INVESTIGATION OF TRAPEZIUS MUSCLE EFFECT USING OGAWA MASTERDRIVE MASSAGE CHAIR WITH ELECTROMYOGRAM (EMG) SENSOR

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FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2019

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RESEARCH REPORT SUBMITTED TO THE FACULTY OF ENGINEERING UNIVERSITY OF MALAYA, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF BIOMEDICAL ENGINEERING

2019

UNIVERSITI MALAYA

ORIGINAL LITERARY WORK DECLARATION

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Registration/Matric No: **KQB170007**

Name of Degree: **MASTER OF BIOMEDICAL ENGINEERING**

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"): **INVESTIGATION OF TRAPEZIUS MUSCLE EFFECT USING OGAWA MASTERDRIVE MASSAGE CHAIR WITH ELECTROMYOGRAM (EMG) SENSOR**

Field of Study: **BIOMEDICAL ENGINEERING**

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ABSTRACT

Stress and repetitive movement from non-ergonomic work condition are two of the many causes of neck and shoulder pain. One of the modalities for the treatment of neck and shoulder pain is massage therapy. This requires the service of a physiotherapist or a chiropractor which may not always be available. To cater for this demand, newer models of automated massage chairs with better functions and modes are being introduced in the market. The OGAWA Master Drive massage chair is one of the latest models of automated massage chairs that incorporates heat or thermotherapy as an added function. This is hoped to better mimic the human hand when delivering massage therapy. This study evaluated the effects of OGAWA Master Drive massage chair on the trapezius muscle by using surface electromyogram (EMG) sensor. Ten subjects with no previous neck and shoulder pain or deformity were subjected to two modes of Sensei massage on OGAWA Master Drive massage chair; with heat and without heat respectively. Surface EMG recordings were taken for baseline, during Sensei massage mode without heat, post massage without heat, post Sensei massage with heat, and post massage with heat. The mean average value for EMG amplitudes were taken and compared. In eight out of ten subjects, the massage mode with heat yielded bigger EMG amplitude shift than that of without heat. The study also found that four out of ten subjects showed increased amplitude shift from baseline average EMG, reflecting muscle tension post massage session with heat. The study also found that six out of ten participants preferred having the massage with heat as compared to without heat. This is not statistically significant ($p > 0.005$).

ABSTRAK

Tekanan dan pergerakan berulang dari keadaan kerja yang tidak ergonomik adalah dua daripada sebab-sebab sakit leher dan bahu. Salah satu modaliti untuk rawatan sakit leher dan bahu adalah terapi urut. Ini memerlukan perkhidmatan ahli fisioterapi atau tukang urut yang mungkin tidak tersedia pada setiap masa. Untuk menampung permintaan ini, model baru kerusi urut automatik dengan fungsi dan mod yang lebih baik sedang diperkenalkan di pasaran. Kerusi urut OGAWA Master Drive adalah salah satu model yang menggabungkan haba atau 'thermotherapy' sebagai fungsi tambahan. Ini diharapkan dapat meniru tangan manusia sewaktu terapi urut dengan lebih baik. Kajian ini menilai kesan kerusi urut OGAWA Master Drive pada otot trapezius dengan menggunakan sensor electromyogram permukaan (EMG). Sepuluh subjek tanpa sakit leher dan bahu sebelumnya atau kecacatan telah diberi dua mod urutan Sensei kerusi urut OGAWA Master Drive; iaitu dengan haba dan tanpa haba. Rakaman EMG permukaan diambil untuk garis dasar, semasa mod urut Sensei tanpa haba, selepas urut tanpa haba, semasa urut Sensei dengan haba, dan selepas urut dengan haba. Purata amplitud EMG diambil dan dibandingkan. Dalam lapan daripada sepuluh subjek, mod urut dengan haba menghasilkan perbezaan amplitud EMG yang lebih besar daripada mod tanpa haba. Kajian ini juga mendapati bahawa empat dari sepuluh subjek menunjukkan perbezaan amplitud yang meningkat dari purata EMG asas, mencerminkan ketegangan otot selepas mod urutan dengan haba. Kajian ini juga mendapati enam daripada sepuluh peserta lebih cenderung memilih untuk mengurut dengan haba berbanding tanpa haba. Semua perbezaan ini tidak signifikan secara statistik ($p > 0.005$).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

EMG	Electromyogram
RMIT	Royal Melbourne Institute of Technology
SMFPQ	Short Form McGill Pain Questionnaire
PSFDM	Patient Specific Functional Disability Measure
CWT	Stroop color word test
TC	Standardized test contractions
MAV	Mean Absolute Value
RMS	Root Mean Square
LDF	Laser-Doppler flowmetry
MVC	Maximum voluntary contraction
EA	Electrical activity
MF	Median frequency
JASA	Joint analysis of electromyogram spectrum and amplitude
CD	Compact disc
RCT	Randomized control trial
MT	Massage therapy
ROM	Range of motion
USB	Universal Serial Bus
GND	Ground
BMI	Body Mass Index

CHAPTER 1: INTRODUCTION

1.1. Overview

Stress, in appropriate amount, can be a powerful stimulus necessary for physical, mental and emotional growth. However, when encountered in high repetitive doses it can be detrimental and even elicit persistent physical symptoms. This can lead to complaints such as headaches, gastric ulcers and musculoskeletal pain. Apart from stress, repetitive movement from work conditions also play a role in causing persistent neck and shoulder pain. One of the methods to alleviate such pain includes massage therapy and acupuncture. Despite limited findings in current literature, both massage therapy and acupuncture have been noted in anecdotes to relieve patients' perception of pain. While the technique for massage therapy has been passed down for generations, an evidence-based, medically certified protocol requires a trained physiotherapist or chiropractor with whom access may be limited for sufferers of chronic pain. Considering the need for faster, convenient and readily available option for massage therapies, innovations in massage chair technology are on the rise to meet the demand for massage equipment that can be used at home. Automated massage chairs technology using internal electric motors and gears have been introduced and improved upon since the mid-1950s. The equipment was designed such that they can mimic human hand-like motions involved in a conventional massage therapy. One such company forerunning the massage therapy market in Malaysia is OGAWA.

More recently, the latest model in their arsenal is the Master Drive 4D Thermocare that incorporates heat or thermotherapy in addition to their conventional massage modes. It combines acupuncture point detection, eastern medical knowledge and technology, as well as chiropractic massage techniques that is tailored to the user's body contour and needs. In this study, the effects of thermotherapy in one of the modes on OGAWA Master Drive massage chair on the trapezius muscle are studied and compared with the conventional mode without heat using the surface electromyogram (EMG) sensor. It is hypothesized that a negative baseline shift in surface electromyogram (EMG) value correlates with a degree of muscle relaxation whereas a positive baseline shift in surface electromyogram (EMG) values correlates with a degree of muscle tension.

