Effects of Whole-Body Heating on Chronic Low Back Pain

by

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ABSTRACT

Low Back Pain (LBP) is a condition that may originate from an injury, disease, or stresses on different parts of the body that transfer as a feeling of pain in the bones, nerves, or muscles of the lower back. The prevalence of LBP at some point in one's lifespan is estimated at 85%, and 2-10% of these individuals will live with chronic LBP (CLBP). The purpose of this study was to investigate the effects of 7 consecutive days of whole body heating on chronic low back pain in individuals between 30-65 years of age. A water-perfused suit, through which 50°C water was passed, was utilized to increase core body temperature (Tc) by 0.8°C for 7 consecutive days. Pain questionnaires were used to assess changes in CLBP during the 7 days of heating, and at 2-days and 2-week post-heating. The average McGill Pain Scores from heating day 1 (H1) to day 7 (H7) decreased 20.2%. The functional limitation scale decreased 12.5% from H1 to H7 and the symptom scale of frequency and intensity of pain symptoms both decreased 2.8% from baseline to 2-weeks post-heating. Varied results acutely following heating were observed between subjects, suggesting heating may provide relief for acute pain in some subjects. All three pain scales utilized in the present study (McGill Pain Questionnaire, the functional limitation scale, and the symptom scales) suggested improvements in CLBP with repeated whole body heating to a 0.8°C increase in Tc. Additionally, these therapeutic effects were still evident 2 weeks following the last day of heat therapy. These results suggest promising potential for whole body heating as a non-invasive, non-pharmacologic method of treating chronic low back with benefits lasting for days or weeks post-therapy.

INTRODUCTION

Low back pain (LBP) is a prevalent issue worldwide and a major cause of disabilities affecting all aspects of daily life. LBP is a condition that may originate from an injury, disease, or stresses on different parts of the body that transfer as a feeling of pain in the bones, nerves, or muscles of the lower back. When tissue is damaged nerve endings called nociceptors transmit a nerve signal through the spinal cord to the brain which recognizes the sensation of pain (Nadler, 2004). The terms used to describe the sensations of back pain may include achey, burning, stabbing or tingling, sharp or dull, and well-defined or vague (Chronic Low Back Pain, 2009). LBP can be categorized as acute, sub-acute with symptoms lasting longer than 4-6 weeks, or chronic with symptoms lasting longer than 12 weeks. The prevalence of experiencing LBP at some point in one’s lifespan is estimated at 85%, and 2-10% of these individuals will live with chronic LBP (Alpert, 2014). In the United States, approximately 18% of the population experiences LPB at any given moment, with a one-year prevalence of 15-45% (Peng, 2013). The prevalence of LBP in adults is rising, with numbers peaking between the ages of 35 and 55 (Hoy et al., 2012) or ages 40 to 80 for chronic LBP (Alpert, 2014). LBP is the second most common cause of lost work time, the fifth most common cause for hospitalization, and the third most common reason to undergo a surgical procedure. In the United States the expense of treating LBP is greater than $100 billion annually and expenses from lost work productivity are approximately $28 billion per year (Phillo Beukes Physiotherapy, 2012).

Development of chronic LBP is complex and multifaceted, with the direct cause not fully understood, and the diagnosis and treatment subsequently remaining a significant challenge. A large number of risk factors are recognized for developing LBP, including occupational posture and physical demand, depressive moods, obesity, body height, and age.

In addition to common strains, sprains, and muscle spasms due to overuse, LBP can also result from any of the following: congenital abnormalities, degenerative disc disease, osteoarthritis, rheumatoid arthritis, post-herpetic neuralgia, vertebrae fractures secondary to osteoporosis, spinal disc rupture or herniation, spinal stenosis, osteomalacia (bone pain due to vitamin D deficiency/insufficiency), bone mass, spondylitis, and infection (osteomyelitis) (Alpert, 2014). There are also several different types of pain associated with LBP including: discogenic pain, radicular pain, facet-joint pain, sacroiliac pain, and muscular pain (Phillo Beukes Physiotherapy, 2012). In a study conducted by DePalma et al (2011), LBP is most likely due to discogenic factors in younger patients and facetogenic or sacroiliac joint pain in older patients. Concerning all adults, problems with the intervertebral disc is the most common etiology of chronic LPB (DePalma et al., 2011). Samini et al (2014) observed the most common causes of LBP to be constant heavy working (40.2%), osteoporosis (35.6%), and sacroiliac joint pain (34.6%).

