in whether my condition improves, stays the same, or gets worse. | 1 | 2 | 3 | 4 | 5 | 6 |
| 8 | Whatever goes wrong with my condition is my own fault. | 1 | 2 | 3 | 4 | 5 | 6 |
| 9 | Luck plays a big part in determining how my condition improves. | 1 | 2 | 3 | 4 | 5 | 6 |
| 10 | In order for my condition to improve, it is up to other people to see that the right things happen. | 1 | 2 | 3 | 4 | 5 | 6 |
| 11 | Whatever improvement occurs with my condition is largely a matter of good fortune. | 1 | 2 | 3 | 4 | 5 | 6 |
| 12 | The main thing which affects my condition is what I myself do. | 1 | 2 | 3 | 4 | 5 | 6 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 13 | I deserve the credit when my condition improves and the blame when it gets worse. | 1 | 2 | 3 | 4 | 5 | 6 |
| 14 | Following doctor's orders to the letter is the best way to keep my condition from getting any worse. | 1 | 2 | 3 | 4 | 5 | 6 |
| 15 | If my condition worsens, it's a matter of fate. | 1 | 2 | 3 | 4 | 5 | 6 |
| 16 | If I am lucky, my condition will get better. | 1 | 2 | 3 | 4 | 5 | 6 |
| 17 | If my condition takes a turn for the worse, it is because I have not been taking proper care of myself. | 1 | 2 | 3 | 4 | 5 | 6 |
| 18 | The type of help I receive from other people determines how soon my condition improves. | 1 | 2 | 3 | 4 | 5 | 6 |

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# Pain Catastrophizing Scale

Everyone experiences painful situations at some point in their lives. Such experiences may include headaches, tooth pain, joint or muscle pain. People are often exposed to situations that may cause pain such as illness, injury, dental procedures or surgery.

We are interested in the types of thoughts and feeling that you have when you are in pain. Listed below are thirteen statements describing different thoughts and feelings that may be associated with pain. Using the scale, please indicate the degree to which you have these thoughts and feelings when you are experiencing pain.

| | Not at all | To a slight degree | To a moderate | To a great degree | All the time |
|---|---|---|---|---|---|
| I worry all the time about whether the pain will end | 0 | 1 | 2 | 3 | 4 |
| I feel I can't go on | 0 | 1 | 2 | 3 | 4 |
| It's terrible and I think it's never going to get any better | 0 | 1 | 2 | 3 | 4 |
| It's awful and I feel that it overwhelms me | 0 | 1 | 2 | 3 | 4 |
| I feel I can't stand it anymore | 0 | 1 | 2 | 3 | 4 |
| I become afraid that the pain will get worse | 0 | 1 | 2 | 3 | 4 |
| I keep thinking of other painful events | 0 | 1 | 2 | 3 | 4 |
| I anxiously want the pain to go away | 0 | 1 | 2 | 3 | 4 |
| I can't seem to keep it out of my mind | 0 | 1 | 2 | 3 | 4 |
| I keep thinking about how much it hurts | 0 | 1 | 2 | 3 | 4 |
| I keep thinking about how badly I want the pain to stop | 0 | 1 | 2 | 3 | 4 |
| There's nothing I can do to reduce the intensity of the pain | 0 | 1 | 2 | 3 | 4 |
| I wonder whether something serious may happen | 0 | 1 | 2 | 3 | 4 |

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# Eysenck Personality Questionnaire-Adult-Revised

Please answer each question by putting a circle around the 'YES' or 'NO' following the question. There are no right or wrong answers, and no trick questions. Work quickly and do not think too long about the exact meaning of the questions.

PLEASE REMEMBER TO ANSWER EACH QUESTION

| | | | |
|---|---|---|---|
| 1 | Do you have many different hobbies? | YES | NO |
| 2 | Do you stop to think things over before doing anything? | YES | NO |
| 3 | Does your mood often go up and down? | YES | NO |
| 4 | Have you ever taken the praise for something you knew someone else had really done? | YES | NO |
| 5 | Do you take much notice of what people think? | YES | NO |
| 6 | Are you a talkative person? | YES | NO |
| 7 | Would being in debt worry you? | YES | NO |
| 8 | Do you ever feel 'just miserable' for no reason? | YES | NO |
| 9 | Do you give money to charities? | YES | NO |
| 10 | Were you ever greedy by helping yourself to more than your share of anything? | YES | NO |
| 11 | Are you rather lively? | YES | NO |
| 12 | Would it upset you a lot to see a child or an animal suffer? | YES | NO |
| 13 | Do you often worry about things you should not have done or said? | YES | NO |
| 14 | Do you dislike people who don't know how to behave themselves? | YES | NO |
| 15 | If you say you will do something, do you always keep your promise no matter how inconvenient it might be? | YES | NO |
| 16 | Can you usually let yourself go and enjoy yourself at a lively party? | YES | NO |
| 17 | Are you an irritable person? | YES | NO |
| 18 | Should people always respect the law? | YES | NO |
| 19 | Have you ever blamed someone for doing something you knew was really your fault? | YES | NO |
| 20 | Do you enjoy meeting new people? | YES | NO |
| 21 | Are good manners very important? | YES | NO |
| 22 | Are your feelings easily hurt? | YES | NO |
| 23 | Are all your habits good and desirable ones? | YES | NO |
| 24 | Do you tend to keep in the background on social occasions? | YES | NO |
| 25 | Would you take drugs which may have strange or dangerous effects? | YES | NO |
| 26 | Do you often feel 'fed up'? | YES | NO |
| 27 | Have you ever taken anything (even a pin or button) that belonged to someone else? | YES | NO |
| 28 | Do you like going out a lot? | YES | NO |
| 29 | Do you prefer to go your own way rather than act by the rules? | YES | NO |
| 30 | Do you enjoy hurting people you love? | YES | NO |
| 31 | Are you often troubled about feelings of guilt? | YES | NO |
| 32 | Do you sometimes talk about things you know nothing about? | YES | NO |
| 33 | Do you prefer reading to meeting people? | YES | NO |
| 34 | Do you have enemies who want to harm you? | YES | NO |
| 35 | Would you call yourself a nervous person? | YES | NO |

Participant ID: 02/

Loughborough University

| | | | |
|---|---|---|---|
| 36 | Do you have many friends? | YES | NO |
| 37 | Do you enjoy practical jokes that can sometimes really hurt people? | YES | NO |
| 38 | Are you a worrier? | YES | NO |
| 39 | As a child, did you do as you were told immediately and without grumbling? | YES | NO |
| 40 | Would you call yourself happy-go-lucky? | YES | NO |
| 41 | Do good manners and cleanliness matter much to you? | YES | NO |
| 42 | Have you often gone against your parents' wishes? | YES | NO |
| 43 | Do you worry about awful things that might happen? | YES | NO |
| 44 | Have you ever broken or lost something belonging to someone else? | YES | NO |
| 45 | Do you usually take the initiative in making new friends? | YES | NO |
| 46 | Would you call yourself tense or 'highly-strung'? | YES | NO |
| 47 | Are you mostly quiet when you are with other people? | YES | NO |
| 48 | Do you think marriage is old-fashioned and should be done away with? | YES | NO |
| 49 | Do you sometimes boast a little? | YES | NO |
| 50 | Are you more easy-going about right and wrong than most people? | YES | NO |
| 51 | Can you easily get some life into a rather dull party? | YES | NO |
| 52 | Do you worry about your health? | YES | NO |
| 53 | Have you ever said anything bad or nasty about anyone? | YES | NO |
| 54 | Do you enjoy cooperating with others? | YES | NO |
| 55 | Do you like telling jokes and funny stories to your friends? | YES | NO |
| 56 | Do most things taste the same to you? | YES | NO |
| 57 | As a child, were you ever cheeky to your parents? | YES | NO |
| 58 | Do you like mixing with people? | YES | NO |
| 59 | Does it worry you if you know there are mistakes in your work? | YES | NO |
| 60 | Do you suffer from sleeplessness? | YES | NO |
| 61 | Have people said that you sometimes act too rashly? | YES | NO |
| 62 | Do you always wash before a meal? | YES | NO |
| 63 | Do you nearly always have a 'ready answer' when people talk to you? | YES | NO |
| 64 | Do you like to arrive at appointments in plenty of time? | YES | NO |
| 65 | Have you often felt listless and tired for no reason? | YES | NO |
| 66 | Have you ever cheated at a game? | YES | NO |
| 67 | Do you like doing things in which you have to act quickly? | YES | NO |
| 68 | Is (or was) your mother a good woman? | YES | NO |
| 69 | Do you often make decisions on the spur of the moment? | YES | NO |
| 70 | Do you often feel life is very dull? | YES | NO |
| 71 | Have you ever taken advantage of someone? | YES | NO |
| 72 | Do you often take on more activities than you have time for? | YES | NO |
| 73 | Are there several people who keep trying to avoid you? | YES | NO |
| 74 | Do you worry a lot about your looks? | YES | NO |
| 75 | Do you think people spend too much time safeguarding their future with savings and insurance? | YES | NO |
| 76 | Have you ever wished you were dead? | YES | NO |
| 77 | Would you dodge paying taxes if you were sure you could never be found out? | YES | NO |
| 78 | Can you get a party going? | YES | NO |
| 79 | Do you try not to be rude to people? | YES | NO |
| 80 | Do you worry too long after an embarrassing experience? | YES | NO |

Participant ID: 02/

Loughborough University

| | | | |
|---|---|---|---|
| 81 | Do you generally 'look before you leap'? | YES | NO |
| 82 | Have you ever insisted on having your own way? | YES | NO |
| 83 | Do you suffer from 'nerves'? | YES | NO |
| 84 | Do you often feel lonely? | YES | NO |
| 85 | Can you on the whole trust people to tell the truth? | YES | NO |
| 86 | Do you always practise what you preach? | YES | NO |
| 87 | Are you easily hurt when people find fault with you or the work you do? | YES | NO |
| 88 | Is it better to follow society's rules than go your own way? | YES | NO |
| 89 | Have you ever been late for an appointment or work? | YES | NO |
| 90 | Do you like plenty of bustle and excitement around you? | YES | NO |
| 91 | Would you like other people to be afraid of you? | YES | NO |
| 92 | Are you sometimes bubbling over with energy and sometimes very sluggish? | YES | NO |
| 93 | Do you sometimes put off until tomorrow what you ought to do today? | YES | NO |
| 94 | Do other people think of you as being very lively? | YES | NO |
| 95 | Do people tell you a lot of lies? | YES | NO |
| 96 | Do you believe one has special duties to one's family? | YES | NO |
| 97 | Are you touchy about some things? | YES | NO |
| 98 | Are you always willing to admit it when you have made a mistake? | YES | NO |
| 99 | Would you feel sorry for an animal caught in a trap? | YES | NO |
| 100 | When your temper rises, do you find it difficult to control? | YES | NO |
| 101 | Do you lock up your house carefully at night? | YES | NO |
| 102 | Do you believe insurance schemes are a good idea? | YES | NO |
| 103 | Do people who drive carefully annoy you? | YES | NO |
| 104 | When you catch a train, do you often arrive at the last minute? | YES | NO |
| 105 | Do your friendships break up easily without it being your fault? | YES | NO |
| 106 | Do you sometimes like teasing animals? | YES | NO |

PLEASE CHECK THAT YOU HAVE ANSWERED ALL THE QUESTIONS

# APPENDIX F

## CLINICAL PATIENT INFORMATION SHEET

Trafford Healthcare NHS
NHS Trust

**PATIENT INFORMATION SHEET**

**Study title**

An observational, comparative study of sleep patterns in patients with osteoarthritis arthritis and fibromyalgia.

You have been invited to participate in the above research project. Before you decide to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

**What is the purpose of the study?**

Patients with fibromyalgia usually experience sleep disturbance and some previous studies have demonstrated that they have an abnormal sleep pattern. The aim of the study is to determine whether patients who report disturbed sleep due to chronic pain as a result of osteoarthritis demonstrate a similar abnormality. Sleep patterns will be recorded by measuring the electrical activity of the brain by a procedure known as electroencephalography (EEG).

**Why Have I been chosen?**

You have been chosen because you have a diagnosis of either fibromyalgia, or osteoarthritis. We are hoping to initially recruit a total of 40 subjects, (20 patients with fibromyalgia and 20 patients with osteoarthritis.)

**Do I have to take part?**

Taking part in this study is entirely voluntarily. It is up to you to decide whether or not to take part. If you do decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time or not to take part, will not affect the standard of care you receive.

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Trafford Healthcare NHS
NHS Trust

**What will happen to me if I take part?**

You will be invited to attend the rheumatology department at Trafford General Hospital. The consultant rheumatologist will explain the study and ask for your written consent to take part. You will be given a copy of this information sheet and a signed consent form to keep. You will be asked about your current medication, height, weight, tobacco and alcohol use.

You will be asked to complete a number of fairly straightforward questionnaires, which are designed to tell us about your physical, psychological and social well- being and the quality and pattern of your sleep.

Some medications can interfere with your sleep pattern (i.e. hypnotic or neuro-psychiatric medication) and therefore if you are using this type of medication you will be asked to stop taking them for 4 weeks prior to measuring your movement and the electrical activity of your brain during your sleep. This includes sleeping tablets and some anti-depressant type drugs. You will not be advised to do so if it is felt that these drugs are having a beneficial effect on your health.

The study will be carried out in your own home. You will be required to wear a device called a wrist actigraph for fourteen consecutive days. This is similar to a wrist watch and records your movement whilst you are asleep.

You will also be required two consecutive nights to be hooked up to an EEG machine, where several electrodes will be attached to your scalp and skin. This is a totally safe, non invasive procedure. In order to make a good contact with your scalp each electrode will be filled with a type of gel. The electrodes will be attached to a machine which you could carry around, and placed beside your bed when you sleep. A trained research worker from the rheumatology dept in Trafford will visit you at home to fit this equipment and give you instructions on what to do.

**What if something goes wrong?**

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action but you may have to pay for it. Regardless of this if you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study the normal National Health Service complaints mechanisms should be available to you.