1.2. Problem Statement

The lifetime prevalence of shoulder pain can be as high as 66.7% according to a study done by Luime et al (2004). To combat this, the demand for massage chair that can be used at home is on the rise. The efficacy of massage chair use for relieving muscle aches have mostly been recorded anecdotally. OGAWA Master Drive massage chair has incorporated thermotherapy as part of its function to further enhance muscle relaxation as this mode better mimics the human hand in delivering massage therapy. Thus far, studies correlating massage chair use and thermotherapy on relieving muscle strain has been very few. In this study, attempt to evaluate trapezius muscle activity is made using surface electromyogram (EMG) recording during the massage sessions.

1.3. Report Organization

This report is composed of five main chapters namely introduction, literature review, methodology, result and discussion as well as conclusion. The introduction opens with a brief discussion on muscle pain as stress response, massage therapy and the OGAWA Master Drive massage chair thermotherapy premise. This chapter also includes the problem statement and objective of the project. Next, the literature review chapter further expands into detailed information regarding massage therapy, the trapezius muscle, and surface electromyography (EMG) as a tool to evaluate muscle activity. The third chapter; methodology; describes the methods taken to execute the project as well as the equipment and tools utilized. Demographic information of subjects is also outlined in this chapter. This is followed by result and discussion which details the data acquired and the comprehensive analysis of the results. Subsequently, a summary of the project and a brief discussion of future work is reviewed in the last chapter conclusion.

1.4. Objective

The objective of this study is to evaluate the effects of thermotherapy and massage using OGAWA Master Drive massage chair in trapezius muscle activity.

1.5. Scope of the research

The sample for this project is taken by convenient sampling. Subjects' age is within the range of 20 - 30 years old. Only individuals who are relatively healthy with no previous history of chronic muscle illness and chronic shoulder pain were taken. In this experiment, a total of ten subjects are tested for their muscle activity after the massage therapy. Only surface electromyogram (EMG) was taken to evaluate subjects' muscle activity. Each subject had two massage therapy sessions and one baseline EMG recording with 5 minutes of rest in between during which post massage EMG were taken, thus yielding five sets of EMG data recorded per subject.

The trapezius muscle is the choice of muscle to be studied in this report due to it being easily accessible, due to its location (close to the surface of the body) and its relation to neck pain in psychosomatic stress. It is also noted to be one of the acupuncture points in complementary medicine. Only the left trapezius muscle was tested in this project.

CHAPTER 2: LITERATURE REVIEW

2.1 Muscle Pain and Stress

The stress response is essential in human survival, manifesting in a fight or flight response in the body. The American Psychology Association defines stress as any uncomfortable "emotional experience accompanied by predictable biochemical, physiological and behavioral changes". It starts with a stimulus that would trigger the autonomic nervous system as well as the hypothalamo-pituitary axis causing a host of physiological responses in a negative feedback loop. However, in conditions where the stimulus is persistent in chronic stress or disease, long term health conditions have been noted to occur, involving the gastrointestinal, immunology, cardiovascular, neurological system and even the psyche. Chronic stress occurs when acute stressors are improperly managed or ignored, as well as when a traumatic experience happens. The Australian Family Physician in its recommendation for the approach in managing patients with chronic stress has listed in its 2013 edition the external and internal modes of combating stress. The list was taken from Professor Mark Cohen from the RMIT University Health Innovations Research Institute and includes pharmacotherapy, massage, aromatherapy, music therapy and acupuncture as external modes of management.

Wahlstrom et al (2003) found that muscle activity as reflected in EMG measurement is linked to physical, social and psychological factors. They discovered that perceived muscle tension is related to EMG recording of muscle activity. This extended Theorell et al's (1999) earlier report in which it was found that perceived muscle tension was linked with symptoms on the back, neck and shoulders. Patients with neck and shoulder symptoms were also found to have a tendency for somatization and mental pathology (Sarquis et al 2016).

2.2 The Trapezius Muscle

The trapezius muscle is a superficial skeletal muscle of the shoulder and neck. It is a paired muscle forming a trapezoid over the posterior region of the neck and thorax. The muscle's origins are from the occipital bone and along the spinous processes of the 7^{th} cervical vertebra to the 12^{th} thoracic vertebra. The muscle then inserts into the spine of the scapula, the acromion process and the clavicle. It is innervated by axillary nerve for its motor function and the anterior rami of the anterior rami of spinal nerves C3 to C4 for sensation. The trapezius muscle helps to move the scapula, allowing the arm to be raised above the level of the shoulder.

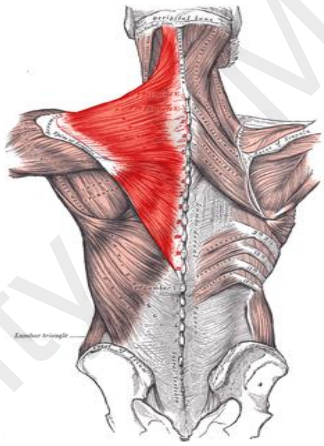

Figure 2.1: The trapezius muscle (Häggström, 2014)

The lower portion of the trapezius muscle is often subjected to frequent loading in support of the shoulder joint (Bateman, 1987). One of the causes of neck and shoulder pain is repetitive work due to the persistent exertion over long periods of time for low intensity load (Westgaard, 1988). This results in increased rate of fatigue (Hagberg, 1984) and low elevation strength of the muscle (Bjelle et al, 1981). In occupational muscle disorders, this is caused by ischemia due to repeated temporary hypoxia and reduced muscle oxygenation from reduced blood flow.

Shoulder pain is a peripheral joint disorder that has high prevalence in the general population; reaching up to 20% (Pope et al 1997). Neck and shoulder pain or stiffness can affect performance efficiency apart from rendering the sufferers less productive. Several reported cases of neck and shoulder pain have high degree of chronicity, remaining persistent over time without improvement, or keep recurring (Austin et al 2016). As the illness persists over time, the prognosis becomes poorer (Bot et al 2005). According to a survey by Van der Widt in 1995, more than 50% of the patients diagnosed with shoulder and neck pain received physical therapy; primarily massage therapy.

2.3 Massage Therapy

Delaney et al (2002) studied the effects of massage therapy such as the myofascial trigger- point massage therapy on the body's autonomic functions. It was found that following the massage, subjects' heart rate as well as blood pressure significantly reduced. The same author found rise in parasympathetic activity alongside great improvement of the subject's emotional state and muscular tension. The same result was reported by Kaye AD et al (2008) with deep tissue massage therapy and reduced blood pressure. Van den Doder et al (2003) published a randomized control trial studying the effects of soft tissue massage in treating shoulder pain. They found great improvements on abduction, flexion and hand-behind-back movement of the shoulder following the intervention. Soft tissue massage was also discovered to be an effective method to reduce pain.