Considering the wide array of causes, back regions affected, and types of LBP, appropriate pain prevention and/or treatment can be extremely difficult. However, treatment of LBP is usually more effective when using a multifaceted approach that addresses the complex etiology and instigators of continued LBP. Multifaceted treatment may include: physical therapy and rehabilitation, psychological interventions such as biofeedback and cognitive behavioral therapy, pharmacological management, and interventional pain procedures (Veizi & Hayek, 2014). Two of the most common treatments for back pain in a healthcare setting are the medical model and the biopsychosocial model. The medical model works best in cases where the cause of the pain can be identified and 1) recognizes patterns of symptoms and signs by history and examination, 2) identifies underlying injury or disease by investigation and diagnosis, 3) treats underlying injury or disease by specific biologicallyoriented therapy, and 4) expects the patient to recover as explained by the cure (Weiner, S. & Nordin, M., 2010). The medical model is straightforward and is generally used in many healthcare situations, while the biopsychosocial model of treatment focuses on the indefinite aspects of etiology such as beliefs, a high perception of disability, kinesiophobia, depression, stress from work or family, job dissatisfaction, anxiety, somatization, and lack of control (Weiner, S. & Nordin, M., 2010).

For patients with chronic LBP, continual visits to different hospitals and healthcare clinics are common with treatments ranging from drugs and surgery to rehabilitation and thermal therapy. There are many different treatment options that have varying research outcomes depending on the particular patient case. Analgesic medication, nonsteroidal anti-inflammatory drugs (NSAIDS), anticonvulsants, counter-irritants (i.e. Icy Hot®), and antidepressants are the most common medications used by LBP patients. Spinal manipulation and spinal mobilization are techniques performed by a licensed chiropractor to mobilize, adjust, massage, or stimulate the spine and surrounding tissue. This method has been shown to provide short-term relief of chronic back pain in some patients, but little to no help for those with acute LBP or underlying complications like osteoporosis. Acupuncture has shown conflicting evidence on its benefits for acute back pain, but is moderately effective for chronic LBP by inserting needles into the back to clear blockages of Qi and/or release painkilling hormones such as endorphins, serotonin, and acetylcholine. Transcutaneous electrical nerve stimulation (TENS) uses an electrical device consisting of electrodes to stimulate the nervous system to possibly release endorphins while blocking pain signals from the peripheral nerves. Finally, invasive surgeries are often a last resort due to the financial cost, health risks, recovery time, and the possible chance of failure.

Despite the wide range of LBP treatment options, the most common methods of acute pain relief are over-the-counter pain medications such as ibuprofen or acetaminophen, and localized application of heat. Improvements in pain relief, lateral trunk flexibility, and disability reduction have been observed to be greater with heat wrap therapy than when using ibuprofen or acetaminophen alone (Nadler et al., 2002). There are several reasons as to why continued heat therapy helps relieve symptoms of pain. According to the Gate Control Theory there is a pain gating mechanism in the spinal cord that controls pain transmission. Small diameter sensory fibers carry pain impulses that open the gate to allow pain impulses to the brain, whilst large diameter sensory fibers which are stimulated by warmth, coolness, massage and transcutaneous electrical nerve stimulation, carry impulses that help close the gate and decrease the prevalence of pain. Superficial heat application reduces striated muscle spasms and excitability, tension within the muscle fibers, and viscosity of synovial fluid which alleviates pain associated with joint stiffness. Thermoreceptors, or temperature-sensitive nerve endings in the skin, detect changes in temperature and activate nerve signals that block nociceptors. In patients with chronic LBP a combination of repeated whole-body thermal therapy, cognitive behavioral therapy (CBT) and rehabilitation was significantly more effective in the short and long-term follow-up than CBT and rehabilitation alone (Masuda et al., 2005).

Multiple studies have examined the effects of heat therapy on pain by using heat wraps, saunas, or warm baths. Most of these studies did not account for the type of pain experienced and how deep the injured tissues may have been, nor did they account for administration of heat therapy based on the weight or size of the subject. In a study conducted by Masuda et al. (2005), the subjects were instructed to lie supine in a 60°C sauna for 15 minutes before returning to a 28°C room where they lay covered with a blanket for an additional 30 minutes. One limitation to this method is that there was no indication of the body temperature rise of the participant or increase in heat intensity on the injured area. Humans show variation in their abilities of thermoregulation, with some of the subjects in the aforementioned study potentially experiencing greater thermal effects than others (Kenney & Munce, 2003). Heat wrap therapy, which is recommended for only 20-30 minutes at a time, can also produce varied results. If the heating pad is not large enough it may not provide thermal effects to the entire area of injured tissue, and with such a short amount of time the thermal effects may not even reach into the subcutaneous tissue or muscle tissue from which the pain originates (Science Letter, 2005). A Whole-body heating protocol utilizing a controlled increase in core temperature ensures that all affected areas will increase in temperature, and all participants will be heated to the same absolute temperature, regardless of body weight and composition. Whole-body heating is a non-pharmacological, non-invasive method of heat therapy, which holds potential for lower back treatment due to its effects of stress relief, muscle relaxation, and potential for improved sleep quality.