Trafford Healthcare NHS
NHS Trust

**Will my taking part in this study be kept confidential?**

All information collected about you during the course of the research will be kept strictly confidential. Any information about you, which leaves the hospital, will have your name and address removed so that you cannot be recognised from it.
With your permission we will write to your GP and inform them of your participation in this research study, and send a copy of this information sheet.

**What will happen to the results of the study?**

The results of the study will be analysed and published in relevant scientific/medical journals. You will be able to obtain a copy by contacting the Rheumatology Department at Trafford Healthcare NHS Trust.

**Who is organising and funding the research?**

The research will be undertaken by the consultant rheumatologist Dr F. McKenna, Wai Kent Yeung (Research Student), Sophie Campbell (Senior nurse specialist) and Professor Kevin Morgan (Loughborough University). Trafford Rheumatic Diseases Research Fund has funded the research.
You will be reimbursed for your travel expenses.

**Who has reviewed the study?**

The Northwest Research Ethics Committee – Greater Manchester East have approved the study.

**Contact for further information.**

If you have any questions please contact: - Dr F. McKenna or Sister Sophie Campbell at The Rheumatic Diseases Unit, Trafford Healthcare NHS Trust, Moorside|Road, Manchester, M41 5SL Tel. (0161) 746 2162 or (0161) 746 2395

**Thank you for considering taking part in our research.**

Dr Frank McKenna (Consultant Rheumatologist, Trafford General Hospital)
Mr Wai Kent Yeung (Research Student, Loughborough University)
Prof. Kevin Morgan (Professor of Gerontology, Loughborough University)

# HEALTHY CONTROLS PARTICIPANT INFORMATION SHEET

Loughborough University

**Participant Information Sheet**

**Study Title**

**A normative baseline study of sleeping patterns and psychological constructs in healthy individuals**

You have been invited to participate in the above research project. Before you decide to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

**What is the purpose of the study?**

Many people exhibit sleep disturbances at some point during their life. Some cases may be attributed to chronic illness. In previous studies, abnormal sleeping patterns have been observed in certain groups of people. The aim of the current study is to combine objective, subjective and psychological measures in order to create a normative baseline in which to compare with clinical populations. Sleeping patterns will be recorded by measuring electrical activity of the brain by a procedure known as electroencephalography (EEG). Activity levels will be monitored using wristwatch actigraphy, and measures of psychology through the administration of a select number of questionnaires.

**Why have I been chosen?**

You have been chosen because you are free from conditions which may affect your sleep. We are hoping to initially recruit a sample of 20 participants for this study.

**What will happen to me if I take part?**

The study will be explained to you and you will be given a copy of this information sheet. We will then ask for your written consent to take part. You will be asked about any medication you are taking, height, weight and tobacco use.

V1.0 (01.01.2012)

Loughborough University

You will then be asked to complete a number of fairly straightforward questionnaires, which are designed to tell us about your physical, psychological and social well-being and the quality and pattern of your sleep.

Some medications can interfere with your sleep pattern (i.e. Hypnotic or neuro-psychiatric medication) and therefore if you are using this type of medication may not be suitable to partake in this study. This includes sleeping tablets and some anti-depressant type drugs. This will be assessed and dependent on circumstances you may or may not be advised to take part.

The study will be carried out in your own home. You will be required to wear a device called a wrist actiwatch for fourteen consecutive days. This is similar to a wrist watch and records your movement whilst you are asleep.

You will also be required two consecutive nights to be hooked up to an EEG machine, where several electrodes will be attached to your scalp and skin. This is a totally safe, non invasive procedure. In order to make a good contact with your scalp each electrode will be filled with a type of paste. The electrodes will be attached to a machine which you could carry around, and placed beside your bed when you sleep. A trained researcher will visit you at home to fit this equipment and give instructions on what to do.

**Will my taking part in this study be kept confidential?**

All information collected about you during the course of the research will be kept strictly confidential. The information will be stored anonymously and securely, and only people with the correct authority will have access. If you decide to withdraw from the study we will destroy your personal information, and any data obtained from you. At all times we will follow strict codes of ethical and legal practice.

**Who is organising and funding the research?**

The research will be undertaken by Wai Kent Yeung (Research Student), and Professor Kevin Morgan (Loughborough University). The research is funded by the Trafford Rheumatic Diseases Research Fund. You will be reimbursed for your travel and inconvenience.

Loughborough University

**Who has reviewed the study?**

The study has been fully approved by the Loughborough Ethical Advisory Committee.

**What if I want to complain?**

If you have concerns about any aspect of this study, you can bring this to the attention of the researchers (office number below) who will do their best to address the matter. If you remain unhappy and wish to complain formally, you can do so directly to the University authorities. The person to contact for complaints is Mrs Zoë Stockdale, Secretary to the Ethical Advisory Committee, Research office, Loughborough University, Tel: 01509222423, email: z.c.stockdale@lboro.ac.uk.

**Do I have to take part?**

Taking part in this study is entirely voluntarily. It is up to you to decide whether or not to take part. If you do decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time or not to take part, will not affect the standard of care you receive.

**Full contact details of the investigators:**

| | |
|---|---|
| Mr. Wai Kent Yeung<br>Clinical Sleep Research Unit<br>Loughborough University<br>Leicestershire<br>LE11 3TU<br>Tel: 01509 228163<br>Email: w.k.yeung@lboro.ac.uk | Professor Kevin Morgan<br>Clinical Sleep Research Unit<br>Loughborough University<br>Leicestershire<br>LE11 3TU<br>Tel: 01509 222472<br>Email: k.morgan@lboro.ac.uk |

If you have any queries, or would just like to discuss the project further, please telephone the project office on: 01509 228 163.

V1.0 (01.01.2012)

# APPENDIX G

## CLINICAL CONSENT FORM

Trafford Healthcare NHS
NHS Trust

### Participant consent form

**Title of Project:**

**An observational, comparative study of sleep patterns in patients with osteoarthritis and fibromyalgia.**

**Participant initials:**_____ **Identification number:** _____

**Centre Name: Trafford NHS Trust** **Name of Researcher: Dr F. McKenna**

| | Please initial box |
|---|---|
| 1. I confirm that I have read and understand the patient information sheet, and I have had the opportunity to consider the information, ask any questions and have had these questions answered satisfactorily. | ☐ |
| 2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, without my medical care or legal rights being affected. | ☐ |
| 3. I understand that all information collected from me for this study will be held in confidence and that my personal details will not appear on any publication of results. | ☐ |
| 4. I understand that relevant sections of my medical notes may be looked at by responsible individuals from regulatory bodies or from the NHS Trust, where it is relevant to my taking part in this study. I give permission for these individuals to have access to my records. | ☐ |
| 5. I agree to my GP being informed of my participation in the study. | ☐ |
| 6. I agree to take part in the above study. | ☐ |

| | | |
|---|---|---|
| _____ | _____ | _____ |
| Name of participant | Signature | Date |
| _____ | _____ | _____ |
| Name of person taking consent | Signature | Date |

When complete distribute 1 copy to patient and 1 copy to research file

# HEALTHY CONTROLS CONSENT FORM

Loughborough University

## Participant consent form

**Title of Project:**

**A normative baseline study of sleeping patterns and psychological constructs in healthy individuals**

**Identification number: ____**

**Name of Researcher: W.K. Yeung**

| | | **Please initial box** |
|---|---|---|
| 1. | I confirm that I have read and understand the information sheet dated (01.01.2012) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. | ☐ |
| 2. | I understand that my participation is voluntary and that I am free to withdraw at anytime without giving any reason, without my medical care or legal rights being affected. | ☐ |
| 3. | I agree to take part in the above study. | ☐ |

| ..... | ..... | ..... |
|---|---|---|
| **Name of Participant** | **Date** | **Signature** |
| ..... | ..... | ..... |
| **Name of Person Taking Consent** | **Date** | **Signature** |

**When complete distribute 1 copy to participant and 1 copy to research file**

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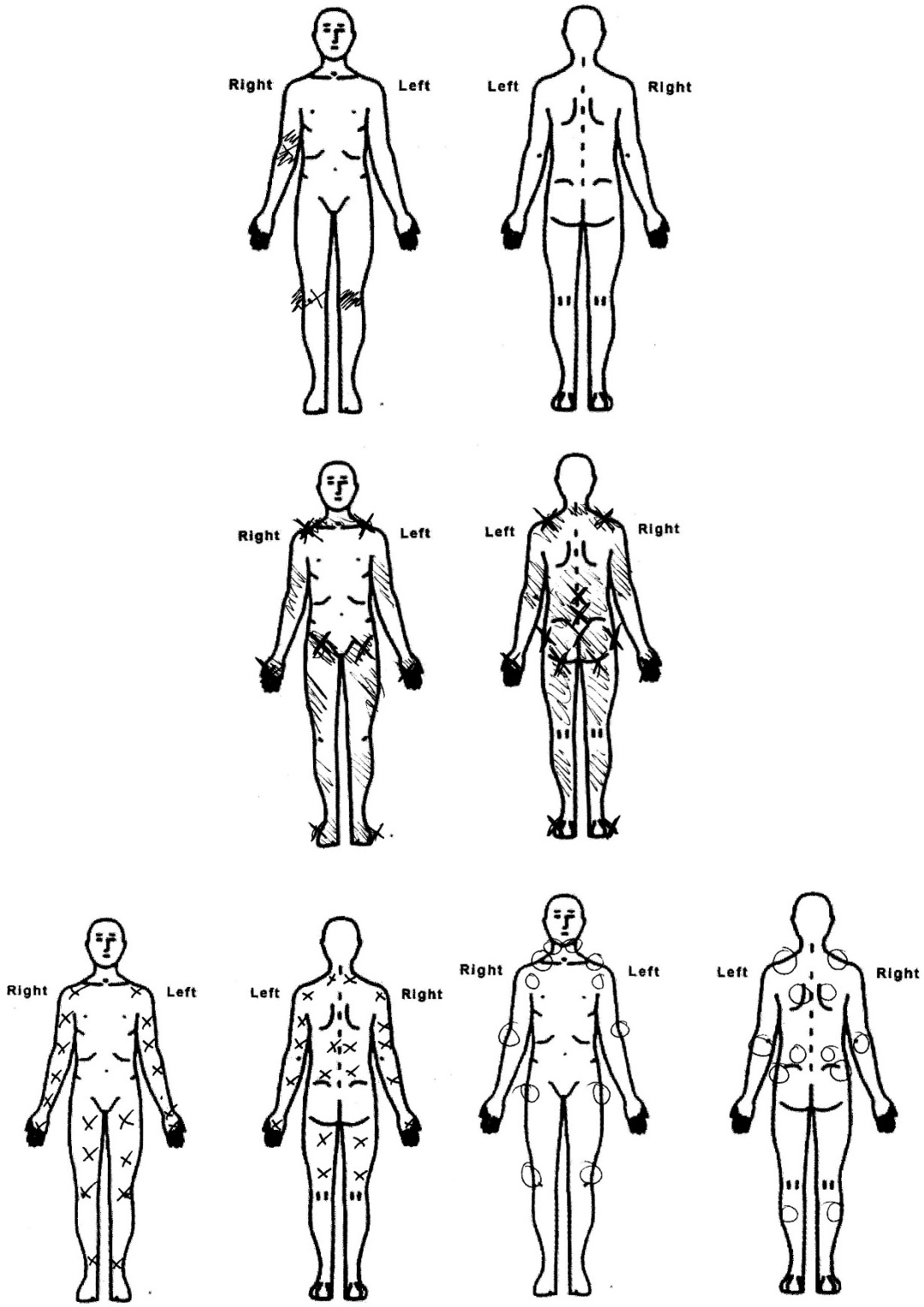
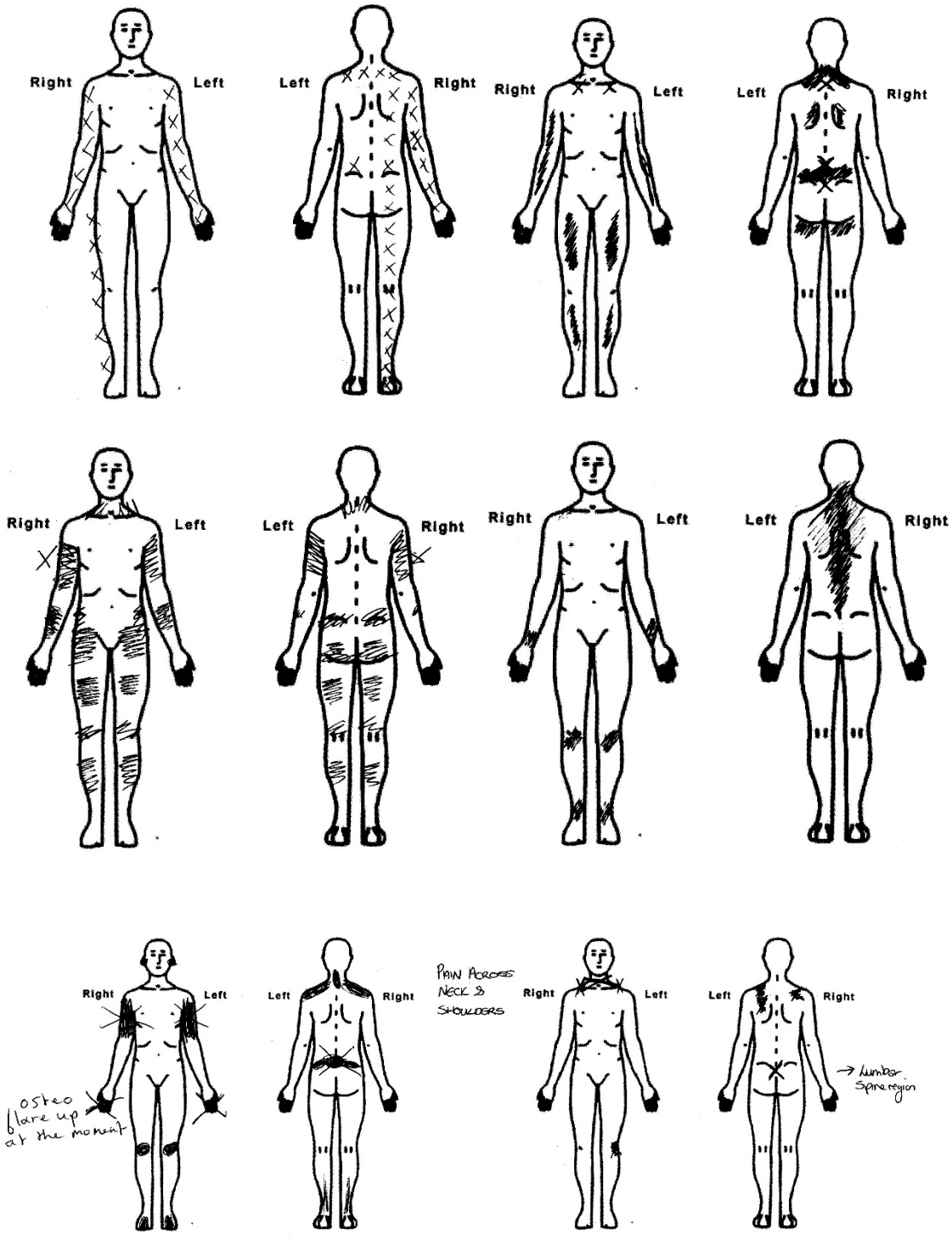
# APPENDIX H