Zullino et al (2005) published a pilot study investigating effect of massage by an automated massage chair on ten healthy volunteers and their back muscles. They evaluated the effects of three different modes of the automated massage chair on the tension of other muscles. The gastrocnemius surface EMG was taken as a measure of general level of tension in the study. Different types of massage which are roll-stretch massage, beat massage and shiatsu massage were given at random order to the subjects. The gastrocnemius EMG was found to have changes reflecting possible reduction of muscle tension after roll-stretch massage and shiatsu massage.

A review done by Ling et al (2013) compared twelve studies on the efficacy of massage therapy in combating neck and shoulder pain. However, massage therapy was shown to only be beneficial when compared to non-active measures (no treatment done). Massage therapy was also not shown to affect the functional status of patients. It should be noted that the randomized control studies compared only considered patients' pain perception and did not explore the effects of massage therapy on muscle activity or electromyogram recording.

2.5 Thermotherapy

Thermotherapy has long been in use in the form of warm compress and hot packs, among others. Previous studies have shown inconclusive evidence of the efficiency of thermotherapy on combating pain. Welch et al (2002) in a review found no significant effect of the application hot packs on pain areas or on functional status on patients suffering from rheumatoid arthritis. This is despite thermotherapy being one of the conventional treatments for pain for this pathology due to its chronicity. It was, however, found to be relatively safe. It should be noted that this review only investigated the effects on joints rather than muscle.

Sakaguchi et al (2010) published a pilot study investigating muscle disuse atrophy and thermotherapy. Wistar rats were used to form a fixed maximum plantar flexion of the ankle joint. They were then subjected to fixation, conventional modes of treadmill and neuromuscular electrical stimulation without heat, as well as with thermal component. From the findings of this study, disuse muscle atrophy in the rats with thermal treadmill running was slowed down. This can indicate some benefit of combining thermotherapy with other activities in those with musculoskeletal abnormalities in preventing early disuse atrophy. This combination is as offered by the new function in OGAWA Master Drive massage chair.

The massage chair also provides the option for self-treatment with thermotherapy at home. Cramera et al (2012) investigated the effect of self-administered thermotherapy using hot mudpacks found that it was effective in reducing pain sensation in patients with long-standing neck pain from mechanical causes. This was evident from significant reduction of pain intensity and as recorded in subjects' pain diary. This study did not explore the muscle effect of thermotherapy.

In another study by Lee et al (2011), 139 subjects were subjected to daily heat and massage for 40 minutes performed by Ceragem M3500 (CERAGEM Co. Ltd., Cheonan, Korea) which is a bed installed with heat generating rolling jades for 5 days a week for 14 consecutive days. The subjects' serum cortisol was found to decrease at the end of 14 days. Subject's norepinephrine levels were also found to be decreased. Heart rate increased after 2 weeks. There were no complications noted in response to the device such as burns or other adverse occurrences.

Although this study provides a promising result on the autonomic parameters of subjects following heat application with massage by an equipment like the OGAWA Master Drive massage chair, there is a large gap of knowledge for its effect on muscle activity as assessed by EMG, providing an opportunity for this report to contribute to the current lack in data.

2.6 Electromyograph (EMG)

When muscles contract, the movement of ions across the calcium and sodium channels along the muscle causes an action-potential that propagates along a muscle fiber. This is observed as electrical activity as it spreads from muscle to skin. There are two ways with which the myoelectric activity can be detected; surface electromyography and an invasive EMG in which the electrodes are placed within the muscle. Surface electromyography is a noninvasive method of analyzing this activity as a group of muscle fibers contract. The action potentials are fired randomly, eliciting readings that can be either a positive value or a negative value. The voltage of integrated EMG values depends on the aggregated action potentials, noise from tissue and amplifier as well as electrical conductance of skin on which the electrodes are placed (Fridlund et al, 1982). There is no accurate way to measure EMG for individuals as it varies according to neural density, thickness of fatty layer and muscle size.

However, according to Hibbs et al (2011), the average amplitude of EMG can reflect the overall amplitude during a certain movement. Several studies have shown that the Mean Absolute Value (MAV) of EMG amplitude do increase with muscle fatigue (Viitasolo and Komi, 1977) (Cifrek et al, 2009). This implies that muscle fatigue is related to muscle tension. This principle is used for biofeedback training as a treatment method for reducing muscle tension in patients with chronic anxiety (LeBouf and Lodge, 1980).

2.6.1 EMG for Trapezius Muscle

Lundberg et al (1994) investigated mental stress and its effect on physical load, perceived stress, physiological responses to stress and muscle tension. Muscle tension is evaluated using electromyogram recording of the trapezius muscle activity. In this study, sixty-two female subjects were given stressors in the form of mental arithmetic, the cold pressor test, standardized test contractions, the Stroop color word test and the combination of the last two tests. They found that the stress induced significant increase in subjects' blood pressure, salivary cortisol, urine catecholamine, pulse rate and self-reported stress. Each stress also caused increase of EMG activity, consistent with the assumption that muscular tension can occur in psychological stress even without physical load.

Larsson et al in the Journal Pain (1999) expanded this and studied the alterations in trapezius muscle perfusion and EMG activity in chronic neck pain in patients with established trapezius myalgia. This study included 20 healthy women as control group. Laser-Doppler flowmetry (LDF) were compared with surface EMG while subjects underwent a series of contractions that increased with each alternating between 1 min of contraction and rest. The EMG was noted to be elevated on the painful side, reflecting consistent low regional perfusion of the affected side. The EMG mean power frequency, however, was unchanged. It should be noted that this study had small sample size and did not elaborate on the specific times at which the EMG readings were taken. The neck pain was also induced rather than taking a sample from patients with pre-existing trapezius myalgia. There was also no mention of the difference between baseline EMG and post contraction EMG.

Luo and Chang (2011) investigated the effectiveness of grasp-kneading massage by a multi-finger robot hand in relieving muscle fatigue. This was done by first inducing muscle fatigue after subjecting the participant's back muscles to a 90 seconds isometric 50% maximum voluntary contraction. The treatment by the robot hand was subsequently administered. Electrical activity (EA) of the EMG was found to increase in this study, and median frequency (MF) decreased post therapy. This indicates the efficiency of the therapy which was verified by the joint analysis of EMG spectrum and amplitude (JASA).

