Sleep Deprivation in Shift Work Alters Pain Perception

***Owoyele BV[1], Yusuf FA[1], Oniyide AA[2], Olaniyi SK[2], Olasehinde OF[1]**

ABSTRACT

Shift work which is mainly characterized with sleep disruption has been reported to alter behavioral alertness, cognition, emotion, attention and general systemic functions. However, it is not known whether sleep deprivation in shift work would alter pain perception. The current study was designed to investigate the effect of shift work on pain perception in healthy Nigeria human and to possibly know if the effect is β-Endorphin dependent. Sixty healthy volunteers were randomly selected from Ilorin, Kwara State, Nigeria (consisting of 30 shift workers from MTN Telecommunication Company and 30 non-shift workers from the members of the public). These individuals were recruited, trained on what they should expect during the study and informed consent was obtained. Questionnaires were administered to gather volunteers' biodata and socio-demographic background. Cold, ischemia and cold+ischemia-induced pain was administered, and the pain threshold and tolerance were estimated. Our results show that shift work significantly decreases ($p<0.05$) the pain threshold and tolerance during ischemia-induced pain test, and causes a significant increase ($p<0.05$) in pain tolerance during cold-induced and cold+ischemia-induced pain tests. Also, the circulating plasma β-Endorphin decreased ($p<0.05$) with shift work during cold-induced and cold+ischemia-induced pain tests when compared with non shift work. The results demonstrate that shift work alters pain perception which is accompanied by alteration in circulating level of plasma β-Endorphin.

Keywords: β-Endorphin, Pain perception, Sleep Threshold, Tolerance, Volunteers.

INTRODUCTION

Shift work remains a global trend that has come to stay in this century, and studies have shown its close association with sleep disruption[1,2]. Previous data have shown that about 20 million workers experience work related health problems and an average of 5,720 people die as a consequence of this endemic situation in Europe[3]. Shift work is a major risk factor; yet, increasing demands in global economy have rendered shift work an integral constituent of modern society[2,4].

From a competitive standpoint, shift work is an excellent way to boost production and customer service without major increases in infrastructure. It is well documented that millions of Americans are considered shift workers especially professionals[5].

Sleep is a recurring state of mind that is characterized by altered consciousness, relatively inhibited sensory activity, inhibition of nearly all voluntary muscles, and reduced attention or interactions[6]. It is one of the most important factors in maintaining good mental and physical health, with many essential physiological processes occurring during sleep[7]. Also, it is a basic human need and a fundamental process[8,9]. Sleep of sufficient duration, continuity, and intensity (depth) without circadian disruption is necessary to promote high levels of attention and cognitive performance during the wake period, and to prevent physiological changes that may predispose individuals to adverse health outcomes[10].

Sleep pattern disruption refers to a reduced ability to achieve nocturnal sleep, with increased wakefulness and altered sleep architecture, resulting in a decrease in non-rapid eye movement (non-REM) and short wave sleep[11]. The evidence linking habitually short sleep or circadian desynchrony to conditions such as weight gain[11,12], obesity[13], diabetes[14], and hypertension[8], as well as to increased mortality[15], has accumulated over the past decade and this remains provocative[16], which has been experimentally demonstrated to result in cumulative deficits in behavioural alertness and vigilant attention.

Pain can be referred to as a sensory and emotional experience, and its emotional component varies from person to person and time to time[17]. This unpleasant sensory and emotional

Neuroscience Research Unit[1], Department of Physiology, University of Ilorin, Ilorin, Nigeria.
Department of Physiology[2], College of Medicine and Health Sciences, Afe Babalola University, Ado-Ekiti, Nigeria.

*Corresponding author: deleyele@yahoo.com

experience is associated with actual or potential tissue damage[18], and motivates individuals to withdraw from damaging situations, to protect a damaged body part while it heals, and to avoid similar experiences in the future[18,19].

Shift work has been associated with sleep disruption[1,2] and sleep pattern disruption has been documented to cause pain[20] but the effect on pain perception and mechanism remains ill defined. The present study aims at investigating the effect of sleep deprivation in shift work on pain perception in healthy Nigeria human and to possibly know if the effect is β-Endorphin dependent.