Based on previous literature and current utilization of thermal therapy in pain management, it is hypothesized that repeated whole-body warming will decrease the intensity, frequency, and perception of pain in 30-65 year olds suffering from CLBP.

METHODS

Subjects

All experimental procedures were approved by the Appalachian State University Institutional Review Board. Written and verbal informed consent were obtained voluntarily from all subjects prior to participation according to the Declaration of Helsinki. Two male subjects, of ages 47 and 52 were tested. Accepted subjects were male or female non-smokers between the ages of 35 to 65 years of age with no chronic diseases, interfering dermatological issues, heat acclimatization, previous heat related illness or injury, hypertension, hypercholesterolemia, or hypertriglyceridemia.

Baseline measurements

Baseline questionnaires were completed to assess perceived intensity of chronic lower back pain. Each subject completed the McGill Pain Questionnaire (Melzack, 1975) and a functional limitation scale (Björklund et al., 2007) to determine the initial and concluding severity and characteristics of chronic back pain. Upon arrival to the laboratory the subject provided a urine sample to test for hydration status via a urine specific gravity test. If the subject was not adequately hydrated they were required to consume Gatorade and re-tested before continuing with the experimental procedure. The subject changed into pre-weighed shorts and t-shirt before measurements of body weight, heart rate, blood pressure, sublingual temperature, and urine specific gravity (USG) were recorded. Throughout the study subjects were instructed to consume 20 ml/kg body weight of fluid throughout the day prior to each whole body heating procedure to ensure hydration. To test for adequate hydration of the subjects, the initial level of hydration was determined using a urine sample and refractometer. If the USG of the sample was greater than 1.020, the subject was instructed to drink fluids and the USG test was repeated before continuation of the protocol.

Whole Body Warming Procedure

Thermocouples were taped to the upper arm, back, abdomen, calf, thigh, and chest of the subject to measure skin temperature (T_{sk}) during whole body heating. Prior to each experimental procedure, thermocouples were calibrated in a 25°C and 50°C circulating water bath. A weighted mean Tsk was calculated following each experiment using the following calculation (Ramanathan, 1964):

$$MST_R = 0.3\ t_{chest} + 0.3\ t_{arm} + 0.2\ t_{thigh} + 0.2\ t_{leg}$$

Following thermocouple placement, the subject donned a water perfused suit and overlying rain suit before being instructed to lie supine. A thermistor was calibrated in a circulating water bath and placed beneath the subject’s tongue at the position of the sublingual sulcus as an index of core temperature (Tcore). A Finapres monitor was used to collect baseline heart rate, blood pressure, mean arterial pressure, and Tcore data 5 minutes before heating began and throughout the entire duration of the experiment.. To calibrate the Finapres, the subject's height/weight/age/sex were entered into the Finapres monitor along with a distance of zero between the finger cuff and transducer, or height correction unit. The finger cuff, which uses infrared to detect blood pressure within the finger, the transducer that lies on the chest at heart level, and the blood pressure cuff were positioned on the subject. The blood pressure of the upper arm and finger were measured so that the Finapres could estimate the subject’s blood pressure from the finger alone. Just before heating began, the subject’s exposed feet were wrapped in towels followed by plastic bags to prevent any sweat evaporation from the feet. The water perfused suit was attached to circulating water baths set at 50°C, with water of ~48°C circulating through the suit. Tcore was recorded throughout the procedure (Biopac

Systems Inc) and the subject was heated until achieving a 0.8°C rise above baseline Tcore. Along with the heart rate, blood pressure, and mean arterial pressure, the subject's thermal sensory perception on a 1-10 scale, and elapsed time were recorded at each 0.1°C increase in Tcore. When the Tcore reached a 0.8°C rise, the water circulation was turned off, all equipment was removed from the subject, they were given weighed bottles of Gatorade to rehydrate, the subject and the clothes worn during heating were weighed again, and the subject's blood pressure, heart rate, and sublingual temperature were recorded to ensure their values returned to normal before departure for health and safety purposes.