2.7 Summary

Table 2.1: Summary of Literature Review

	Research title	Aim of the study	Methodology	Results	Pros	Cons	Contributors
1	"The short- term effects of myofascial trigger point massage therapy on cardiac autonomic tone in healthy subjects" (Delaney, J. P. A., Leong, K. S., Watkins, A. & Brodie, A., 2002)	To investigate the effects of myofascial trigger- point massage therapy to the head, neck and shoulder areas on cardiac autonomic tone.	5- minute cardiac recording, blood pressure and subjective self- evaluations of muscle tension and emotional state before and after myofascial trigger point massage in 30 healthy subjects.	Significant decrease in heart rate and blood pressure and increased in parasympathetic activity. Improved muscle tension and emotional state.	Suggests benefit of massage therapy on autonomic responses in healthy subjects	No EMG analysis, did not investigate effect on skeletal muscle	Delaney, J. P. A., Leong, K. S., Watkins, A. & Brodie, A. (2002)
2	"A trial into the effectiveness	To investigate the effects of soft tissue massage	Random treatments of soft tissue massage around the shoulder to	Range of motion for abduction, flexion and	Explores the benefits of soft tissue	No EMG assessed, small sample	van den Dolder P. A. & Roberts D.

	of soft tissue massage in the treatment of shoulder pain" (van den Dolder P. A. & Roberts D. L. 2003)	on range of motion, reported pain and reported function in patients with shoulder pain.	patients with pre-existing shoulder pain. The other fourteen patients in control received no treatment. Flexion, hand-behind-back movements and abduction were assessed from range of motion. Pain was assessed via Short Form McGill Pain Questionnaire (SFMPQ) and Patient Specific Functional Disability Measure (PSFDM) assesses functional ability.	hand-behind-back improved. Pain is reduced based on the SFMPQ and on the visual analogue scale. Function on the PSFDM also improved.	massage in shoulder pain	size	L. (2003)
3	"The effect of deep -tissue massage therapy on blood pressure and heart rate" (Kaye, A. D. et al, 2008)	To describe the effects of deep tissue massage on systolic, diastolic, and mean arterial blood pressure	Overall muscle spasm/muscle strain was categorized as either moderate or severe for each patient and assessed for baseline and after intervention. Blood pressure and heart rate also taken for all 263 subjects. Deep tissue massage was performed with 21 soothing CDs	Blood pressure, mean arterial pressure and average heart rate all reduced.	Demonstrates the beneficial effect if deep-tissue massage therapy on blood pressure and heart rate	Does not explore muscle effect or EMG reading	Kaye, A. D., Kaye, A. .J, Swinford, J., Baluch, A., Bawcom, B. A., Lambert, T. J. & Hoover, J. M. (2008)

			playing for 45 to 60 minutes in duration.				
4	"Massage therapy for neck and shoulder pain: A systematic review and meta-analysis" (Ling, J. K. et al, 2013)	To evaluate the effectiveness of massage therapy for neck and shoulder pain	Randomized controlled trials (RCTs) of massage therapy for neck and shoulder pain were searched and picked from 7 different databases in English and Chinese. The meta-analyses of MT for neck and shoulder pain were performed.	12 RCTs were identified and analyzed.Massage therapy can be effective when compared to no therapy. Evidence of short term effect of massage therapy also discovered. However, effects are not as good as other active therapies. Functional status is not affected by massage therapy.	Only considered high quality studies	Did not subdivide into types of massage therapies, modalities of assessment were not specified to EMG	Ling, J. K., Hong, S. Z., Ying, W. C., Wei, A. Y., Bo Chen & Min Fang (2013)
5	"Local back massage with an automated massage chair: general muscle and psychophysiol	To test massage applied with an automated massage chair on the back muscles with regard to the effects on the	10 healthy volunteers underwent three different massage programs alternating with rest periods. The frontalis (for affective state) and gastrocnemius (for general muscle	Participants preferred shiatsu and roll-stretch massage. Similar frontal EMG reading for all conditions. The gastrocnemius	Uses EMG recording, analyzes relation with automated massage chair, most similar to	Small sample size, uses gastrocnemius muscle, however EMG data analysis was not clearly	Zullino, D. F., Krenz, S., Emanuelle, F., Cancela, E. & Khazaal, Y. (2005)

	ogic relaxing properties" (Zullino et al, 2005)	tension of other muscles or on the neurovegetative tone, and to compare three different automated massage techniques	tension) electromyogram (EMG) activity were taken and compared.	EMG showed changes in roll-stretch massage, and shiatsu massage.	current study	explained	
6	"Thermotherapy for treating rheumatoid arthritis" (Welch et al, 2002)	To evaluate the effectiveness of different thermotherapy applications on disease activity in patients with rheumatoid arthritis	EMBASE, Pedro, MEDLINE, Current Contents, Sports Discus, CINAHL ,The Cochrane Field of Rehabilitation and Related Therapies, and the Cochrane Musculoskeletal Review Group were searched until September 2001.	7 studies were selected. Hot pack and ice pack had no effects on joint swelling, range of motion (ROM), pain, disease pattern, medication consumption, strength or function. Patient preference was insignificant for all thermotherapy.	Studied effect of heat on joint pain and range of motion	Only reviewed on rheumatoid arthritis which is a joint condition and not muscle, did not compare on different types of thermotherapy	Welch, V,. Brosseau, L., Casimiro, L., Judd, M., Shea, B., Tugwell, P. & Wells, G. A. (2002)

7	"Inhibitory effect of a combination of thermotherapy with exercise therapy on progression of muscle atrophy" (Sakaguchi, A., Ookawara, T., Shimada, T., 2010)	To investigate the inhibitory effect of a short-term thermal load in combination with treadmill running or neuromuscular electrical stimulation on the progression of disuse muscle atrophy and its causative mechanism	Using Wistar rats with fixed at maximum plantar flexion of the ankle joint. The rats were divided and given different types of intervention: control, fixation, treadmill running, neuromuscular electrical stimulation, as well as the last two intervention methods with heat.	Disuse muscle atrophy was slowed down only in the group given treadmill running with thermal load.	Reflects some benefit of thermothera py	Studies on animals and not humans. Studied on diseased limb and not normal limb. No EMG measurement recorded	Sakaguchi, A., Ookawara, T. & Shimada, T. (2010)

8	"The effects of heat and massage application on autonomic nervous system" (Lee, Y. H., Park, B. N. R. & Kim, S. H., 2011)	The objective of this study is to evaluate the effects of heat and massage application on autonomic nervous system.	Heat and massage was given to 139 subjects every day for 40 minutes, 5 days a week for 14 days. Heart rate changes, sympathetic system skin response, serum cortisol and norepinephrine levels were measured and compared.	Reduction in serum cortisol levels were noted. Plasma norepinephrine also reduced. Heart rate was noted to be increased. Results suggest that heat combined with massage therapy provide autonomic relaxation and is safe.	Uses massage chair as modality to deliver heat and massage	No EMG comparison	Lee, Y. H., Park, B. N. R. & Kim, S. H (2011)
9	"Thermothera py self-treatment for neck pain relief—A randomized controlled trial" (Cramera et al, 2012)	To evaluate the potential of thermotherapy self-treatment in relieving pain and improving sensory function in patients with chronic mechanical neck pain.	Treatment group of patients with neck pain were given mud heat pack to be used daily for 14 days. The control group was not treated. Intensity of neck pain intensity was recorded after 2 weeks. Subjects were also given pain diary, quality of life assessment and functional disability.	Treatment group showed improved pain intensity and pain diary. Results suggest thermotherapy self-treatment can help reduce pain sensation and improve sensory function of patients.	Promising result on role of thermothera py as self-treatme nt	No EMG assessment	Cramera, H., Baumgarten, C., Choi, K. E., Lauche, R., Saha, F. J., Musial, F. & Dobos, G. (2012)