MATERIALS AND METHODS

Subjects and Grouping

Sixty healthy human subjects volunteered to participate in the study. They were made up of 30 shift workers (15 males and 15 females) from MTN Telecommunication Company and 30 non shift workers (15 males and 15 females) from the members of the public. All the subjects are within the age of 18-40 years. These individuals were recruited, trained on what they should expect during the study.

Inclusion criteria for the selection of subjects

The subjects selected were free from diabetes (Random blood sugar not greater than 7mmol/L, which was determined using ONETOUCH®-Life Scans, Inc., Milpitas, CA, USA), hypertension (Blood pressure not greater than 120/80mmHg, which was determined using sphygmomanometer), had normal sensation (touch, pain, vibration etc), not on any medications, not on hospital admission in the last one month, did not have surgery done in the last three month, not suffering from chronic pain syndrome, with no comorbidity and were willing to abide by the rules, protocol and voluntarily signing the consent form. The investigation was carried out under approval of the Research and Ethical Review Committee of the University of Ilorin, Ilorin, Nigeria.

Protocol

The subjects were visited in their working place and informed about the study; subsequently volunteers were recruited, trained and administered questionnaires to obtain their biodata and socio-demographic background. Subjects were made to sit comfortably in a reclining chair that provides adequate support for the head, arms and legs. The testing facility was at a comfortable room temperature, and provides a quiet and neutral environment with no distraction. Having trained the subject about the procedures and what to expect during the experiment, the following assessments were performed:

Cold-induced pain

Cold sensation and pain in humans are mediated by A and C fibres. The subjects were asked to hold a cold gel bag maintained at 0^0c for as long as possible as previously described[21].

Ischaemia-induced pain

The ischaemic pain testing was based on the method by Plesan *et al.,*(2000)[21]; a blood pressure cuff was placed around the non-dominant arm of the subject. The cuff pressure was inflated to 20mmHg above the subject's systolic pressure. With the pressure maintained, subject performed a hand grip exercise on an elastic ball. The subjects closed their eyes for the entire procedure to minimize distraction and time clues. They were asked to indicate when they first detected the pain and when they could no longer tolerate the pain (to a maximum of 5 minutes). Once pain tolerance was reached, the pressure curve was immediately deflated and end-points were measured in seconds with the process performed 3 times and average of the readings documented as previously described[22].

Assessment of pain threshold and tolerance

The pain threshold is defined as the point between being "about to be painful" and "just became painful" and the time taken for this to occur is recorded in seconds, while the pain tolerance is defined as the point subject can no longer withstand the pain and the time taken for this to occur is recorded in seconds. The processes were performed 3 times and the averages were documented.

Biochemical Analysis

Blood sample was collected into EDTA bottles, centrifuged for 30mins at 3000 rpm. The plasma β-Endorphin was determined using ELISA kit (Cruz Biotechnology, Canada).

Statistical analysis

All data were expressed as the Mean ± S. E. M. Statistical analysis was performed using SPSS version 20 software. One-way analysis of variance (ANOVA) was used to compare the mean values of variables among the groups. Duncan *post hoc* test was also used to compare significant difference among groups. A difference between two means was considered to be statistically significant when $p < 0.05$.

RESULTS

Physiological parameters of shift and non shit workers

There were no significant difference in the blood pressure and blood glucose level of the shift workers when compared with the non shift workers (Table1).

Effect of sleep deprivation on cold-induced pain threshold and tolerance

There was no difference in the pain threshold in the two groups following cold-induced pain (Figure 1a). However, a significant increase ($p<0.05$) was observed in pain tolerance when shift workers (84.90±23.80) were compared with non shift workers (74.10±14.40).

Effect of sleep deprivation on ischemia-induced pain threshold and tolerance

The results showed that there were significant ($p<0.05$) decreases in pain threshold and tolerance in shift worker compared with non shift workers following ischemia-induced pain (Figure 2a, b).

Effect of sleep deprivation on cold+ishemia-induced pain threshold and tolerance

Cold+ischemia-induced pain showed that there were no significant ($p<0.05$) changes in pain threshold between shift workers and non shift workers following cold+ischemia-induced pain (Figure 3a), but the pain tolerance significantly ($p<0.05$) increased in shift workers compared to non shift workers (Figure 3b).