RESULTS

From Baseline to day 2 of heating (H2) the average McGill Pain Score increased 11.0% from 21 to 29 points. Overall, from day 1 to day 7 of heating (H7) the average McGill Pain score decreased an average of 14.75 points or 20.2% with an R^2 value of 0.93.The average McGill pain score decreased a further 4.1% from H7 to the 2-day follow-up (FU-Day 2), with a maximum decrease of 6.8%, before increasing another 2.74% by FU-Week 2.

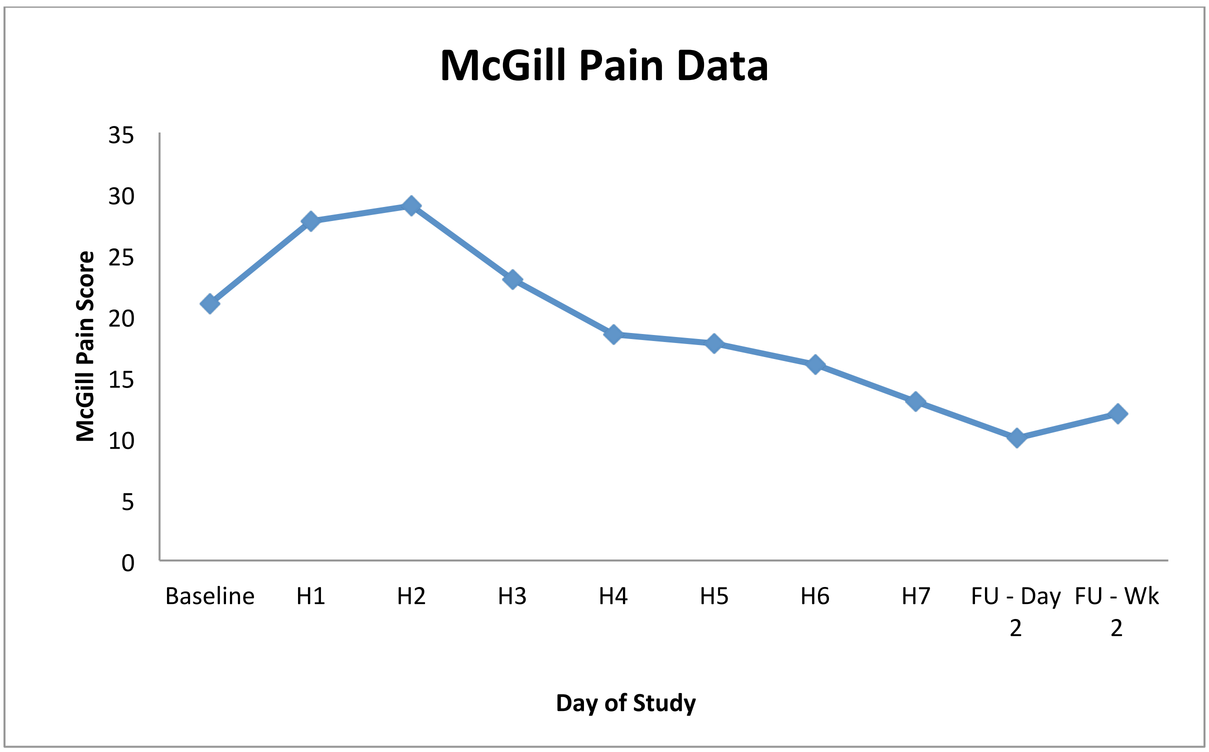
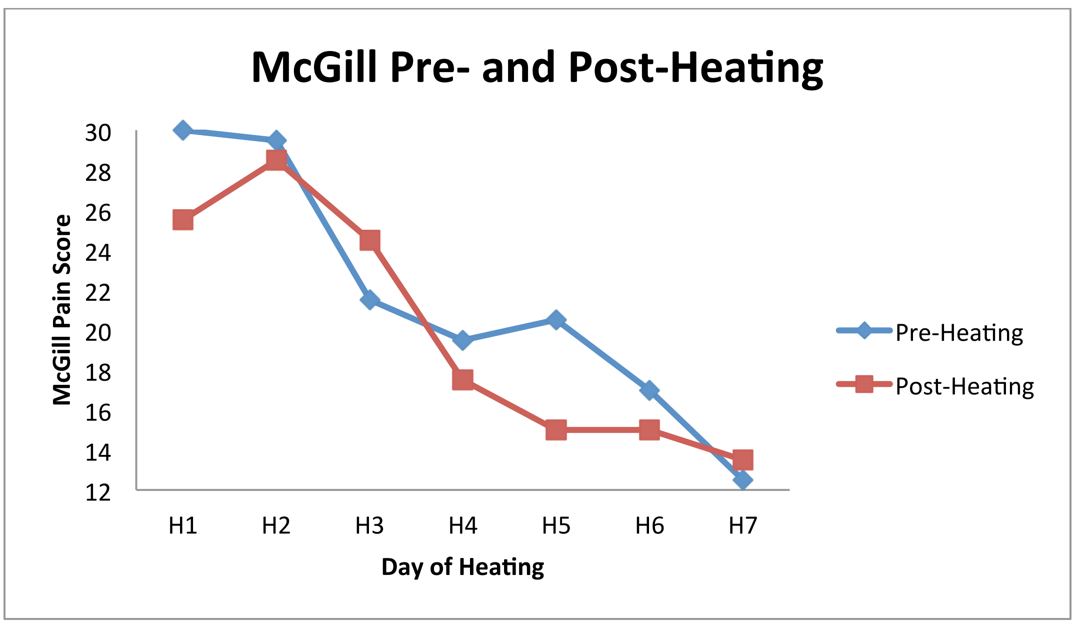