10	"Psychophysiological stress and EMG activity of the trapezius muscle." (Lundberg et al, 1994)	To examine the effects of mental stress as well as of physical load, separately and in combination, on perceived stress, physiological stress responses, and on muscular tension as reflected in electromyographical (EMG) activity of the trapezius muscle	62 female subjects were given stressors in the form of mental arithmetic, the cold pressor test, standardized test contractions, the Stroop color word test and the combination of the last two tests	They found that the stress induced significant increase in subjects' blood pressure, salivary cortisol, urine catecholamine, pulse rate and self-reported stress. Each stress also caused increase of EMG activity, consistent with the assumption that muscular tension can occur in psychological stress even without physical load.	Shows that stress can cause significant EMG activity in healthy individuals	Does not explore treatment options and effect on EMG	Lundberg, U., Kadefors, R., Melin, B., Palmerud, G., Hassmen, P., Engstrom, M. & Dohns, I. E. (1994)
11	"Changes of trapezius muscle blood flow and electromyography in chronic	To investigate the single-fibre technique for clinical determination of the	76 patients suffering from chronic trapezius myalgia and 20 healthy women were taken. Laser-Doppler flowmetry (LDF) were	The EMG was noted to be elevated on the painful side, reflecting consistent low	Describes the physiological and EMG changes in the trapezius	Does not investigate treatment options and changes on the EMG	Larsson, R. I., Oberg, P. A. & Larsson, S. E. (1999)

	neck pain due to trapezius myalgia." (Larsson, R. I., Oberg, P. A. & Larsson, S. E., 1999)	microcirculation (LDF) in the trapezius muscles in relation to electromyography (EMG)	compared with surface EMG of left and right trapezius muscles while subjects underwent a series of contractions that increased with each alternating between 1 min of contraction and rest	regional perfusion of the affected side. The EMG mean power frequency, however, was unchanged.	muscle in trapezius myalgia	activity	
12	"Electromyographic evaluation of therapeutic massage effect using multi-finger robot hand" (Luo, R. C. & Chang C, C., 2011)	To evaluate surface electromyographic (EMG) of therapeutic massage effects using multi-finger robot hand	inducing muscle fatigue after subjecting the participant's back muscles to a 90 seconds isometric 50% maximum voluntary contraction. The treatment by the robot hand was subsequently administered. EMG reading was taken for comparison.	Electrical activity (EA) of the EMG was found to increase in this study, and median frequency (MF) decreased post therapy. This indicates the efficiency of the therapy which was verified by the joint analysis of EMG spectrum and amplitude (JASA)	Compares human hand delivered massage therapy and automated robot hand delivered	Does not test thermotherapy	Luo, R. C. & Chang C. C. (2011)

CHAPTER 3: METHODOLOGY

3.1. Introduction

This chapter describes the device used to measure the EMG signal, the muscle being tested, the massage modes used for the project, the Likert scale as a measure for participant satisfaction as well as the number and salient details of participants.

3.2. Technical Specification

3.2.1. Overview

The EMG sensor was built using the following components: an Arduino MEGA, Arduino USB cable, a computer to read values, the muscle sensor board, connecting cables, EMG disposable gel surface electrodes, two 9V batteries and connecting wires.

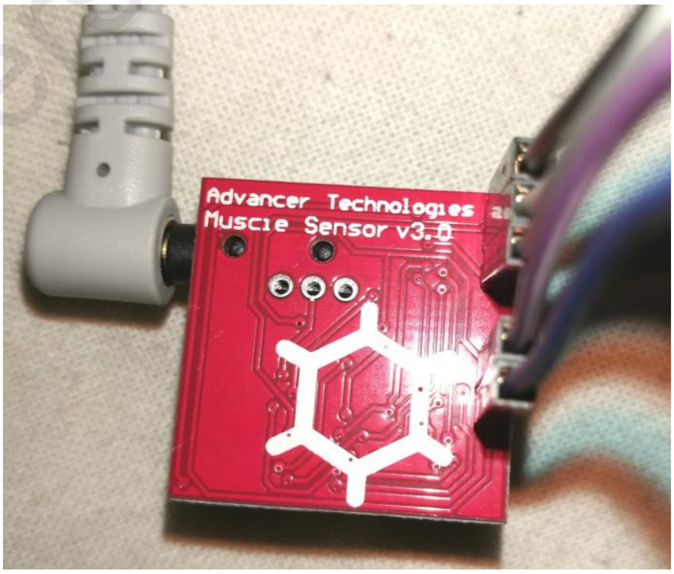

Figure 3.1: EMG sensor board

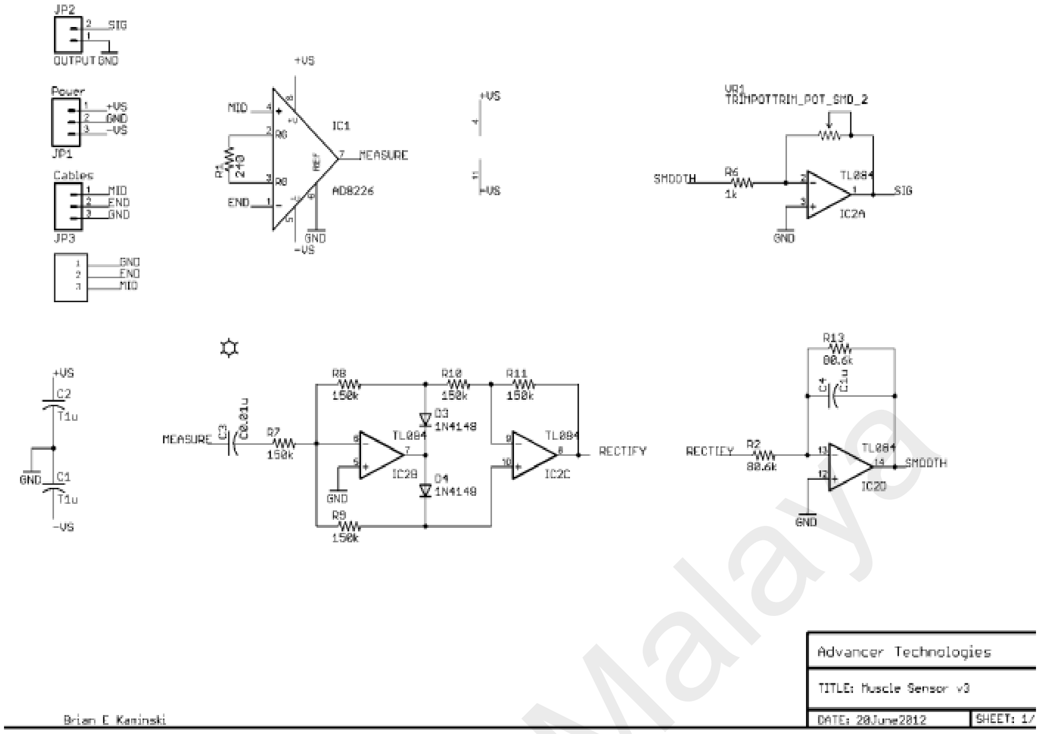

Figure 3.2: Circuit schematic of Advancer Technologies muscle sensor version 3 (Kaminski 2012)