## PAIN MANIKINS FROM THE BRIEF PAIN INDEX FOR FMS

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Pain across neck & shoulders
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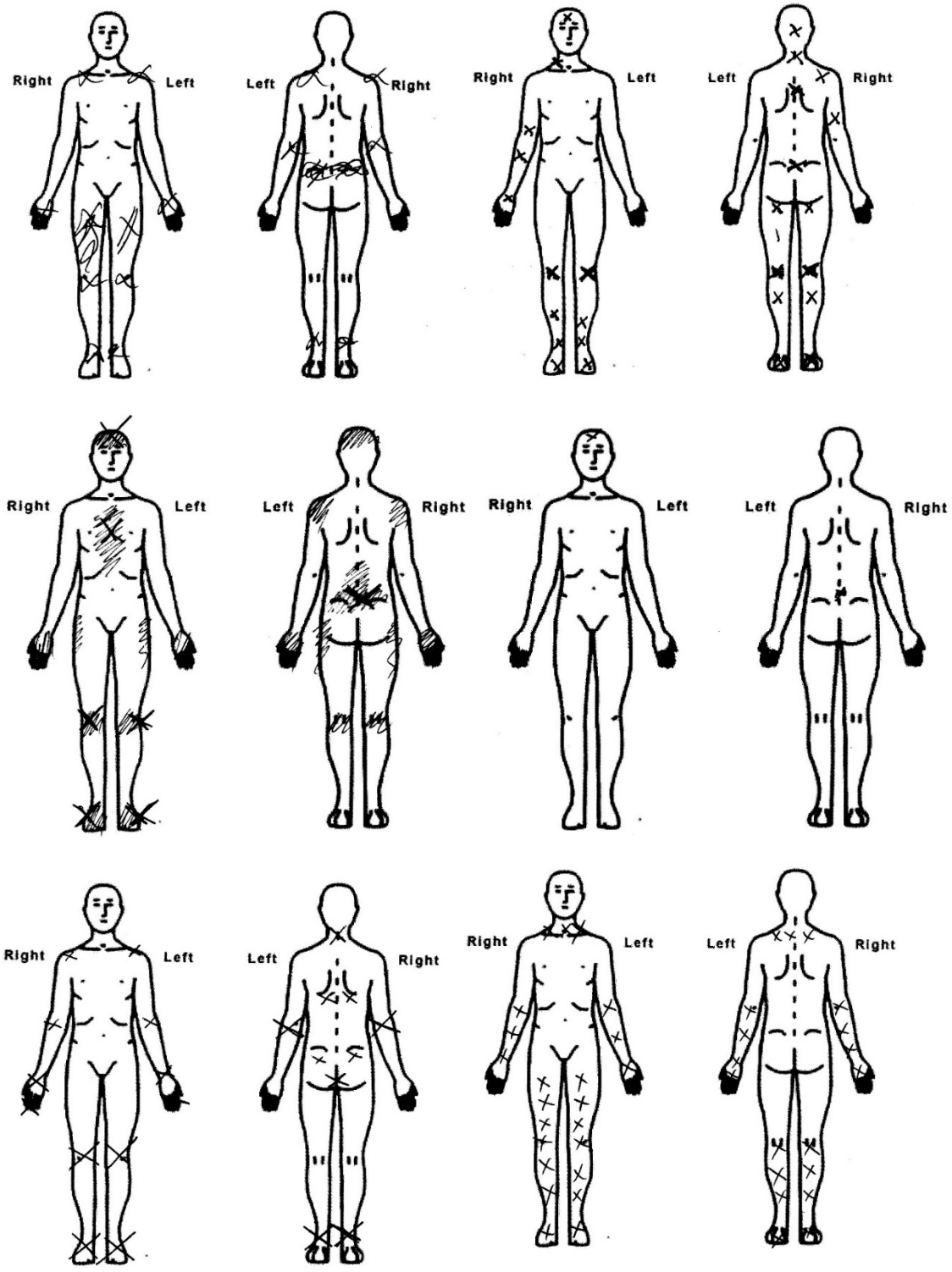
→ lumbar spine region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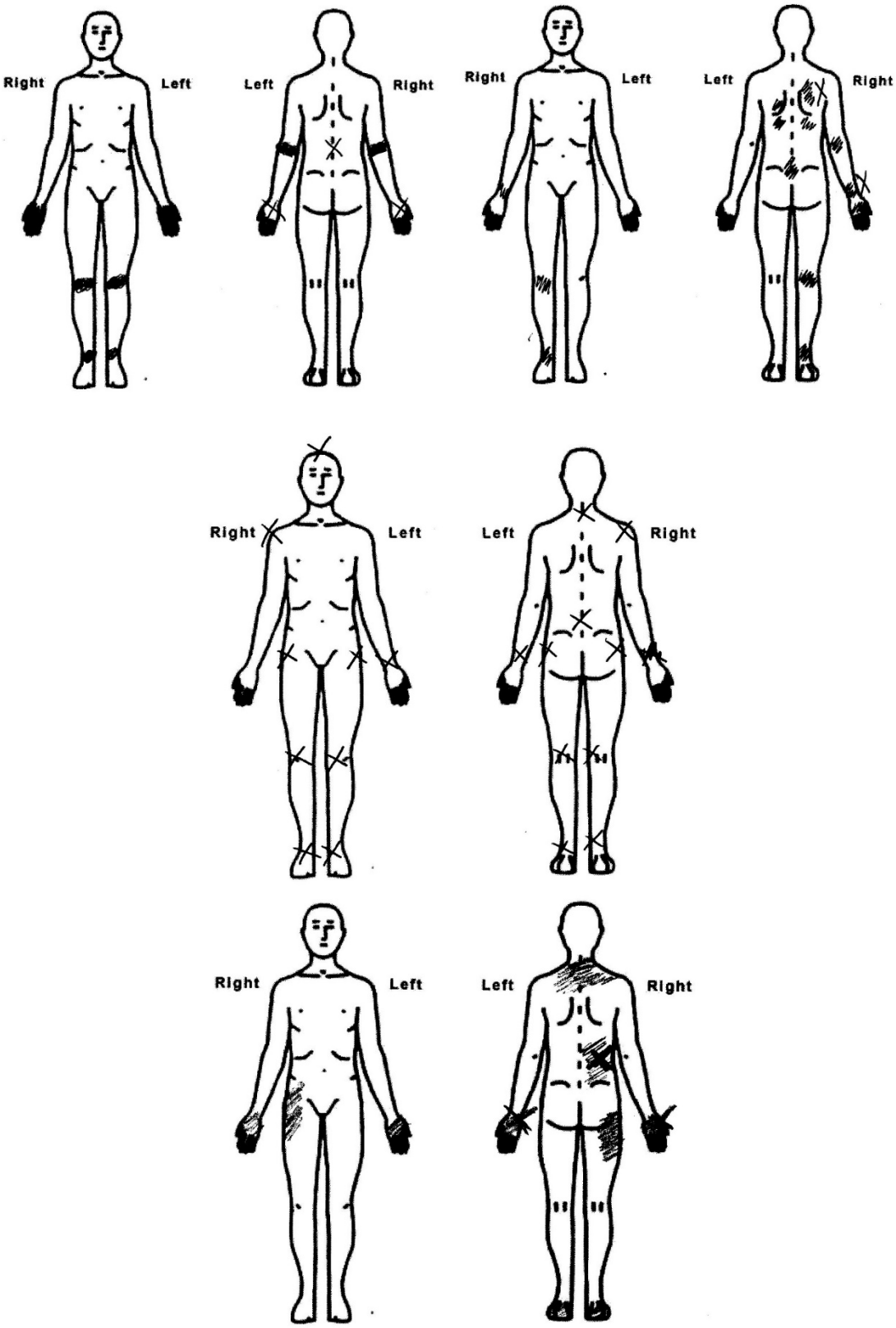
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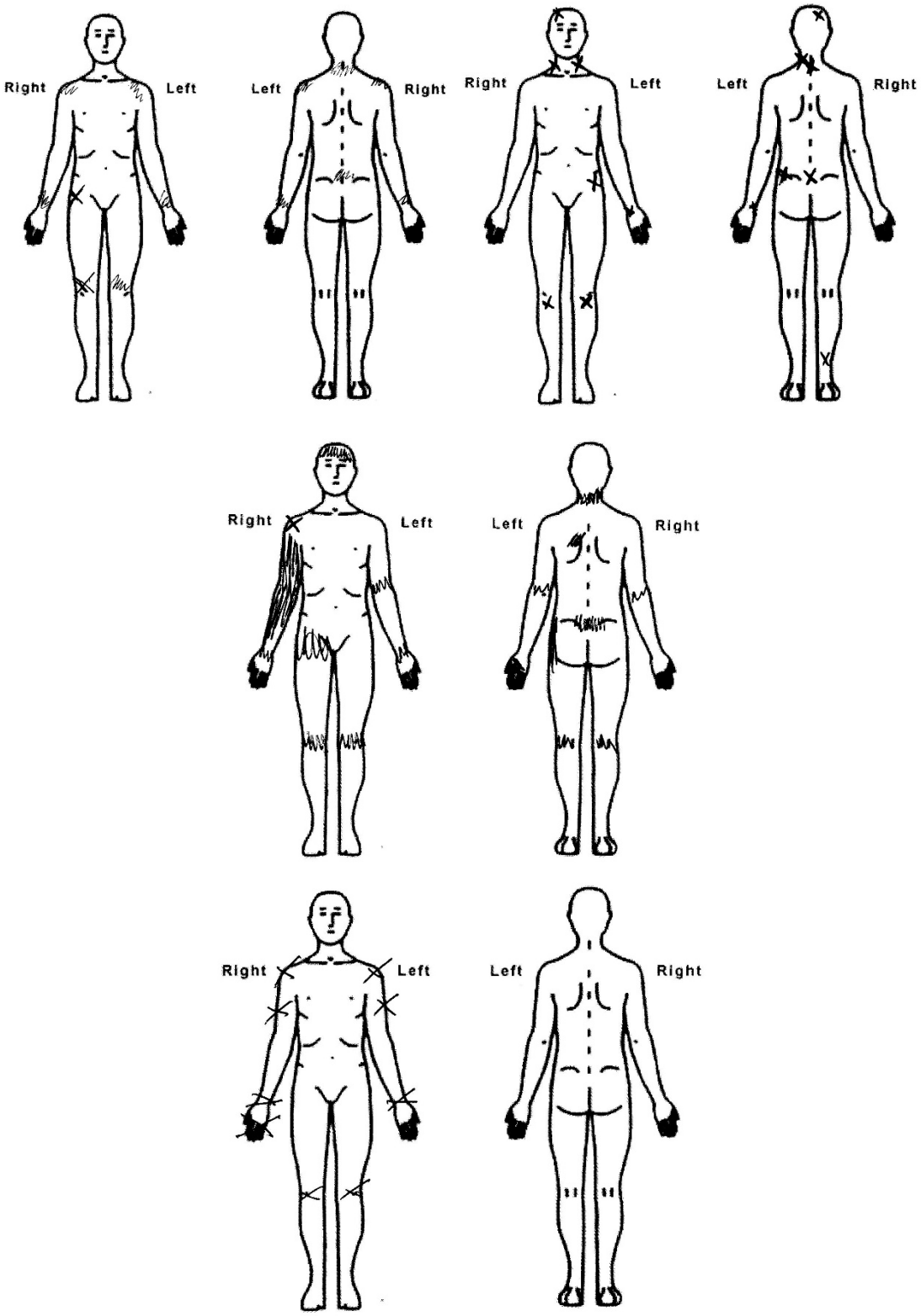
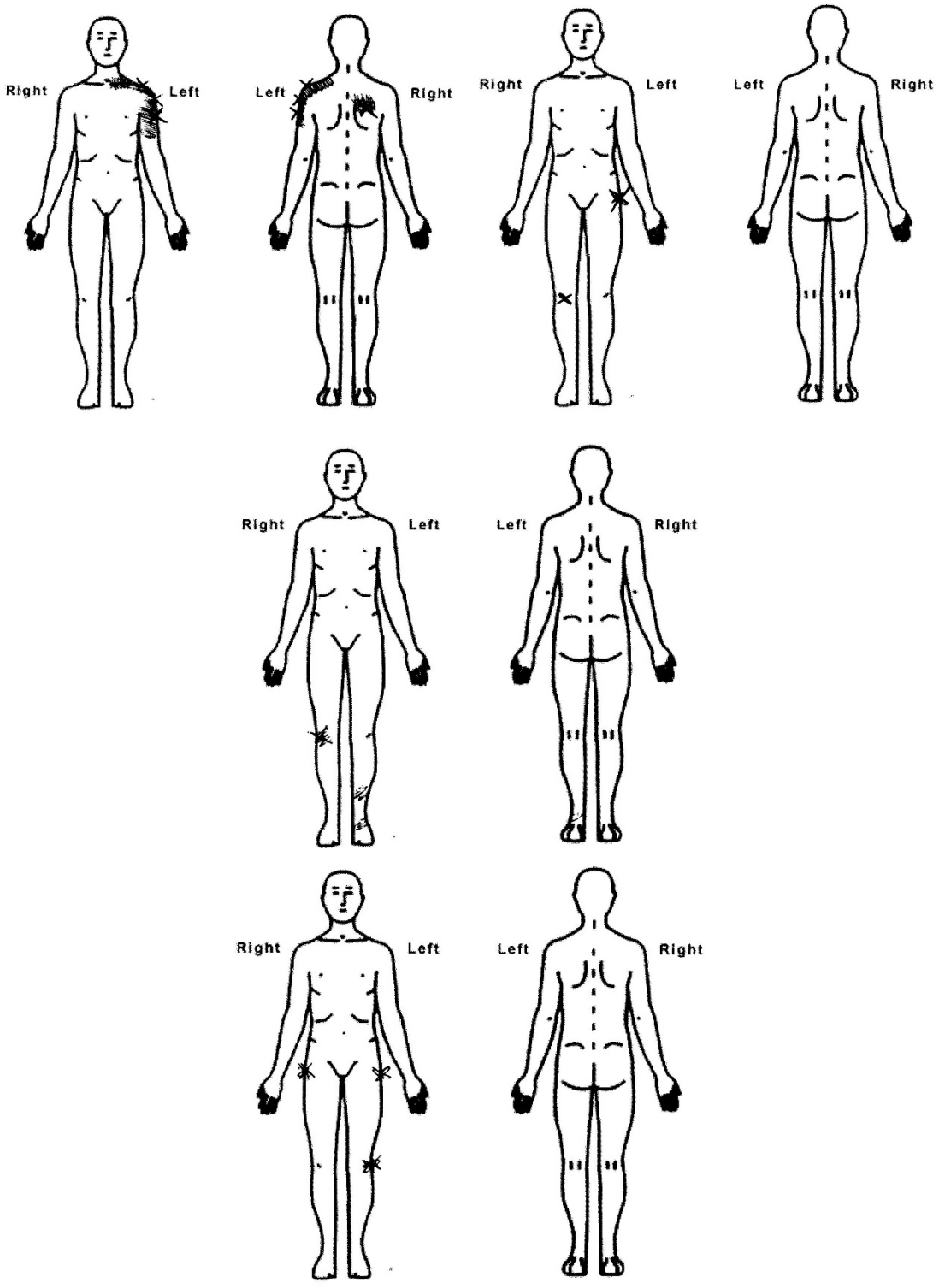
**PAIN MANIKINS FROM THE BRIEF PAIN INDEX FOR OA**