Fig. 1. Group average of total points scored on the McGill Pain Questionnaire from Baseline through the 2-Week Follow-up (Follow-Up Week-2). From H1 to H7 there was a gradual decrease in pain (R^2 = 0.93) followed by a decrease to FU-Day2 and a slight increase to FU-Wk 2, still falling below baseline.

The McGill pain scores observed before and after heating on each individual day had varied outcomes. Subject 1 and Subject 2 showed different acute pain responses following whole-body heating. Subject 1 experienced a decrease in the McGill pain scores from before heating to after on all days except H3 (Fig. 2b.), while Subject 2 experienced a small increase in the McGill pain score following heating for five of the seven days (Fig. 2c.). The average pre- and post-heating pain scores for Subject 1 were 16.1 and 11.9 (P = 0.001), while the average pre- and post-heating pain scores for Subject 2 were 26.9 and 28, respectively; a 3.5% difference in individual total point difference (P = 0.27).



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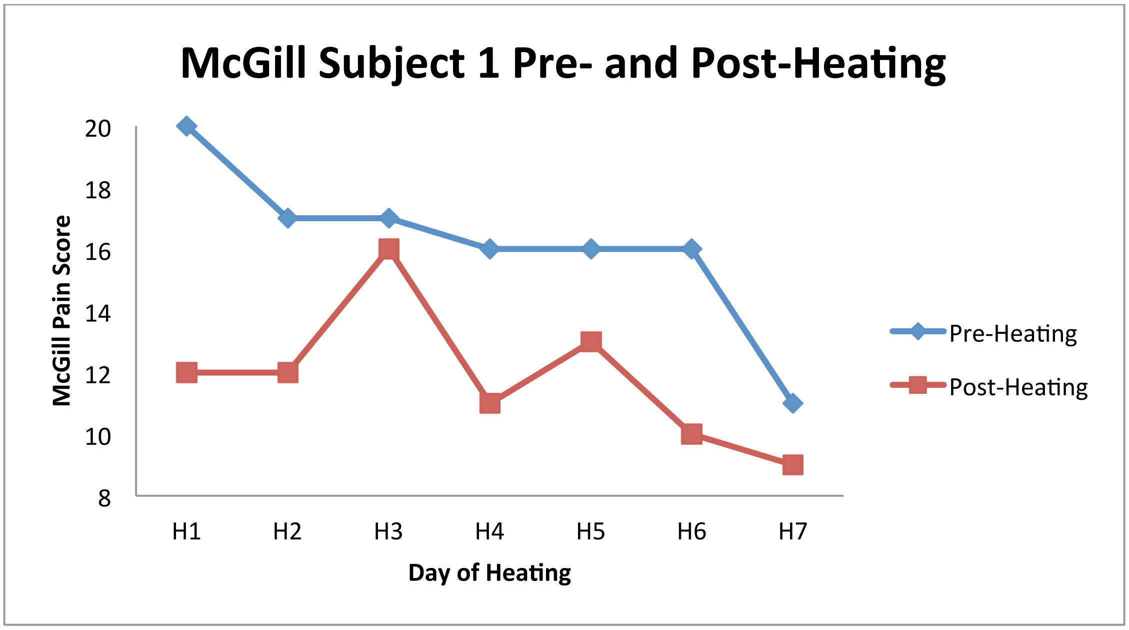