Effect of sleep deprivation on circulating level -Endorphin during cold-induced pain, ischemia-induced pain and cold+ischemia-induced pain tests

The circulating plasma level of -Endorphin significantly ($p<0.05$) decreased in shift workers compared to non shift workers in all the tests (Figure 4) except during ischemia-induced pain where a decrease was observed in the circulating level of -Endophin of shift workers but not statistically significant (Figure 4b).

Table 1: Physiological parameters of shift and non-shit workers

	Shift Workers	Non Shift workers
Age (year)	31.1±0.4	28.4±0.9
Blood Glucose (mmol/L)	5.2±0.1	5.0±0.1
Systolic Blood Pressure (mm/Hg)	111.3±2.1	112.0±1.8
Diastolic Blood Pressure (mm/Hg)	73.9±1.5	67±1.0

Data are expressed as mean ± S.E.M. n=10. Data were analysed by one-way ANOVA followed by Duncan *post hoc*test. (**p*<0.05 vs control).*CIP; cold-induced pain, IIP; ischemia-induced pain*

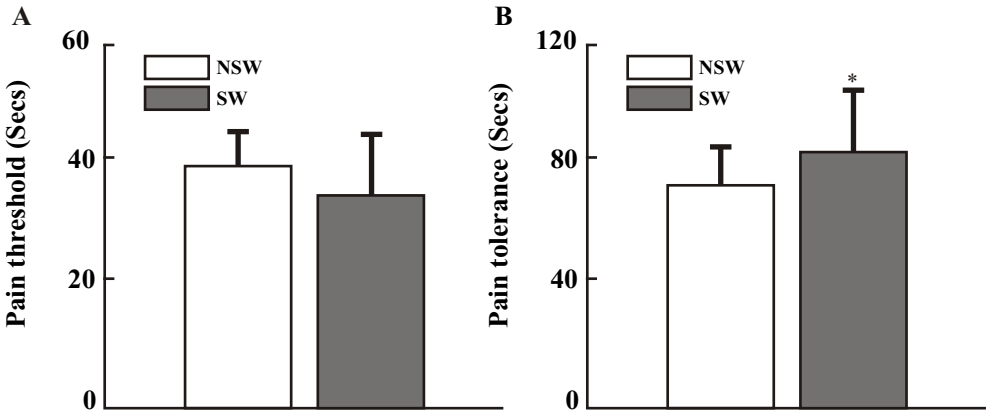

Fig.1. Effect of sleep deprivation on cold-induced pain threshold (a) and tolerance (b). Data are expressed as mean ± S.E.M. n=10. Data were analysed by one-way ANOVA followed by Student *t-test.* **P*<0.05 vs NSW (Non-shift workers); SW (Shift workers).

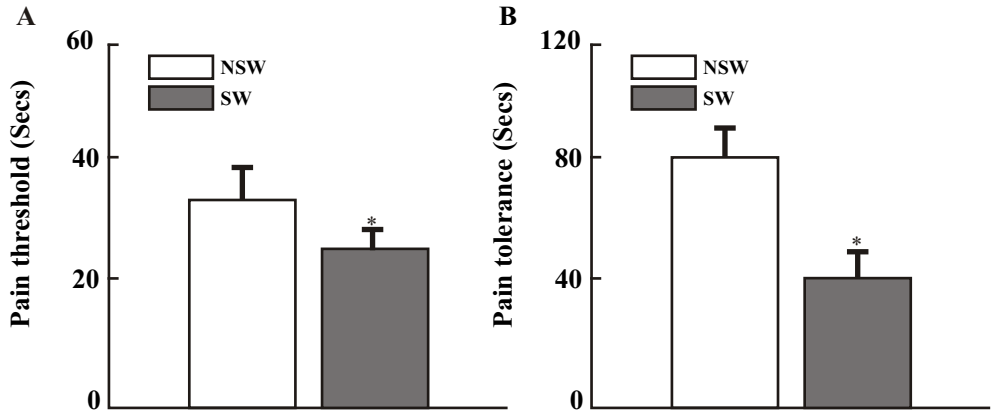

Fig.2. Effect of sleep deprivation on ischemia-induced pain threshold (a) and tolerance (b). Data are expressed as mean ±S.E.M. n=10. Data were analysed by one-way ANOVA followed by Duncan *post hoc*test. **P*<0.05 vs NSW (Non-shift workers); SW (Shift workers).