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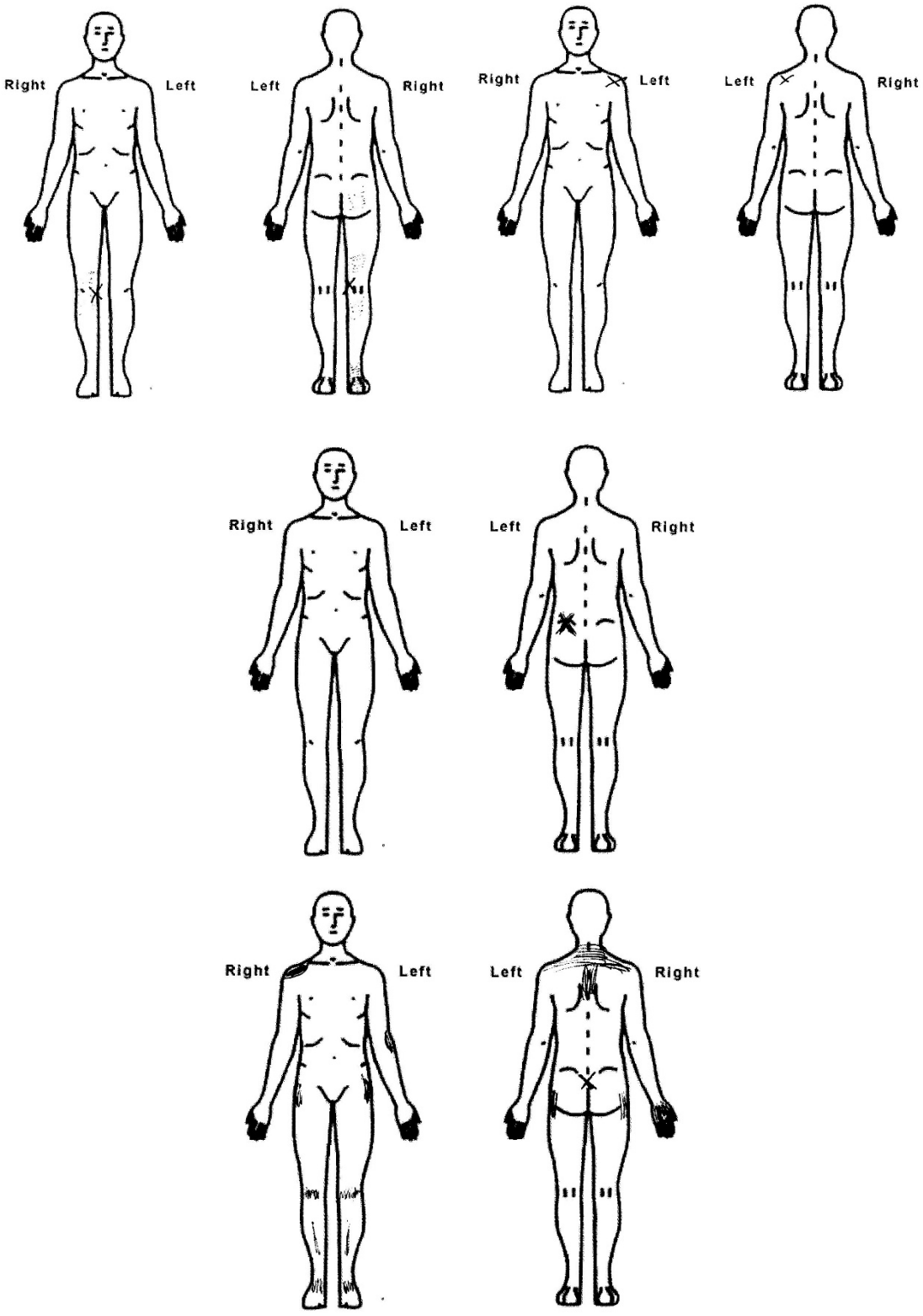
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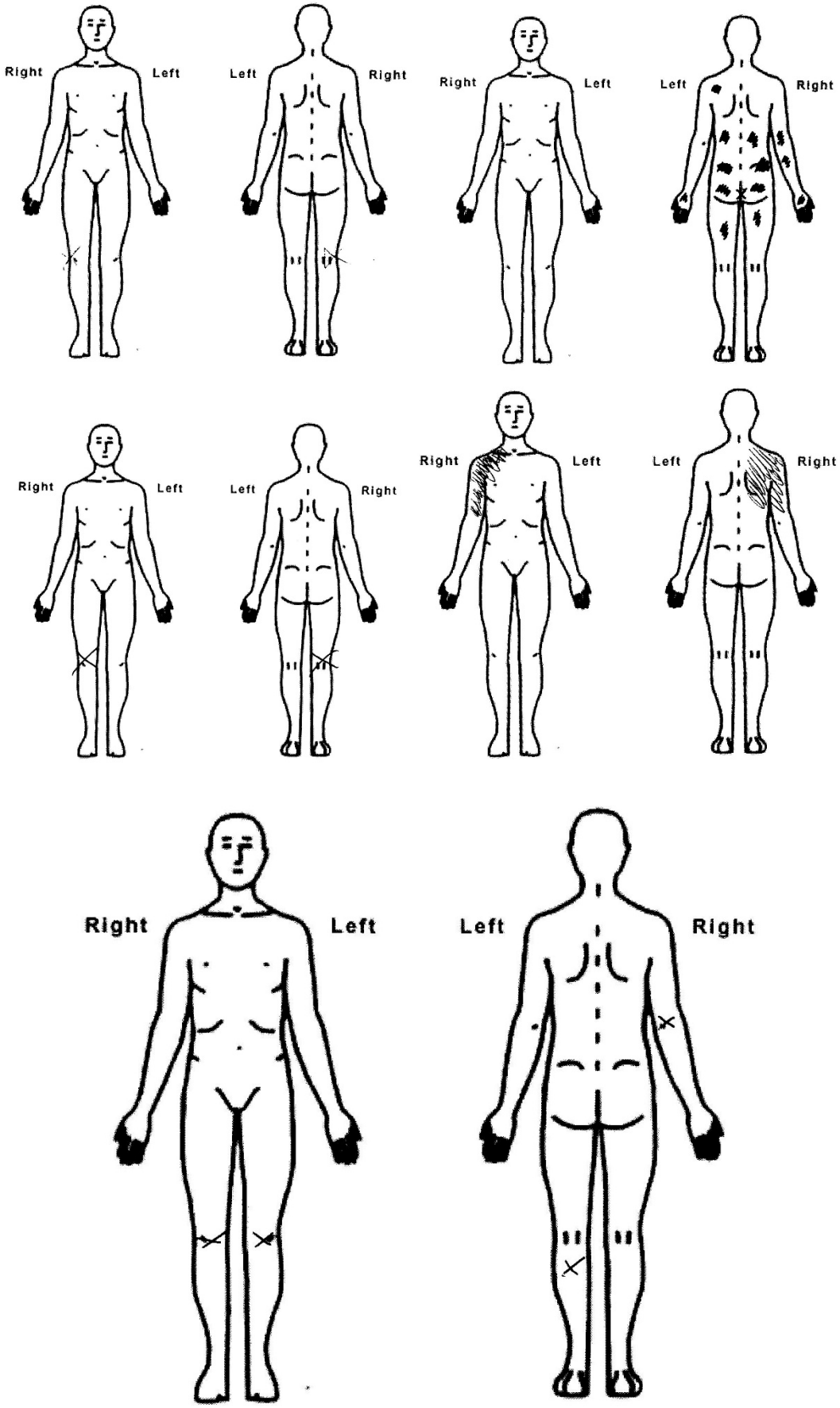
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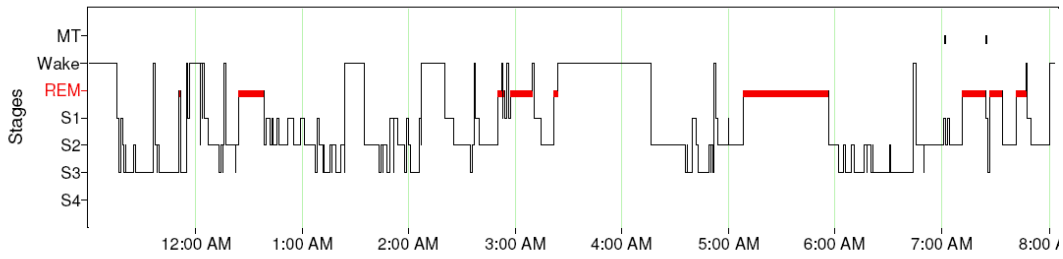
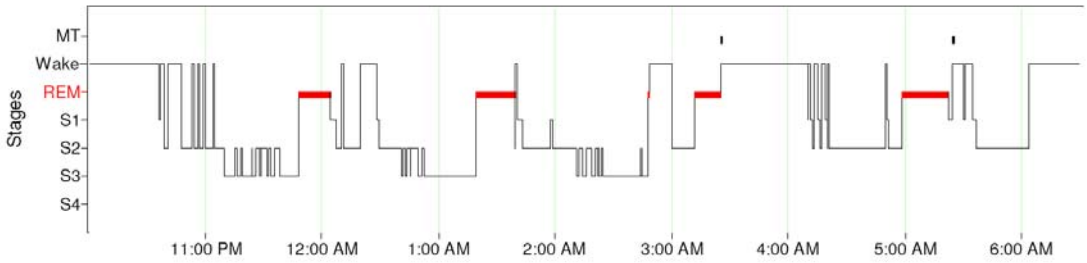
# APPENDIX I