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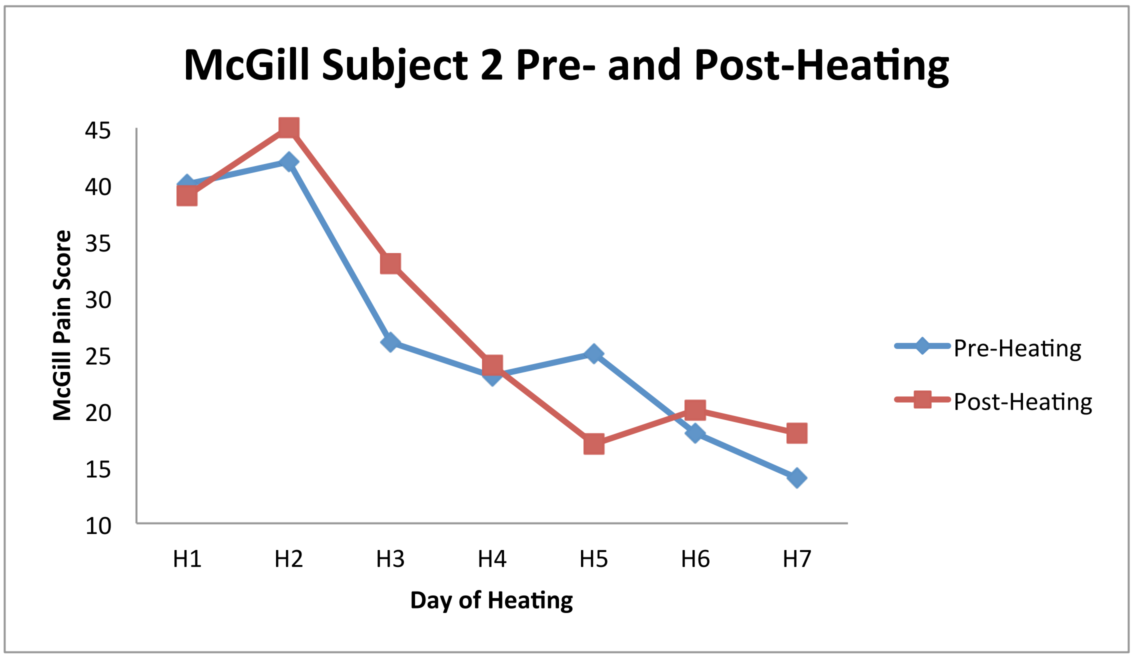

2c.

Fig. 2. Group mean and individual pre- and post-heating McGill pain scores for days 1-7 of heating. (2a) As the week of heating progressed, a consistent decline in average McGill pain score was observed. (2b) Subject 1 showed a consistent decrease in McGill pain score throughout the study as well as an immediate decrease in pain score following heating each day. (2c) The McGill Pain Score of Subject 2 showed a gradual daily decrease from H2 to H7, but an immediate increase in pain score following heating was observed the majority of heating days.

The average Functional Limitation (FL) Scale of both subjects showed a decrease of 12.5% from 66 to 45 from H1 to H7 of the heating protocol. At the 2-Week Follow-up, the FL score had increased 1.5% to an average score of 47.5. The total increase in functional abilities throughout the course of the study was 11.0%