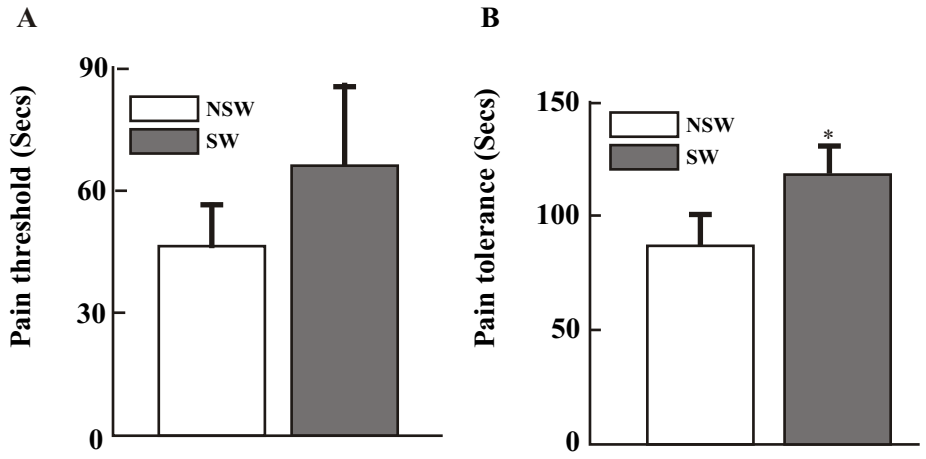

Fig.3. Effect of sleep deprivation on cold+ishemia-inducedpain threshold (a) and tolerance (b). Data are expressed as mean ± S.E.M. n=10. Data were analysed by one-way ANOVA followed by Duncan *post hoc*test. **P*<0.05 vs NSW (Non-shift workers); SW (Shift workers).

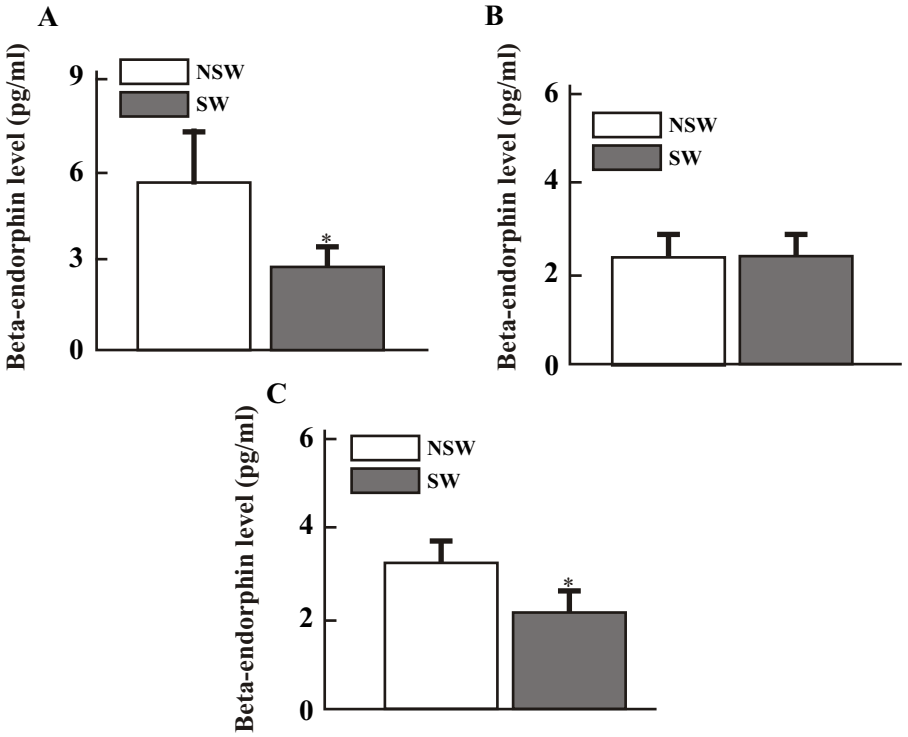

Fig. 4.Effect of sleep deprivation on β-Endorphin during cold-induced pain (a), ischemia-induced pain and cold+ischemia-induced pain tests. Data are expressed as mean ± S.E.M. n=10. Data were analysed by one-way ANOVA followed by Duncan *post hoc* test. *$p<0.05$ vs NSW (Non-shift workers); SW (Shift workers).