## HYPNOGRAMS FROM POLYSOMNOGRAPHY FOR FIBROMYALGIA

### P01 – Age 47




### P02 – Age 54

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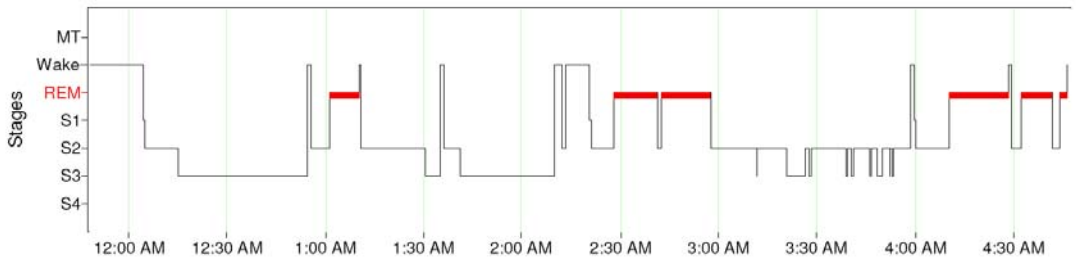
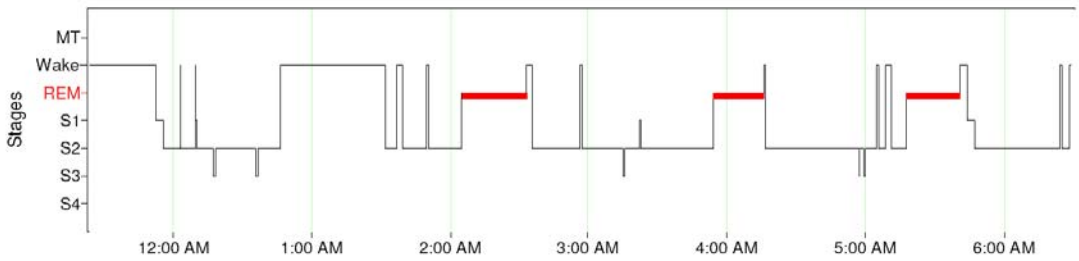
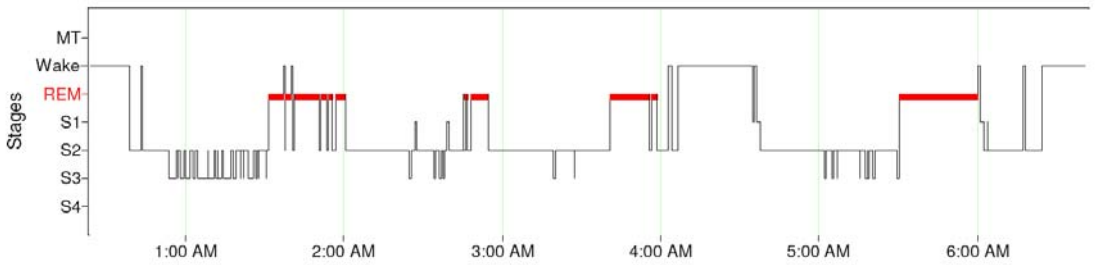