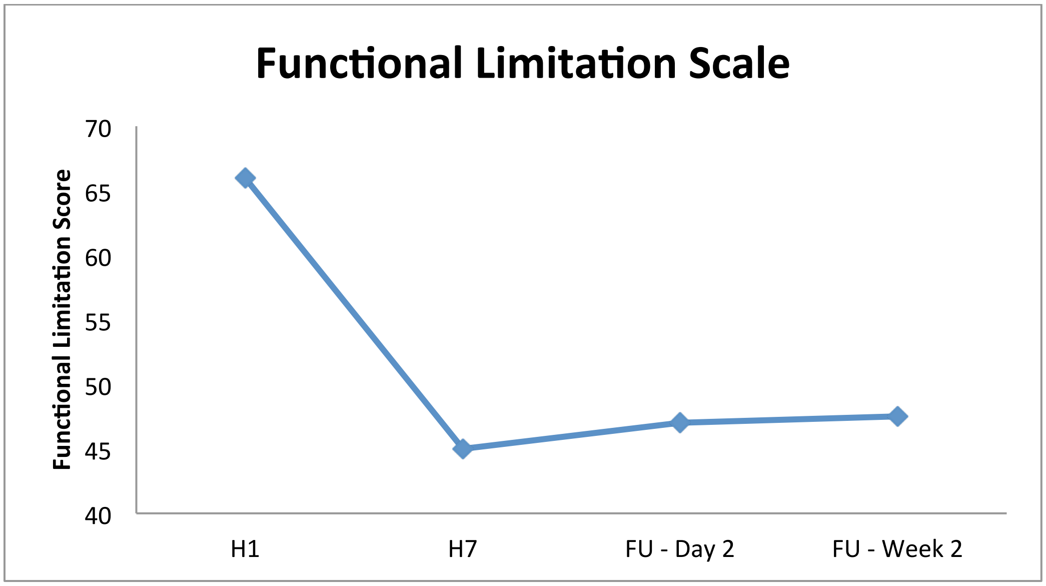

Fig. 3. Average points scored on the Functional Limitation Scale from H1 to Follow-Up-Week 2. There was a large decrease in subject function limitations from H1 to H7, and a gradual increase in limitation from the last day of heating (H7) to the 2-Week follow-up (FU-Week 2.)

The Symptom Scale was measured based on 27 different symptoms on how much pain (1-6 points) and how often the pain is experienced (7-12 points). The average baseline scores were 66.5 for how much pain and 227.5 for how often the pain was experienced. These values had decreased to 62 and 218.5, respectively, by the 2 week follow-up. Both the average pain intensity and the average frequency decreased from baseline to the 2 week post heating follow-up visit by 2.8%.

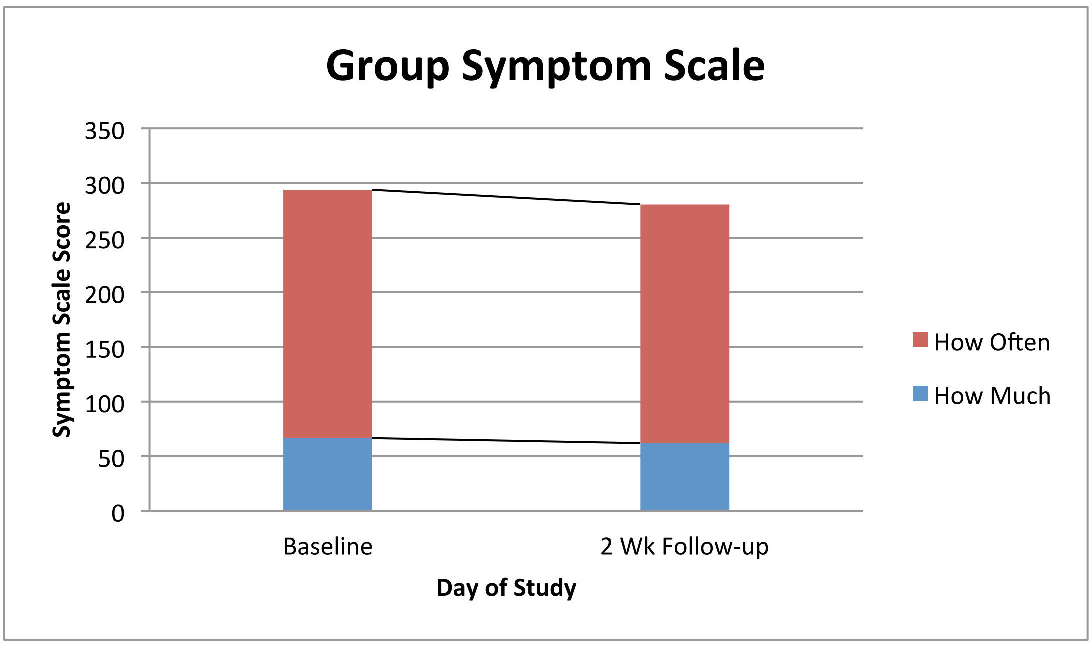

Fig. 4. Average Symptom Scale score comparing baseline and the 2-Week post-heating Follow-up of frequency and intensity of pain. Both the frequency and intensity of pain decreased from baseline to the 2-Week Follow-up.

DISCUSSION

The present study aimed to investigate the effects of 7 consecutive days of whole body heating on chronic low back pain in individuals aged 30-65. The results of this study suggest that whole-body heating has beneficial effects on chronic LBP when administered for seven consecutive days, but immediate effects on pain can either be positive or negative and require further investigation. For both subjects the McGill Pain Questionnaire showed a negative correlation between the day of heating and the total points scored, suggesting that whole-body heating was the cause of decreased pain. On average, the subjects experienced a 20.2% decrease in points scored on the McGill Pain Questionnaire from the 1st to 7th day of heating with an R^2 value of 0.93, indicating the 7 days of successive whole body heating to a 0.8C rise in sublingual temperature showed beneficial effects on pain. However, whether further improvements in pain with additional days of heating or eliciting a higher sublingual temperature requires further investigation in order to potentially optimize the protocol.