DISCUSSION

Considerable evidence has substantially shown that work related health problems are a major concern for public health. Also, pain has been documented as the most important symptom of work related problems[2,3]. However, there is dearth in information regarding the effect of sleep disruption on pain perception.

The current findings show that sleep disruption through shift work in telecommunication workers led to significant increase in pain tolerance during cold-induced pain test and significant decrease in both pain threshold and tolerance during ischemia-induced pain test. In addition, a significant increase in pain tolerance was observed during cold+ischemia-induced pain test. Sleep disruption in telecommunication workers further showed significant alteration in circulating level of -Endorphin.

The observation in this study showing that sleep disruption through shift work in telecommunication workers significantly decreases the pain threshold during ischemia-induced pain test is in consonance with previous observation that disruption of sleep pattern increases sensitivity to pain[23]. This observation implies that people with low pain threshold as in shift work-induced sleep disruption are highly sensitive to ischemia-induced pain test compared with non-shift workers. In addition, the pain threshold was significantly reduced during the test, which is also consistent with a previous study that pressure pain tolerance was significantly reduced after one night of total sleep deprivation and remained lower after rapid eye movement sleep interruption[24]. Furthermore, the observation that pain tolerance significantly increased in telecommunication shift workers during cold-induced pain test is in consonance with earlier study, which reported that pain tolerance to cold pressortest were increased in shift workers[25], therefore sleep disruption decreases sensitivity to cold-induced pain. This is contrary to another earlier observation which reported that sensitivity to thermal pain is enhanced by both slow-wave-sleep deprivation and forced awakenings during REM sleep in humans[24]. In addition, the concomitant administration of cold and ischemia-induced pain tests significantly increased pain tolerance without altering the pain threshold during sleep disruption through shift work

compared to non-shift work. This implies that the sensitivity to cold+ischemia-induced pain is significantly low during sleep deprivation through shift work. The decrease in pain sensitivity during cold and cold+ischemia-induced tests might be due to earlier report that cooling may have significant analgesic properties than ischemic pain and this is in agreement with other studies that cooling of the body reduces pain in patient with fibromyalgia syndrome[26], post episiotomy pain[27]and postpartum perinea pain[28].Cooling reduces serum level of inflammatory markers thereby reducing pain perception. Various inflammatory biomarkers have been previously quantified in subjects exposed to very low temperatures. One of the earlier studies showed that treating top-level rugby players with whole body cooling (WBC) for 1 week led to reduced rates of pro-inflammatory cytokines (IL-2 and IL-8) and increased levels of anti-inflammatory cytokines (IL-10)[29]. Also, cooling or cold exposure has been shown to activate reticular activating system and central nervous system (CNS) to recruit motor neurons as well as activating the sympathetic nervous system (SNS).

-endorphin is an endogenousopioid peptide derived from pro-opiomelanocortin, a neurohormone secreted by the anterior pituitary into the systemic circulation. Endorphins are found in regions of the brain involved in the perception of pain, including the nucleus accumbens and the arcuate nucleus. It has been documented to be involved in natural reward circuits such as feeding, drinking, sex and maternal behavior[30]. However, the role of plasma -endorphin in pain regulation is unclear, plasma -endorphin levels have been reported to correlate inversely with pain levels in cancer pain[30], chronic daily headache[31] and post-operative pain[32]. That is, plasma -endorphin levels are lower in patients with poorly controlled pain, and increase with pain relief. Evidence has shown that -endorphin is involved in attenuation of the experience of pain[33], and it has been found to reduce the experience of emotional and physical distress including pain[20,34]. In this study, plasma -endorphin was measured and there was a significant decrease in plasma level of -endorphin in shift work compared to the non shift work. This implies that sleep disruption through shift work alters plasma -endorphin; this corroborates earlier studies that -endorphin depletion might result from prolonged stress and trauma, leading to an increase in distress, anxiety, and depression[35]. Also, low levels of -endorphin could mirror a defective endogenous pain control system in the shift workers. In 1978, Almay *et al.* reported that levels of unspecific "endorphins" was low in the plasma of patients with predominantly "neuralgic" pain, compared both to patients with what was labelled "psychogenic" pain and to healthy controls[35]. Also, in 1988, Tonelli *et al.,* found low -endorphin in patients scheduled for spinal cord stimulation, compared to historic controls[36].