The Advancer Technologies muscle sensor version 3 is used for this study which acts to measure, filter, rectify and amplify the electrical activity of target muscle. It produces analog output signal that can be read by a microcontroller with any analog-to-digital converter, in this case, the Arduino MEGA.

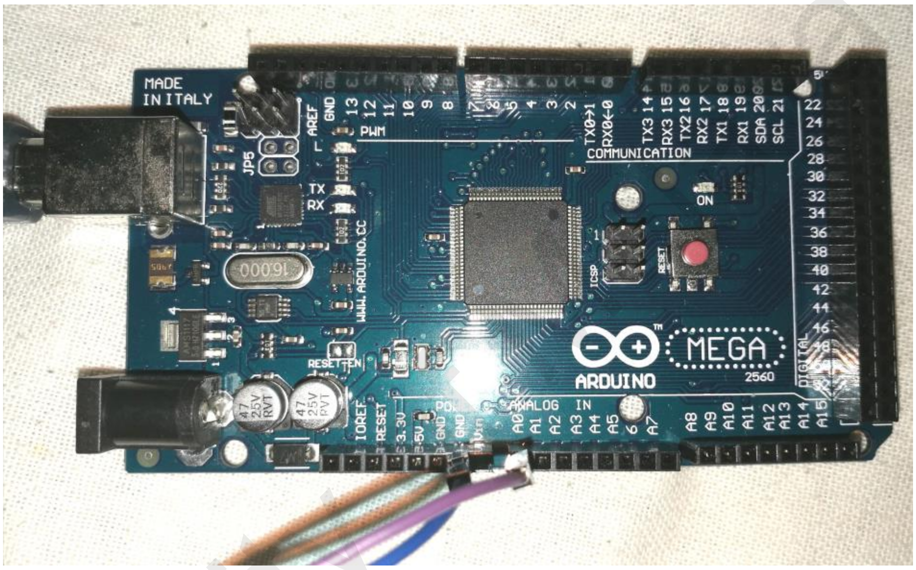

Figure 3.3: Arduino MEGA processor

In setting up the sensor, the EMG sensor board was connected to the power supply (two 9V batteries) by attaching the positive terminal of the first 9V battery to the +Vs pin on EMG sensor and the negative terminal of the first 9V battery to the positive terminal of the second 9V battery. These were then connected to the GND pin on EMG sensor. The negative terminal of the second 9V battery was then connected to the –Vs pin of the EMG sensor board. The components were connected as per diagram below.

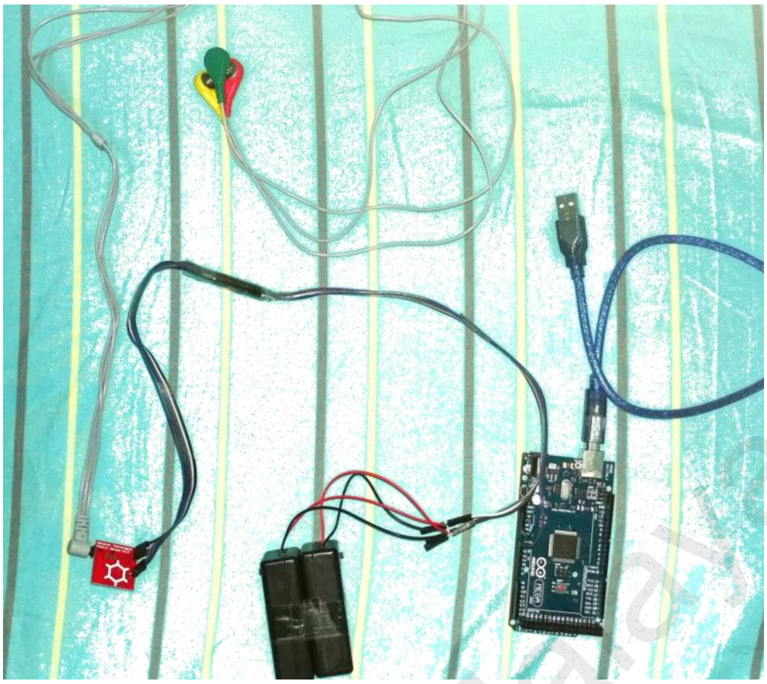

Figure 3.4: EMG sensor circuit connection

3.2.2. Electrode placement and skin preparation

The electrodes were first connected to the EMG sensor board. After determining the trapezius muscle target on the left shoulder, the skin was cleaned thoroughly. The red electrode was placed in the middle of the trapezius muscle body. The yellow electrode was attached to one end of the trapezius muscle body near the muscle attachment to the cervical vertebrae. The third electrode was placed on the vertebra prominens at the C7 spinous process, which is a bony prominence near the targeted trapezius muscle. The electrodes were placed as depicted in the diagram below.