At the 48-hour follow-up visit, both subjects still experienced similar therapeutic effects, but at the 2-week follow-up they both showed an increase in their total individual point change by 6.3% and 13%, respectively, remaining below baseline. In a similar 4-week heat study, during a 2-year follow-up, subjects who underwent heat therapy for 30 minutes per day for 4 weeks showed a greater percentage to return to work and a lesser percentage to result in poor outcomes than the subject group who just received cognitive behavioral therapy (Masuda, 2005). Additionally, a study conducted by Nadler et al. (2002) revealed a gentler tapering of benefits from continuous heat-wrap therapy than with over-the-counter pain medications. These studies suggest that upon heat therapy discontinuation, the pain intensity will eventually return to baseline levels depending on the duration and effectiveness of the heat therapy.

When comparing the immediate effects of heating on pain, Subject 1 showed a significantly lower McGill Pain Score following heating at a 39.0% difference between pre-heating and post-heating scores. Similar studies have attributed these effects to either vasodilation and muscular relaxation allowing for more nutrients to the affected area, or to direct effects on the thalamus of the brain which controls the sensory and motor relay of consciousness and sleep (Nadler et al., 2002). Contrary to Subject 1 and several previous studies (Nadler et al., 2004; Chandler et al., 2002; Nadler et al., 2002) Subject 2 showed a negative pain response to the actual heating process for 5 of the 7 days of heating. The average McGill Pain Score for Subject 2 was 3.5% higher post-heating than pre-heating. There are many explanations as to why heat application resulted in increased pain, but the most likely explanation may be that the back tissue was already inflamed, swollen, or irritated from the day's activities, and heat application further increased the inflammation (Nadler et al., 2004). Another cause of increased pain may be due to the procedure itself, however, this is unlikely and a control protocol will be added to address the effects of the protocol alone on pain.

The Symptom Scale and Functional Limitation Scale (Björklund et al., 2007), showed a decrease in intensity and frequency of pain symptoms and a decrease in the functional limitations that their LBP has on their abilities of daily life. The Symptom scale results showed a 2.8% decrease in intensity and frequency of symptoms from baseline to the 2-Week Follow-up and the Functional Limitation Scale results showed a 12.5% decrease in limitations during heating and only a 1.5% increase over the next two weeks. Both of these tests show lasting therapeutic effects as did the McGill Pain Questionnaire and previous studies, suggesting heat therapy is not necessary every day, but depending on the rate of decreasing pain relief will determine the frequency of therapy for necessary maintenance.

Many studies have demonstrated the positive effects of evening whole-body heating on the quality of sleep including enhance slow wave sleep, reduce REM sleep, and decreased sleep-onset latency and sleep arousal (Liao, 2002). Furthermore, research has revealed that insufficient sleep can have negative effects on the perception of chronic pain (Smith & Haythornthwaite, 2004), suggesting that improved quality of sleep due to whole-body warming can in-turn relieve pain and/or improve pain perception.

At present, the mechanisms underlying the reduction in pain with repeated whole body warming are unclear. One potential mechanism is similar to developing a fever as an immune response to infection. A fever is an adaptive response to many infectious and foreign invading microorganisms with an increase to at least 38.3°C in T_C generated by cytokines released from immune cells and controlled by the hypothalamus. This increase in temperature causes a 25% increase in oxygen consumption, increases in metabolic rate, and vasodilation in the kidneys, liver, skin, and upper and lower limbs in an attempt to eradicate foreign and harmful stimuli (Hossein & Yvuz, 2014). The whole body warming procedure used in this study may have imitated the natural immune response of a fever producing the beneficial effects on CLBP, however, this study did not focus on the mechanistic principles of whole body warming and further research is required to elucidate the mechanisms involved.

One limitation of the present study was the lack of a control group or protocol. The simple act of coming into the lab with a possibility of improving back pain may have affected the results of the questionnaire, so testing the same subjects wearing a room-temperature water-perfused suit in the same circumstances would be advantageous.

In conclusion, repeated whole-body warming has demonstrated beneficial effects on the intensity, frequency, and pain perception of low back pain during 7 consecutive days of whole body warming to a 0.8°C sublingual temperature, which persisted for 2 weeks. Varied acute pain responses were observed with whole-body warming, indicating that some individuals may benefit immediately from the muscular relaxation induced by whole body warming. The acute and long effects of whole body warming may provide a non-pharmacological alternative to treatment to alleviate chronic low back pain, however, this requires further investigation.

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