Generally, sleep disruption has been clinically associated with longer reaction time, distractedness, attention/concentration deficit, memory deficit, stress, tiredness, drowsiness, pain, increased irritability, decreased work effectiveness, low motivation and declined reasoning[20,37]. However, the results from the present study become the first to suggest that sleep disruption through shift work alters pain perception which is dependent on the circulating level of plasma -endorphin.

CONCLUSION

The present study demonstrates that sleep disruption through shift work alters pain perception which is accompanied by alteration in circulating level of plasma -Endorphin.

Conflict of Interest

The authors declare that there are no conflicts of interest.

REFERENCES

1. Harrington JM. "Health effects of shift work and extended hours of work". *Occup Environ Med*. 2001; 58:68-72.
2. Frost P, Kolstad HA and Bonde JP. Shift work and the risk of ischemic heart disease-a systematic review of the epidemiologic evidence. *Scand J Work Environ Health* 2009;35:163-179.
3. European Statistical Data Support. *Annual Report,* 2009.
4. International Labour Office Geneva. *Annual Report*, 2004.
5. National Sleep Foundation. *Annual Report*, 2015.

6. Michael S and Christopher DH. "Physiology of Sleep". *British Journal of Anaesthesia CEPD Reviews* 2003; 3:3-10.
7. Mental Health Foundation. *Annual Report,* 2011.
8. Wang Q, Xi B, Liu M, Zhang Y and Fu M. "Short sleep duration is associated with hypertension risk among adults: systemic review and meta-anlysis". *Hypertens Res.*2012; 35:1012-1018.
9. Siegel JM. "Sleep viewed as a state of adaptive inactivity". *Nat Rev Neurosci*. 2009; 10:747-753.
10. Buxton OM, Can SW and O'Connor SP. "Adverse metabolic consequences in humans of prolonged sleep restriction combines with circadian disruption". *Sci Transl Med.*2012;129:12-43.
11. Arble DM, Bass J, Laposky D, Vitaterna MH, Turek FW. "Circadian timing of food intake contributes to weight gain". *Obesity* 2009; 17:2100-02.
12. Goel N, Stunkard AJ and Rogers NL. "Circadian rhythm profiles in women with night eating syndrome". *J Biol Rhythm* 2009; 24:85-94.
13. Kobayashi D, Takahashi O, Deshpande GA, Shimbo T and Fukui T. "Association between weight gain, obesity and sleep duration: a large scale 3-year cohort study". *Sleep Breath* 2012; 16: 829-833.
14. Chao CY, Wu JS and Yang YC. "Sleep duration is a potential risk factor for newly diagnosed type 2 diabetes mellitus". *Metabolism* 2011; 60:799-804.
15. Cappucino FP, D'Elia L, Strazzullo P and Miller MA. "Sleep duration and all-cause mortality: a systematic review and meta-analysis of prospective studies". *Sleep* 2010; 33:585-592.
16. Center for Disease Control & Prevention, 2011.
17. Rajagopal MR. "Pain-Basic Considerations". *Indian J.* Anaesthesia 2006; 50(5): 331-4.
18. Winlow W and Holden AV. "The neurobiology of pain": Symposium of the Northern Neurobiology Group, *held at Leeds* on 18 April 1983. *Manchester:" Manchester University Press.*
19. Breivik H, Borchgrevink PC, Allen SM, Rosseland LA, Romundstad L, Hals EK, Kvarstein G and Stubhaug A. "Assessment of pain". *Br J Anaest.* 2008; 101(1):1724.
20. Hebb AL, Laforest OS and Drolet G. "Endogenous Opioids, Stress, and Psychopathology". *Techniques in the Behavioral and Neural Sciences*. 2005;(15)561-583.
21. Plesan A, Sollevi A and Segerdahl M. "The N-methyl-D-aspartate-receptor antagonist dextromethorphan lacks analgesic effect in a human experimental ischemic pain model". *Acta Anaesthesiol Scand.* 2000; 44:924-8.
22. Goodin BR, Fillingim RB, Machala S, McGuire L, Buenaver LF, Campbell CM and Smith MT "Subjective sleep quality and ethnicity are interactively related to standard and situation-specific measures of pain catastrophizing". *Pain Med.* 2011; 12(6):913-922.
23. Lee J, Kim J and Shin H. "Effect of sleep deprivation on pain sensitivity in healthy subjects"*Sleep Medicine.* 2013;14(1); e180.
24. Onen SH, Alloui A, Gross A, Eschallier A and Dubray C. "The effects of total sleep deprivation, selective sleep interruption and sleep recovery on pain tolerance thresholds in healthy subjects". *J Sleep Res.* 2001; 10:35-42.
25. Rohers T, Hyde M, Dell B, Greenwald M and Roth T. "Sleep loss and REM sleep loss are hyperalgesic". *Sleep* 2006; 29:145-160.
26. McVeigh JG, Mc Gaughey H, Hall M and Kane P. "The effectiveness of hydrotherapy in the management of fibromyalgia syndrome": "A systematic review". *Rheumatol Int*.2008; 29:119-30.
27. LaFoy J and Geden EA. "Post episiotomy pain": "Warm versus cold sitzbath". *J Obstet Gynecol Neonatal Nurs.* 1989; 18:399-403.
28. Ramler D and Roberts JA. "Comparison of cold and warm sitzbaths for relief of postpartum perineal pain". *J Obstet Gynecol Neonatal Nurs.* 1986;15:4714.
29. Banfi G, Melegati G, Barassi A and d'Eril GM. "Effects of whole-body cryotherapy on serum mediators of inflammation and serum muscle enzymes in athletes". *J Therm Biol.* 2009; 34:55-59.