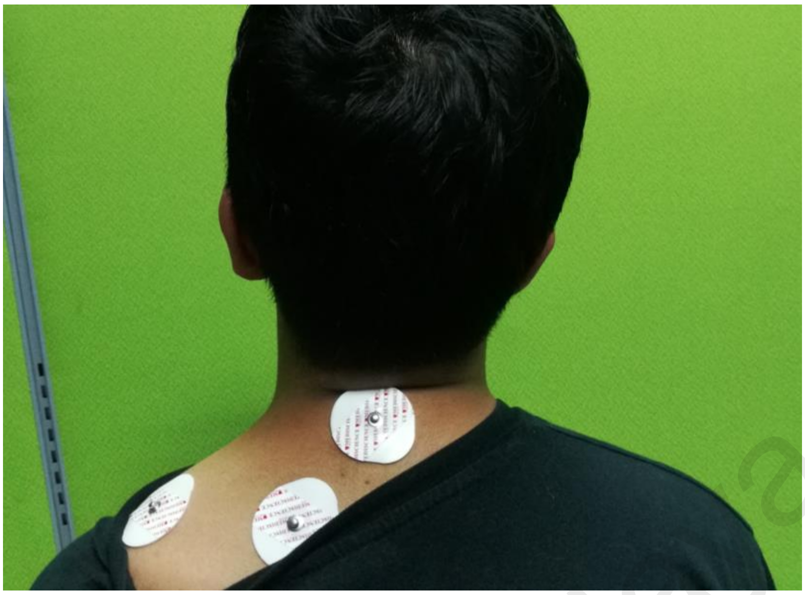

Figure 3.5: EMG leads and placement on skin

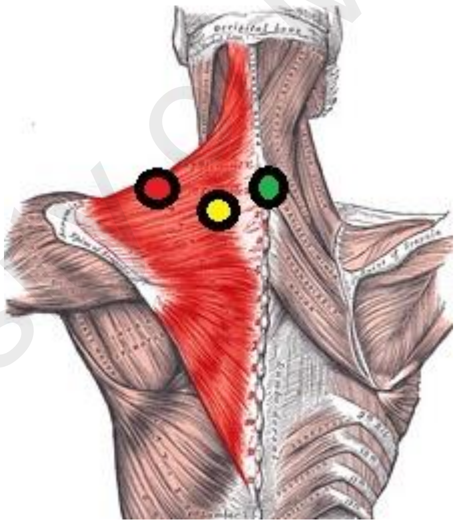

Figure 3.6: EMG electrodes and placement with respect to trapezius muscle

(Haggstrom, Mikael 2014)

3.2.3 OGAWA Master Drive

The OGAWA Master Drive massage chair boasts a state-of-the-art massage technology the body's landmarks using the M.5 Gen Microprocessor; enabling massage therapy with strength and function that is tailored to the user. The extended 1.35 M Sensing L-Track claims to deliver the most optimum spine care, especially tailored through the Sensei mode shoulder and back massage. Participants were subjected to 15 minutes of Sensei mode back and shoulder massage session without heat followed by another 15 minutes session with heat for comparison.

Figure 3.7: OGAWA Master Drive massage chair

Figure 3.8: OGAWA Master Drive massage chair massage modes on touchscreen controller

Figure 3.9: OGAWA Master Drive massage chair Sensei massage mode without heat

3.2.4: Likert scale for participant satisfaction

Post 15 minutes massage session without heat, the participants were given a Likert scale adapted to objectively assess the participants' satisfaction. After that, they were subjected to 15 more minutes of massage session using Sensei mode with heat. This was also followed by a similar Likert scale for participants' satisfaction.

<u>Participant Satisfaction Questionnaire:</u>

After experiencing the Sensei Mode without heat on OGAWA Master Drive massage chair, how would you rate your massage session?

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neither Satisfied or Dissatisfied	Satisfied	Very Satisfied

After experiencing the Sensei Mode with heat on OGAWA Master Drive massage chair, how would you rate your massage session?

1	2	3	4	5
Very Dissatisfied	Dissatisfied	Neither Satisfied or Dissatisfied	Satisfied	Very Satisfied

Which mode do you think is better?

a) OGAWA Master Drive massage chair Sensei mode without heat

b) OGAWA Master Drive massage chair Sensei mode with heat

c) Both are equal

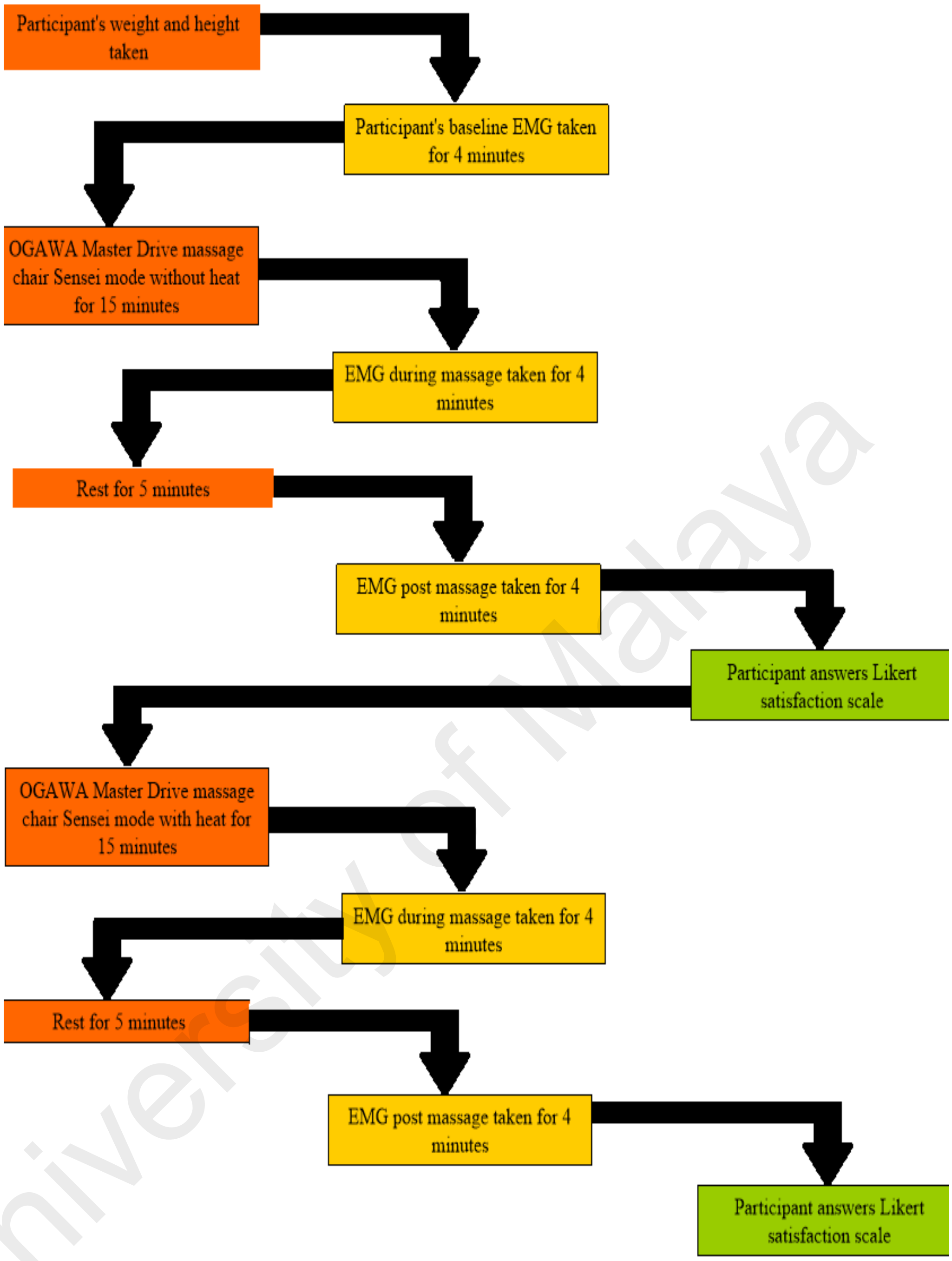

Figure 3.10: Flowchart for project methodology

3.3. Demographic data

3.3.1. Subjects

Table 3.2 Subjects' measurements and details

Subjects	**Gender**	**Age**	**Weight (kg)**	**Height (cm)**	**Body Mass Index/BMI (kg/m²)**
Subject 1	Female	27	43	154	18.1312
Subject 2	Female	26	56	158	22.4323
Subject 3	Female	25	60	154	25.2994
Subject 4	Male	26	84	176	27.1178
Subject 5	Female	27	58	154	24.4560
Subject 6	Male	28	78	170	26.9896
Subject 7	Male	30	90	176	29.0548
Subject 8	Female	28	50	158	20.0288
Subject 9	Female	23	50	153	21.3593
Subject 10	Male	20	53	168	18.7783