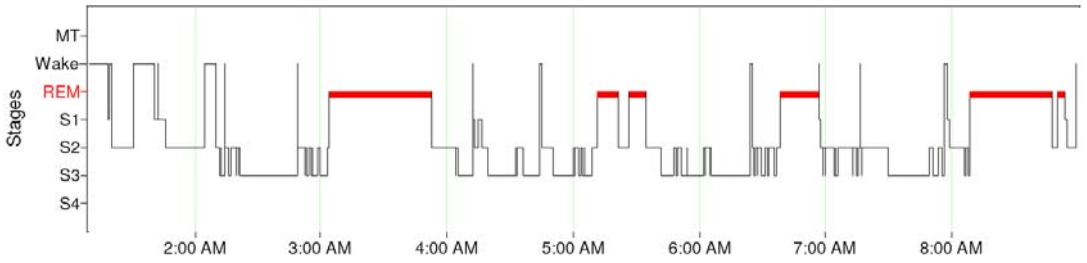

### P04 – Age 51



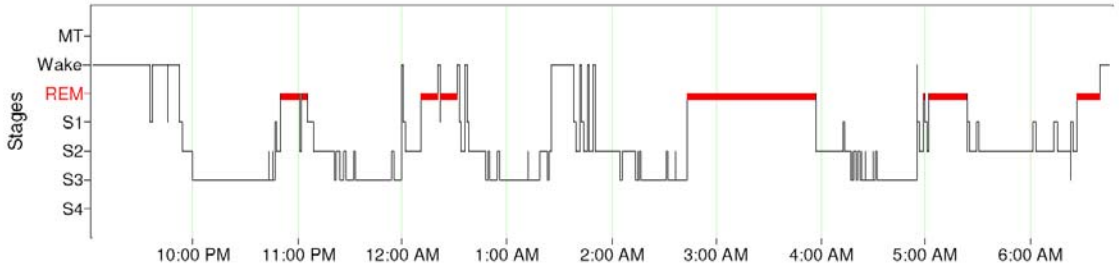
**P05 – Age 41**



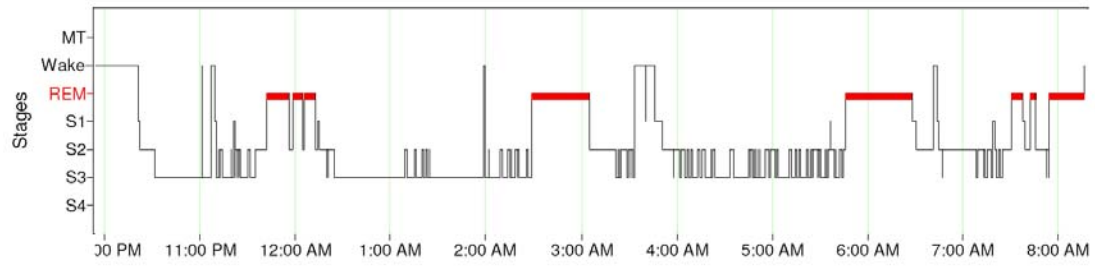

**P06 – Age 48**



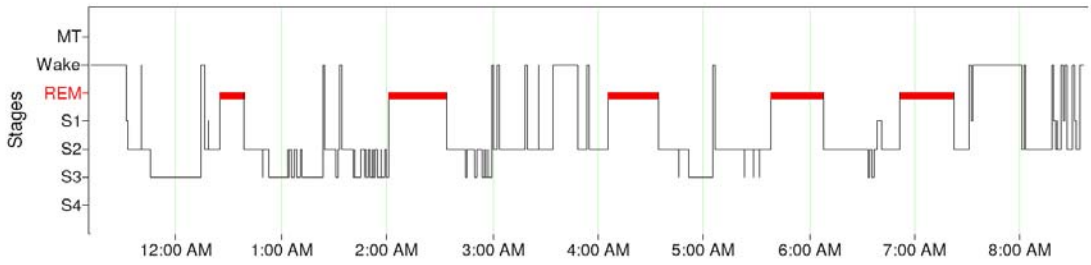

**P07 – Age 24**



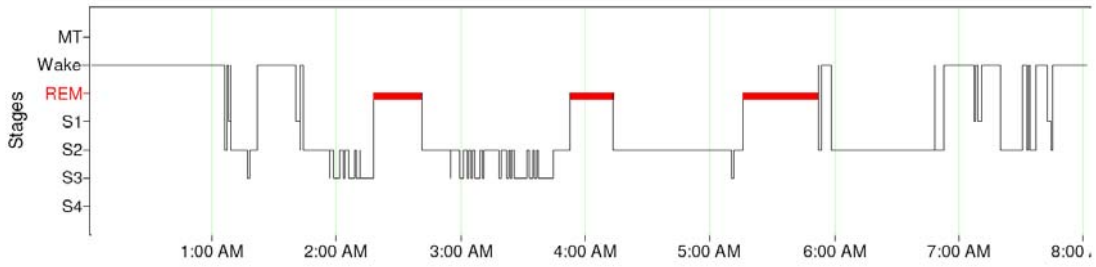

**P08 – Age 58**



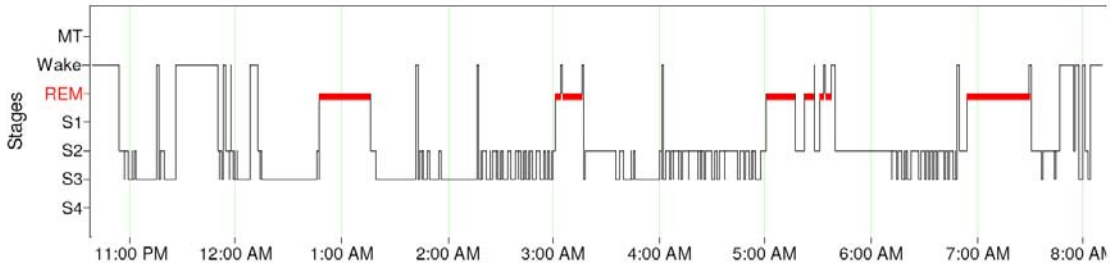

**P09 – Age 31**



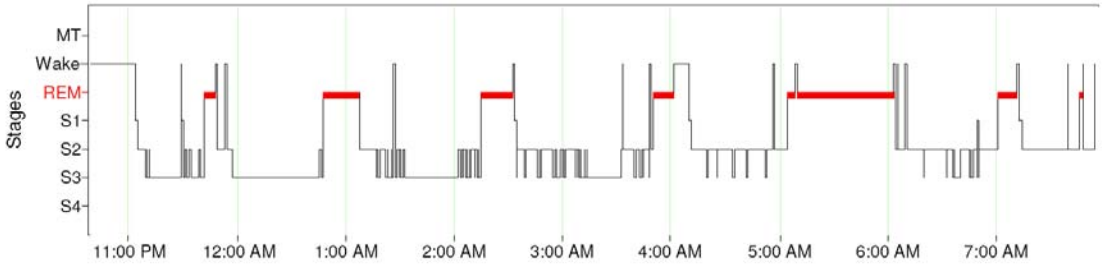

**P10 – Age 48**



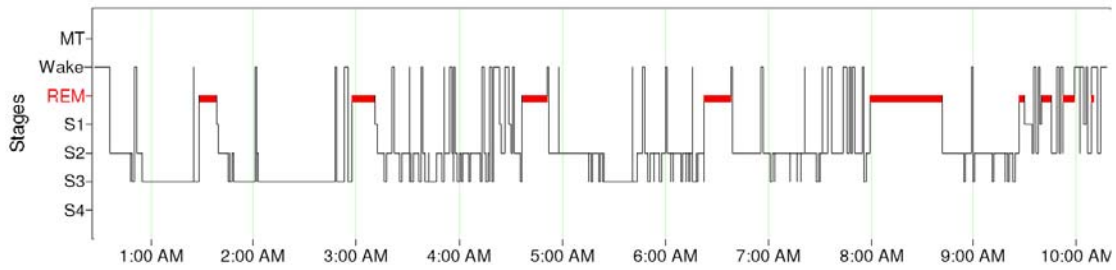

**P11 – Age 49**



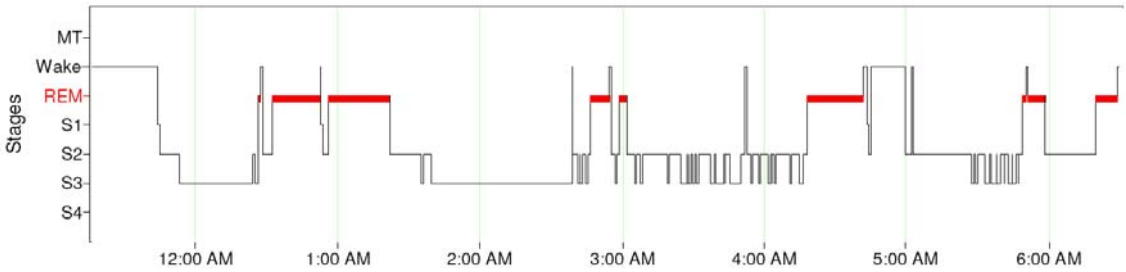

**P13 – Age 42**



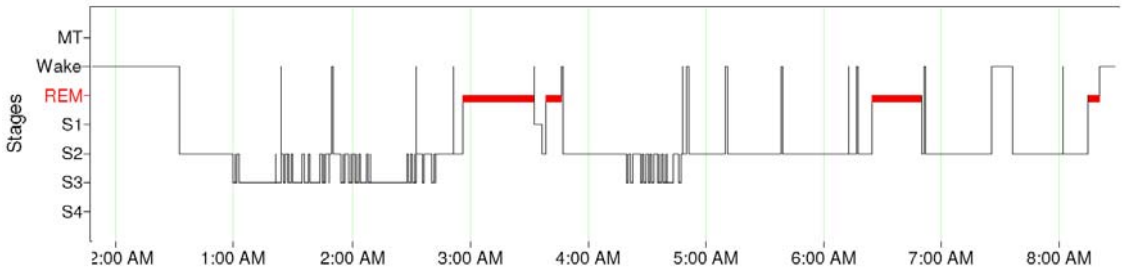
**P14 – Age 19**



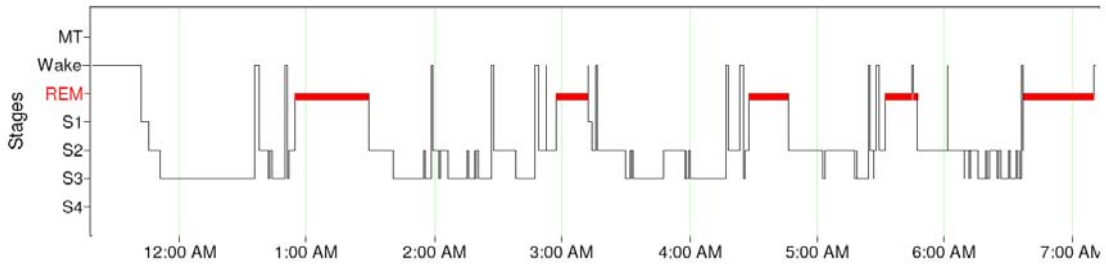

**P15 – Age 42**



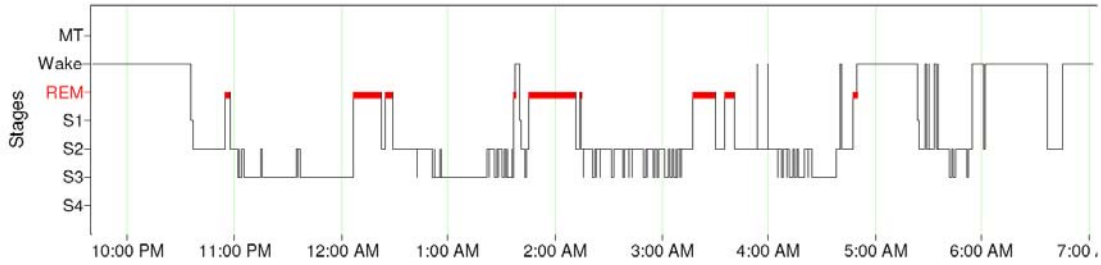

**P16 – Age 41**



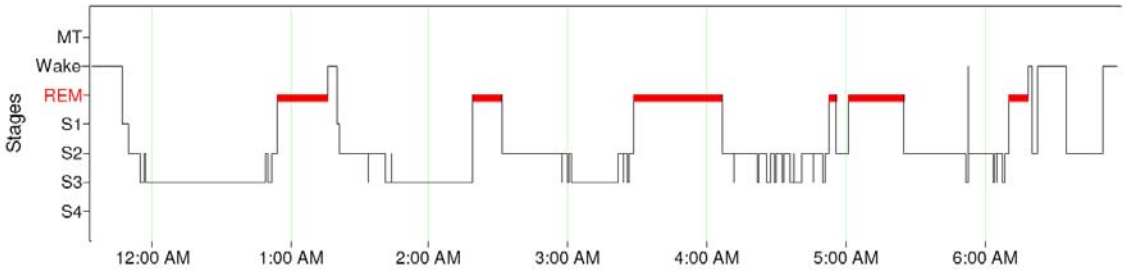

**P17 – Age 30**



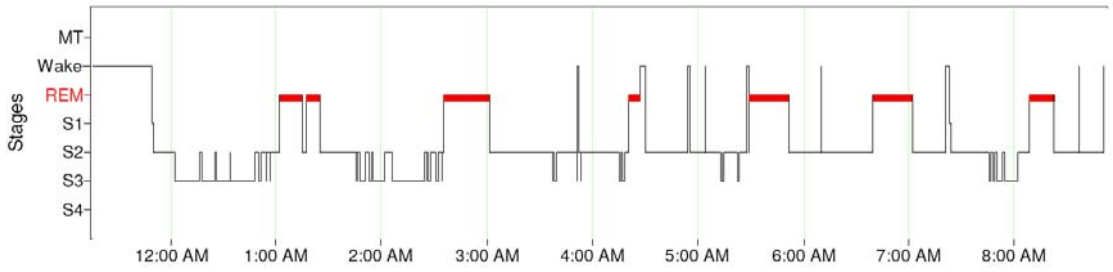
**P18 – Age 51**




**P19 – Age 30**

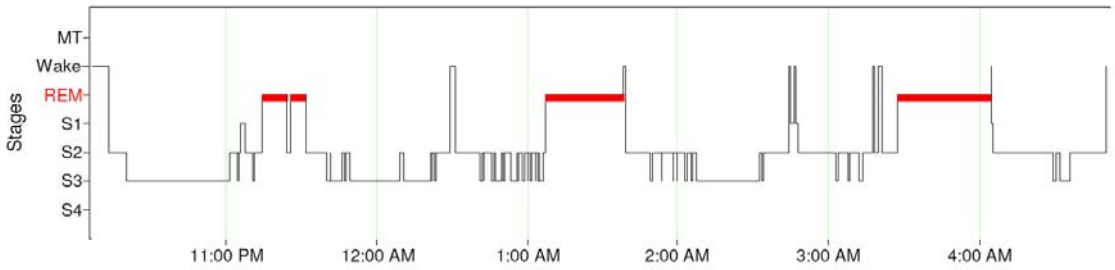



**P20 – Age 22**

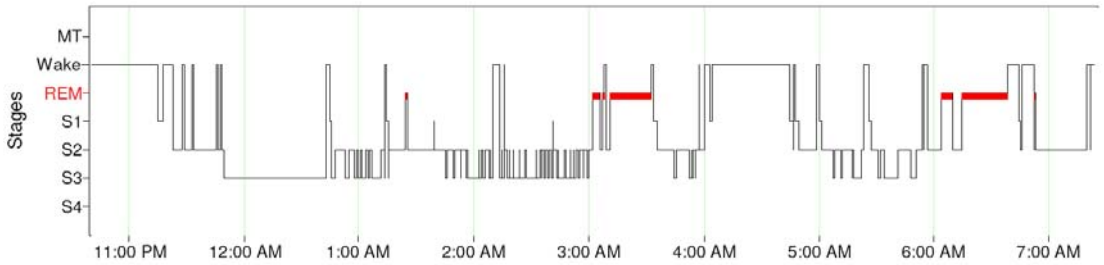


## HYPNOGRAMS FROM POLYSOMNOGRAPHY FOR OSTEOARTHRITIS

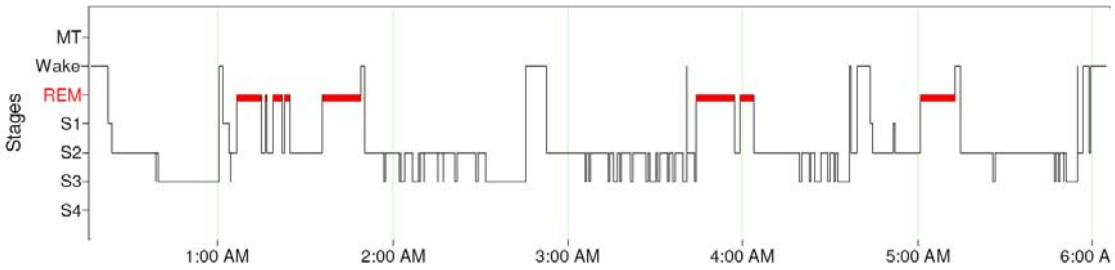