30. Mystakidou K, Befon S and Hondros K. "Continuous subcutaneous administration of high-dose salmon calcitonin in bone metastases: pain control and beta-endorphin plasma levels". *J Pain Symptom Man age* 2006; 18:323-330.
31. Facchinetti F, Nappi G, Savoldi F and Genazzani AR. "Primary headaches: reduced circulating -lipotropin and -endorphin levels with impaired reactivity to acupuncture". *Cephalalgia*1981; 1:195-201.
32. Leonard TM, Klem SA and Asher MA. "Relationship between pain severity and serum -endorphin levels in postoperative patients". *Pharmacotherapy*. 1993; 13:378-381.
33. Tseng LF. "Mechanisms of -Endorphin-Induced Anti- nociception," In: L. F. Tseng, Ed., *The Pharmacology of Opioid Peptides*, *Harwood Academia Publishers, Newark, United States,* 1999; 249-269.
34. Parikh D, Hamid A, Friedman TC, Nguyen K, Tseng A, Marquez P and Lufty K. "Stress-Induced Analgesia and Endogenous Opioid Peptides: The Importance of Stress Duration". *European Journal of Pharmacology 2011;* 650:563-567.
35. Hoffman L, Watson PB, Wilson G and Montgomery J. "Low Plasma -Endorphin in Post-Traumatic Stress Disorder". *Australian and New Zealand Journal of Psychiatry* 1989;23:269-273.
36. Tonelli L, Setti T, Falasca A, Martignoni E, Torcia E, Calcaterra FM, Merli GA and Facchinetti F. "Investigation on cerebrospinal fluid opioids and neurotransmitters related to spinal cord stimulation". *Appl Neurophysiol.* 1988;51(6):324-32.
37. Bonnet MH and Arand DL. Clinical effects of sleep fragmentation versus sleep deprivation. *Sleep Med Rev*. 2003; 7:297-310.