### P21 – Age 39



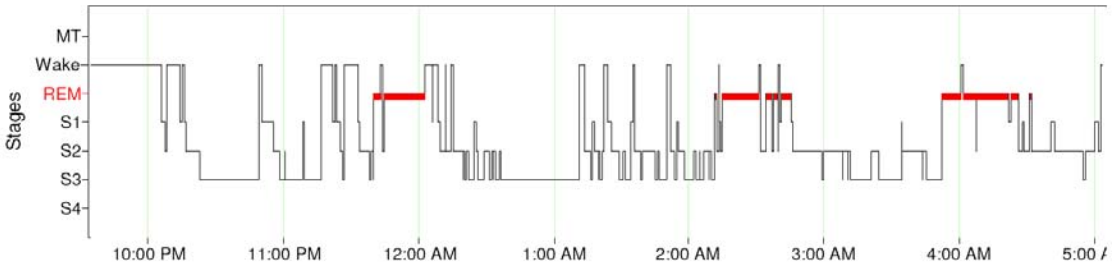

### P22 – Age 53



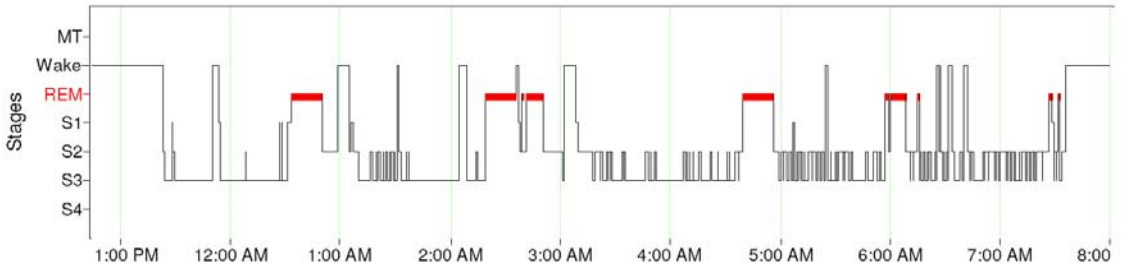

### P23 – Age 60



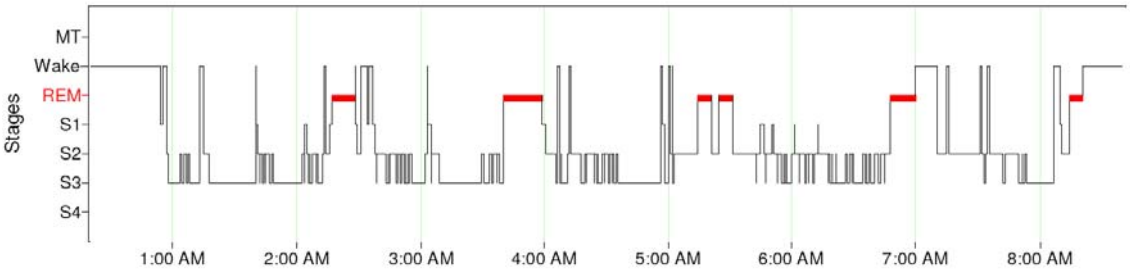

### P24 – Age 32



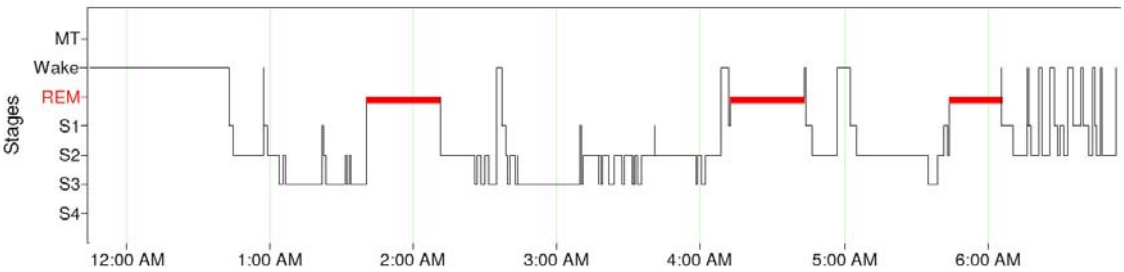
**P25 – Age 46**



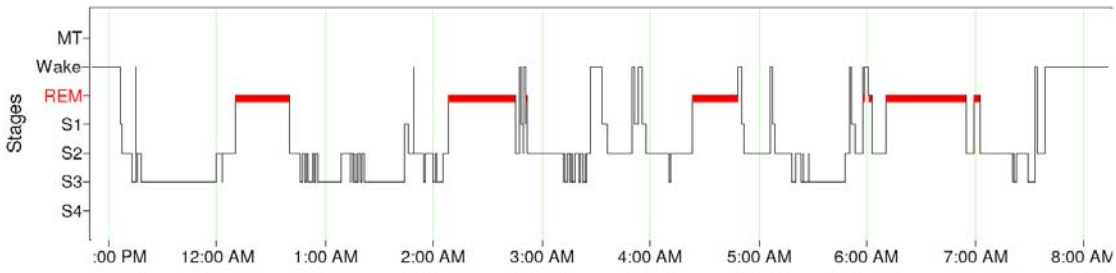

**P26 – Age 48**



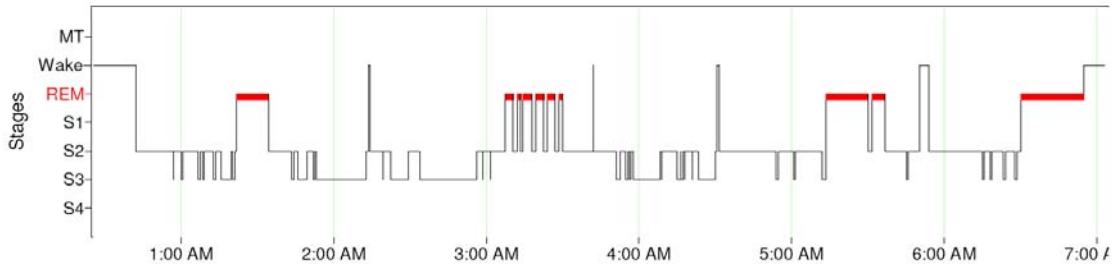

**P27 – Age 55**



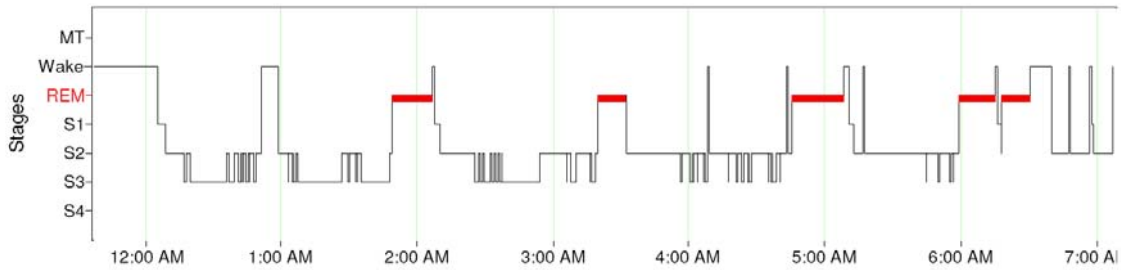

**P28 – Age 36**



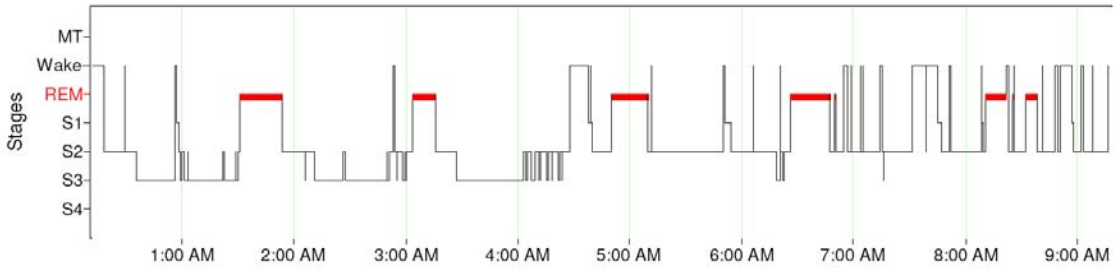
**P29 – Age 54**



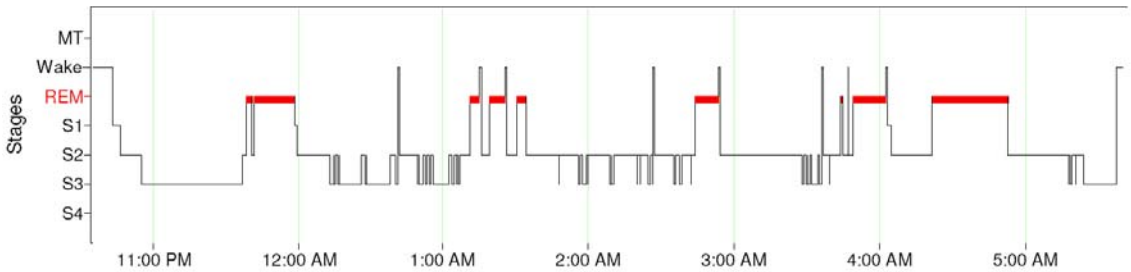

**P30 – Age 47**



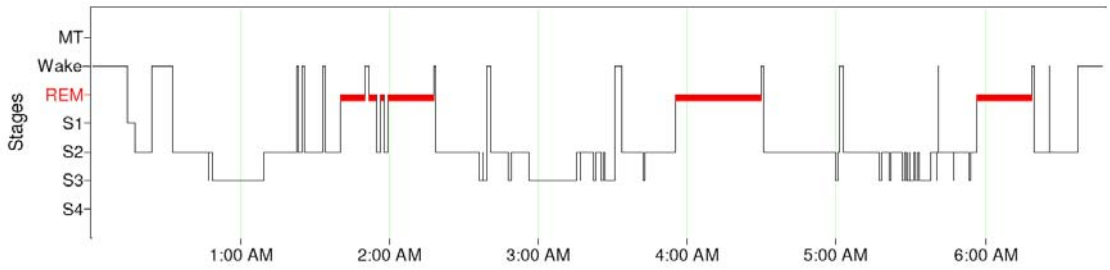

**P31 – Age 54**



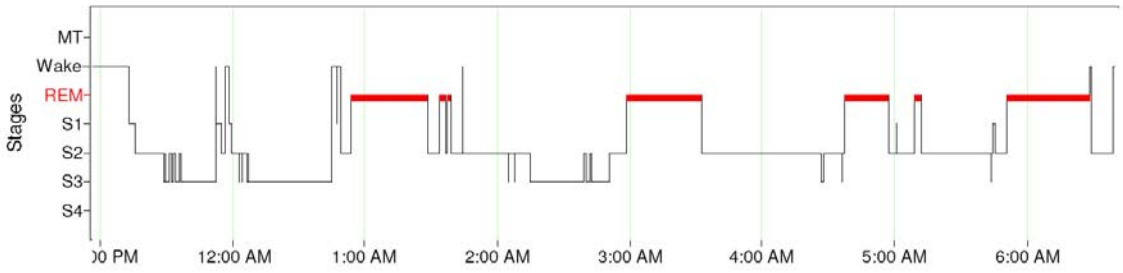

**P32 – Age 34**



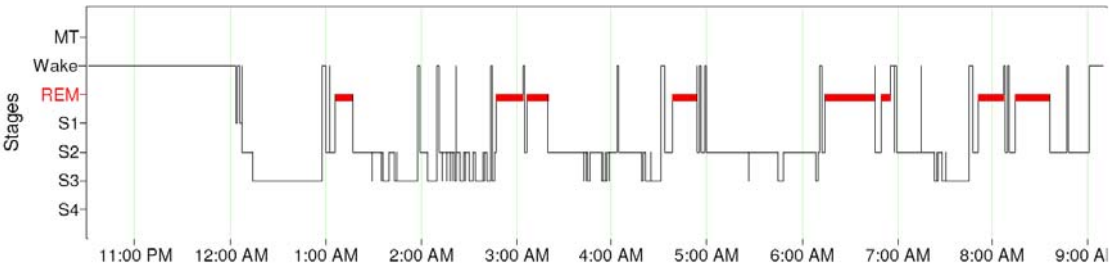
**P33 – Age 51**



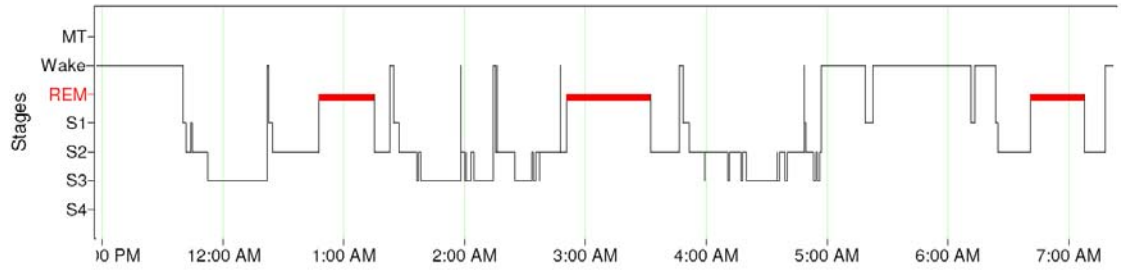

**P34 – Age 41**



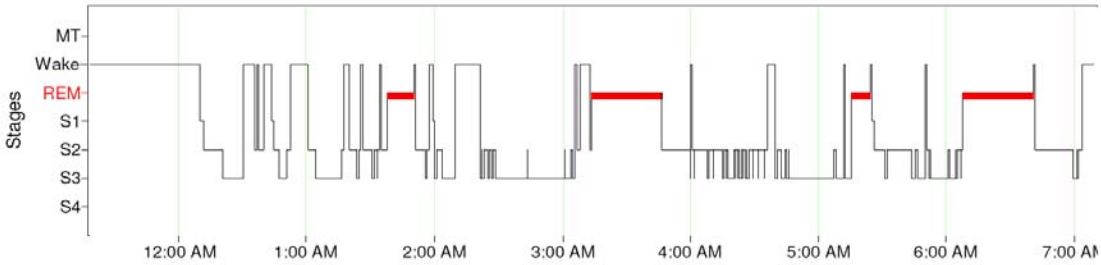

**P35 – Age 19**




**P36 – Age 58**

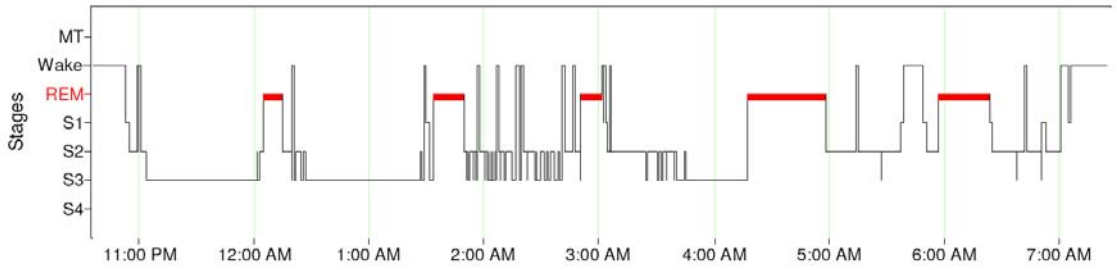


**P37 – Age 63**

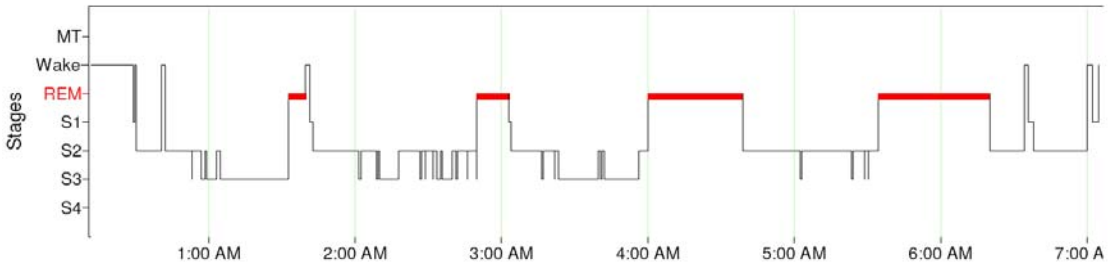

MT
Wake
REM
S1
S2
S3
S4
Stages
12:00 AM
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM

## HYPNOGRAMS FROM POLYSOMNOGRAPHY FOR HEALTHY CONTROLS

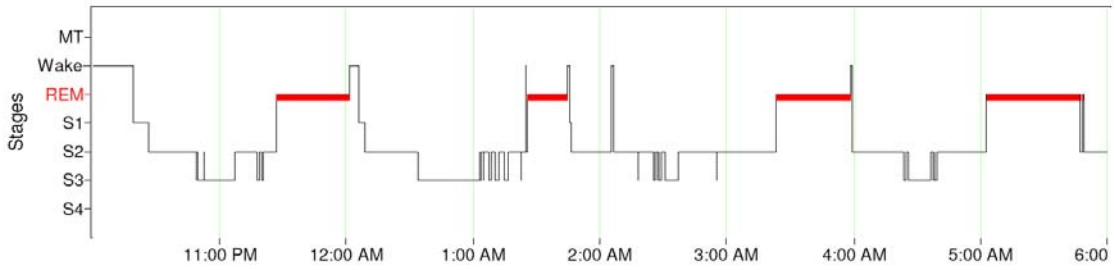
### C02 – Age 23



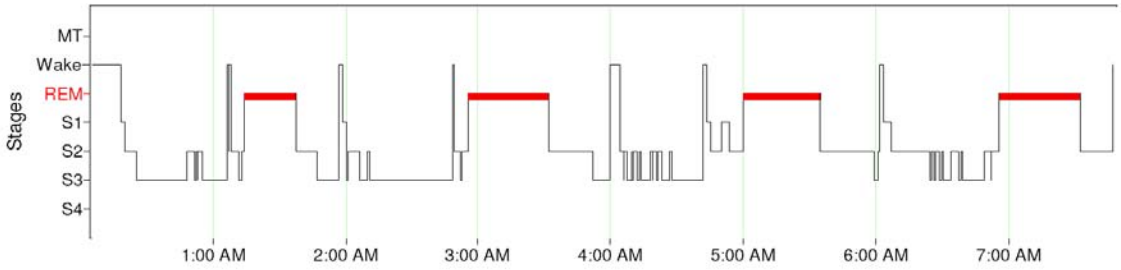

### C03 – Age 28



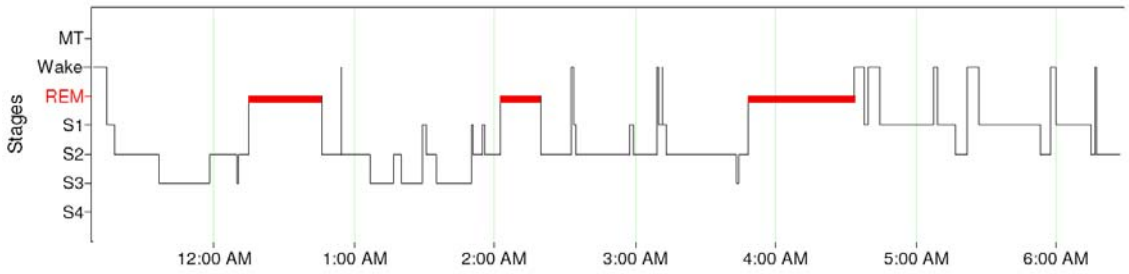

### C04 – Age 25



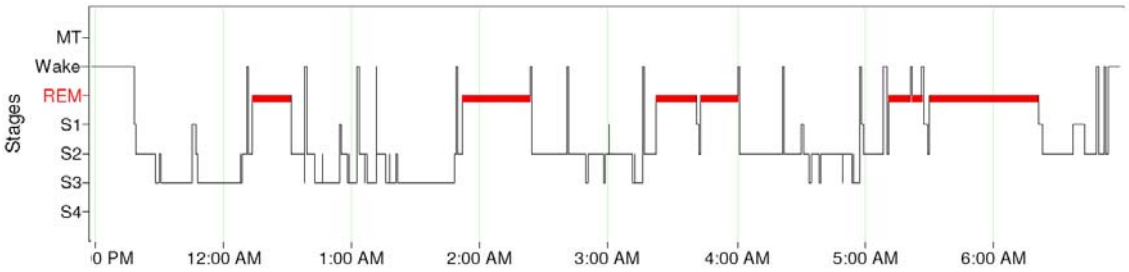

### C05 – Age 61



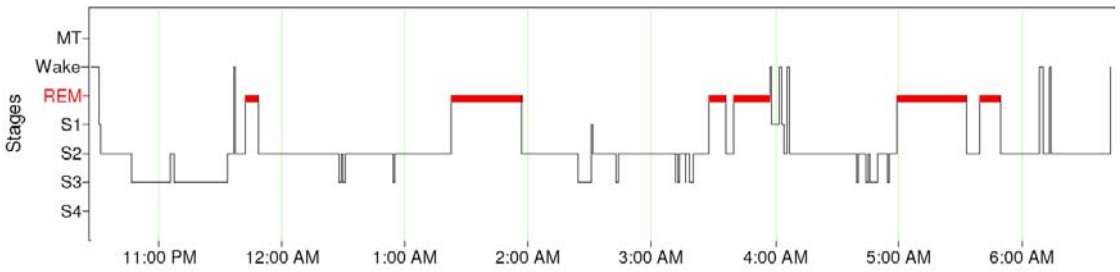
**C06 – Age 57**



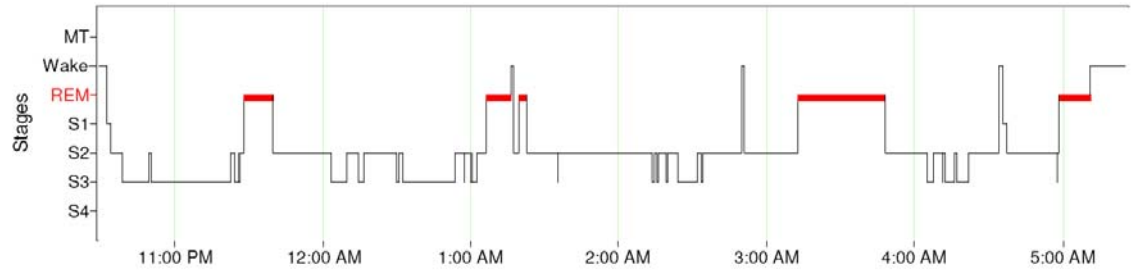

**C07 – Age 29**



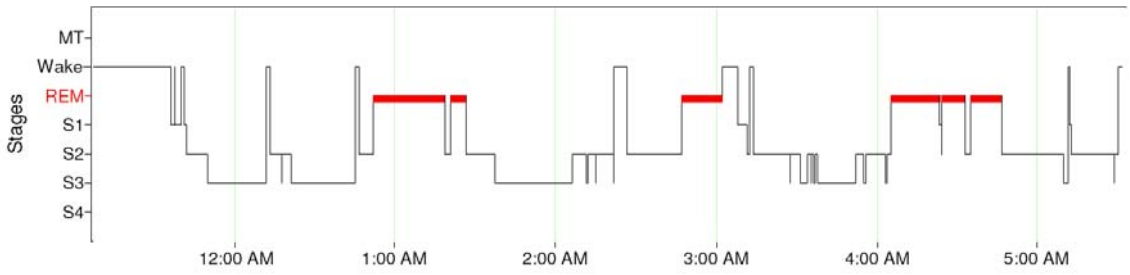

**C08 – Age 38**



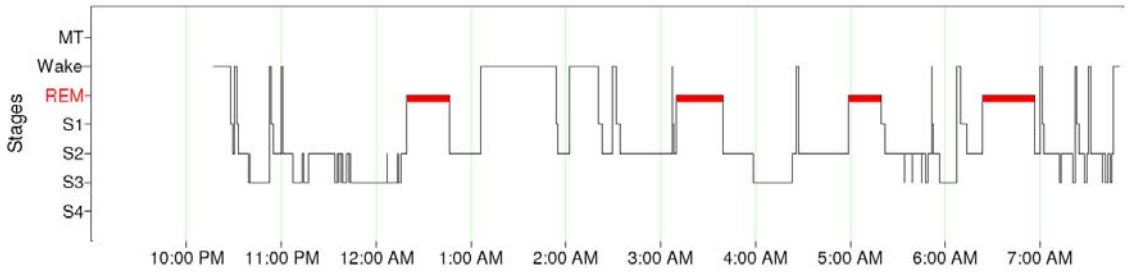

**C09 – Age 40**



**C10 – Age 31**

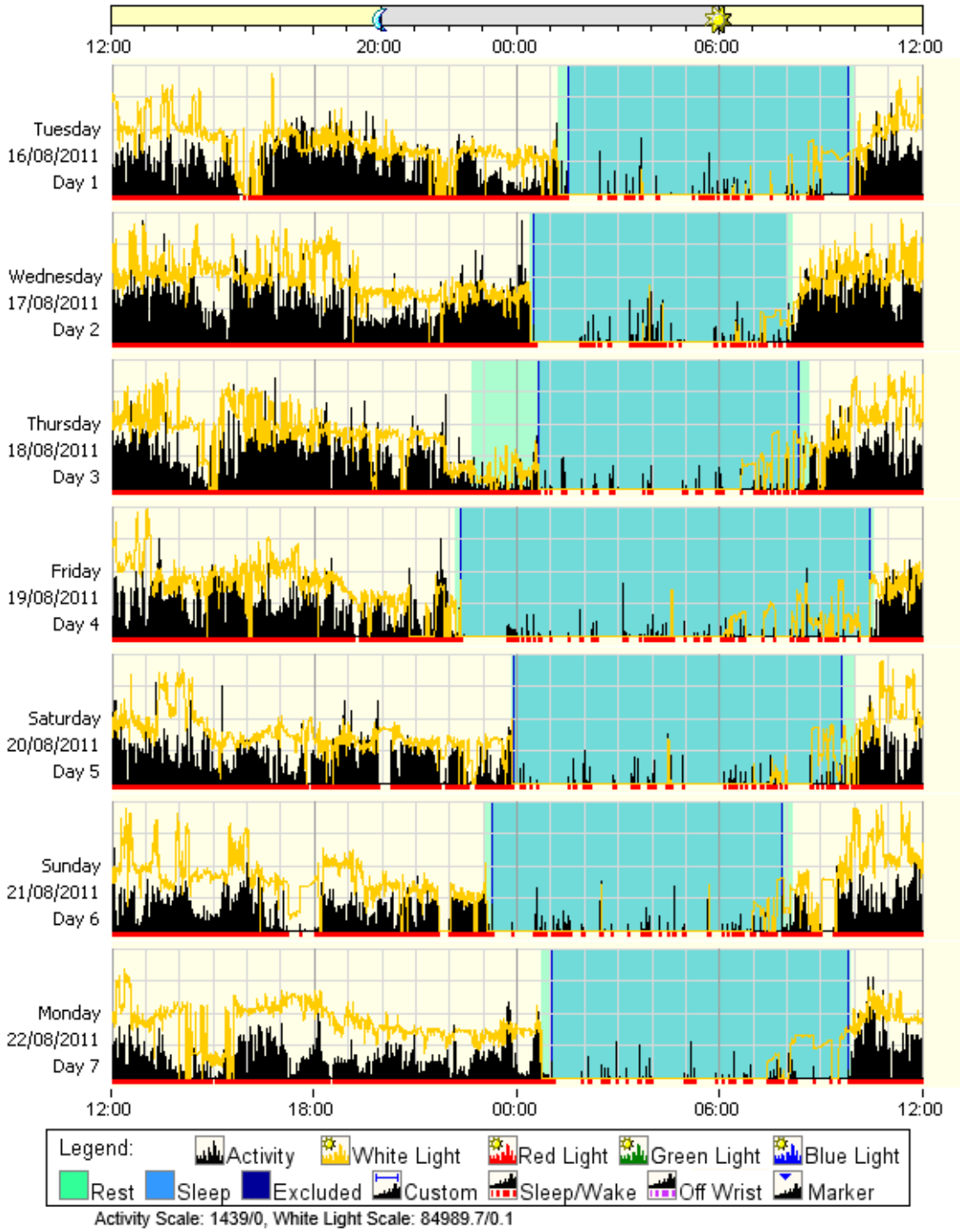



**C11 – Age 52**



# APPENDIX J

## EXAMPLE ACTIGRAPH FROM ACTIGRAPHY IN AN FMS PATIENT

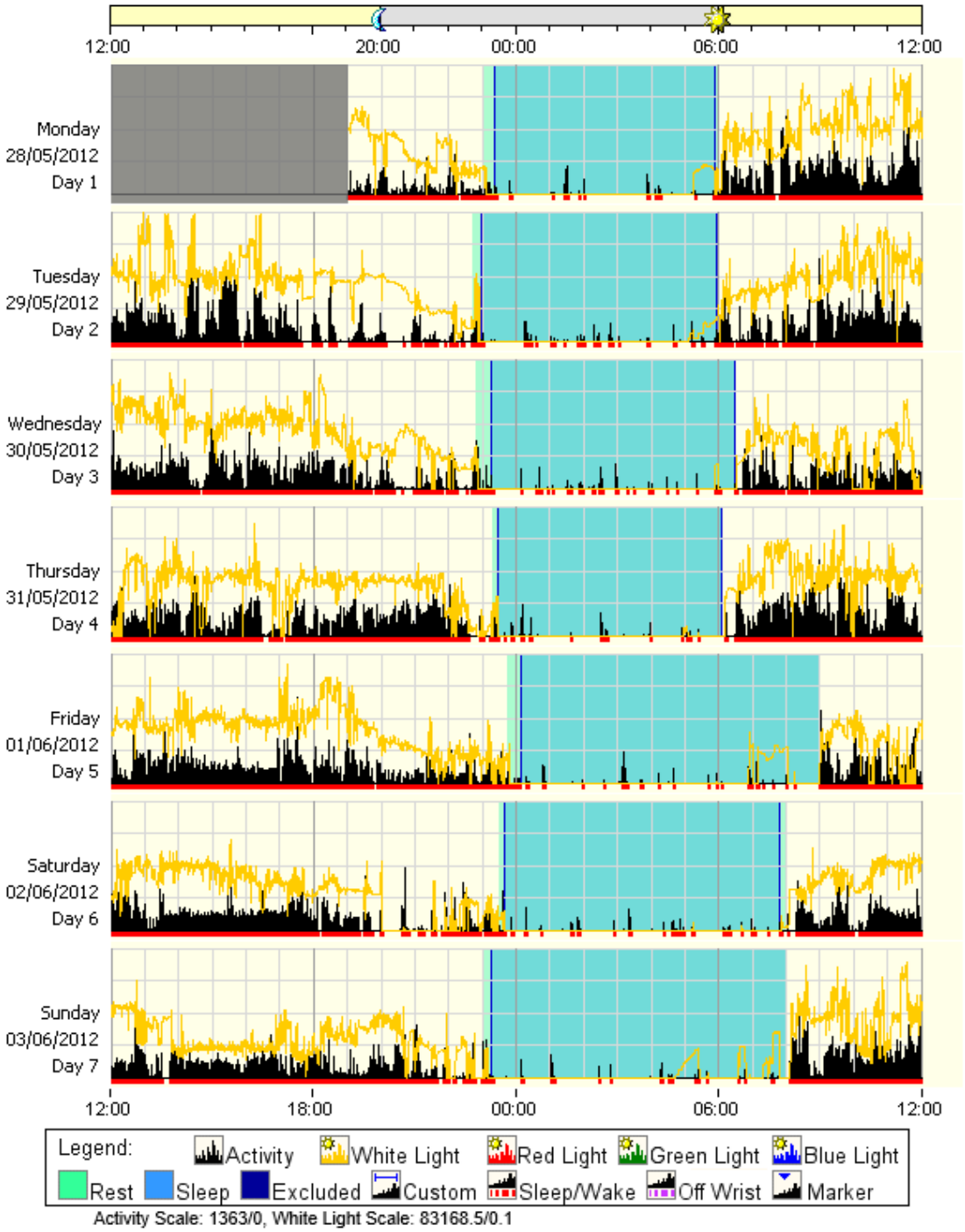



**SUBJECT ID: P01**

**AGE: 47**

***FROM THE FIRST WEEK OF ACTIGRAPHY MONITORING**

**EXAMPLE ACTIGRAPH FROM ACTIGRAPHY IN AN OA PATIENT**

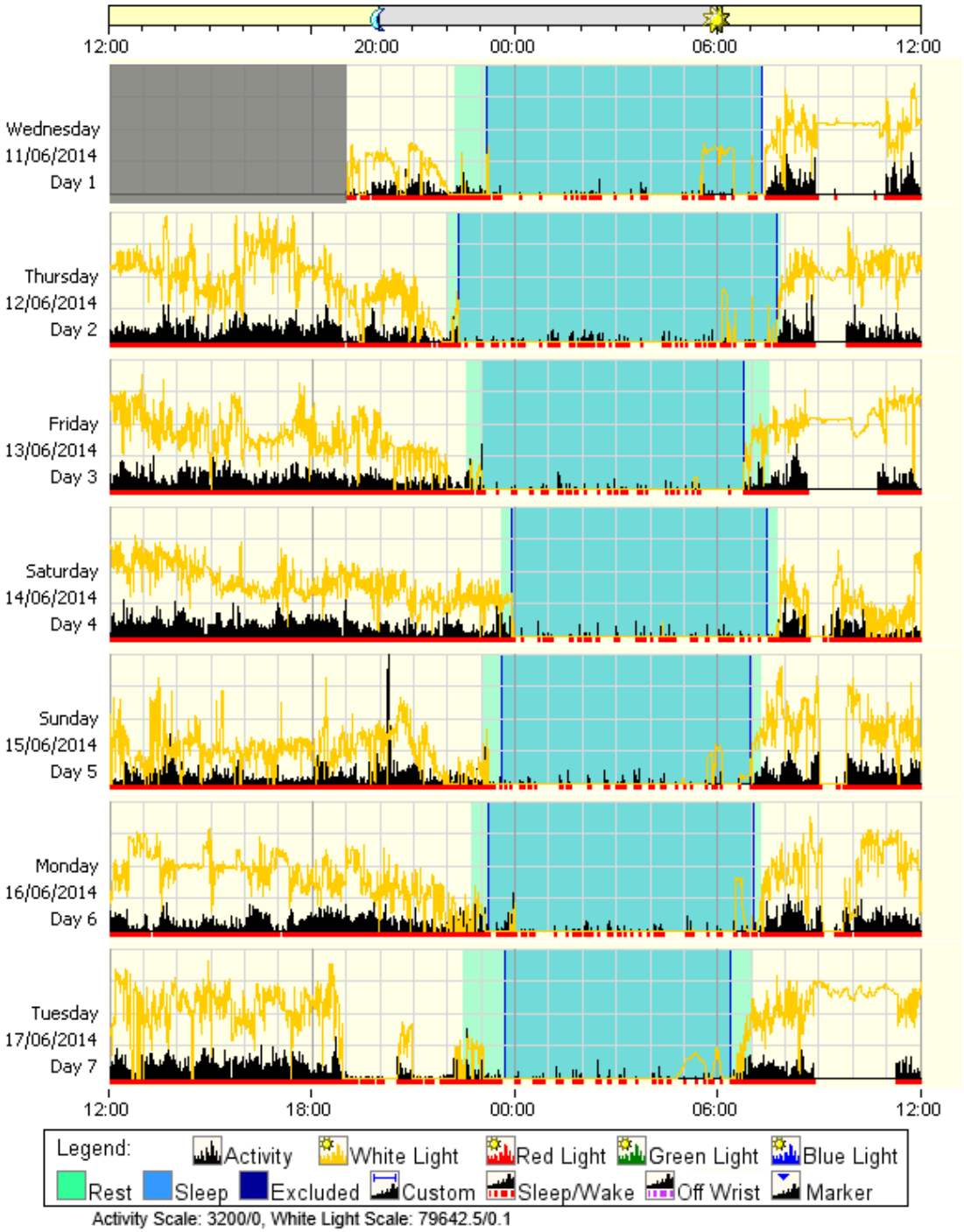



**SUBJECT ID: P23**

**AGE: 60**

***FROM THE FIRST WEEK OF ACTIGRAPHY MONITORING**

**EXAMPLE ACTIGRAPHY FROM ACTIGRAPHY OF NHC PARTICIPANT**




**SUBJECT ID: C11**

**AGE: 52**

***FROM THE FIRST WEEK OF ACTIGRAPHY MONITORING**