3.4 Data collection and statistical analysis

The digital reading collected from the Arduino serial monitor were captured and tabulated on Microsoft Excel 365. The mean absolute value (MAV) for each EMG set were calculated using the formula below and is used to determine muscle fatigue, or tension.

$$\text{MAV} = \frac{1}{N}\sum_{i=1}^{N}|x_i|$$

Where x_i is the $_i$th sample of a signal whereas N is the number of samples. This, together with the graphs of muscle activity over time (4 minutes or 240seconds), were generated by Microsoft Excel. The values were taken for statistical analysis using IBM SPSS Statistics version 20. The mean for participants' baseline EMG and post massage EMG were compared using paired t-test. Results of $p < 0.05$ were accepted as significant.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Muscle activity

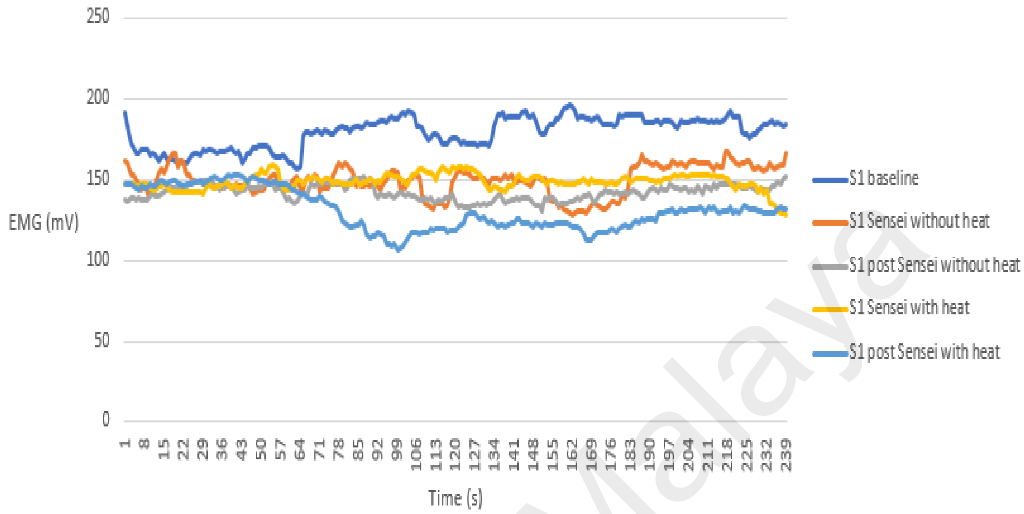

Figure 4.1: Graph of EMG activity over time for subject 1 during various activities

Table 4.1: Mean Absolute Value of EMG amplitude for subject 1 during various activities

Pre-massage baseline MAV	179.5125 mV
Sensei without heat MAV	149.9125 mV
Post Sensei without heat MAV	142.4167 mV
Sensei with heat MAV	148.9375 mV
Post Sensei with heat MAV	130.9875 mV

Subject 1 depicts the expected result as was referred to in literature; that is the MAV for EMG recording pre-massage was reduced from 179.5125mV to 142.4167mV after the subject had undergone a massage session without heat. This indicates that there is reduced muscle tension after the massage therapy; similar to studies by Viitasolo et al (1977) and Cifrek et al (2009). Further reduction of MAV was noted after the massage session with heat to 130.9875mV indicating better effect seen when thermotherapy is incorporated.

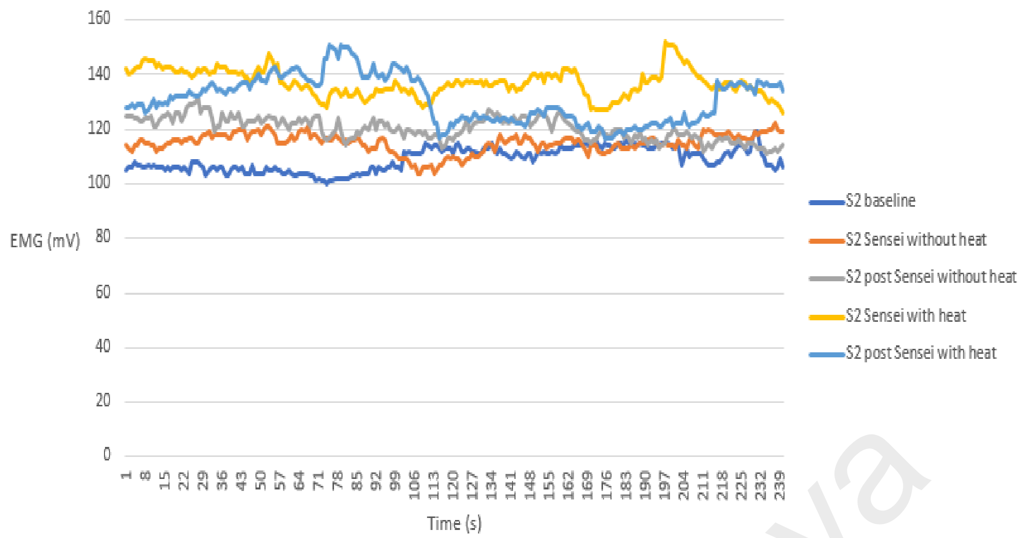

Figure 4.2: Graph of EMG activity over time for subject 2 during various activities

Table 4.2: Mean Absolute Value of EMG amplitude for subject 2 during various activities

Pre-massage baseline MAV	109.0208 mV
Sensei without heat MAV	114.8917 mV
Post Sensei without heat MAV	120.25 mV
Sensei with heat MAV	137.075 mV
Post Sensei with heat MAV	130.9083 mV

Subject 2, on the other hand, depicted a different finding. The subject's EMG MAV after massage without heat was increased from 109.0208mV to 120.25mV, signifying a degree of increased muscle tension. The EMG MAV then further increased to 130.90803 mV indicating more muscle tension. This increase can either be due to force acting on the trapezius muscle as the subject was not entirely relaxed during EMG recording, or due to muscle fatigue which can also happen after a massage therapy.

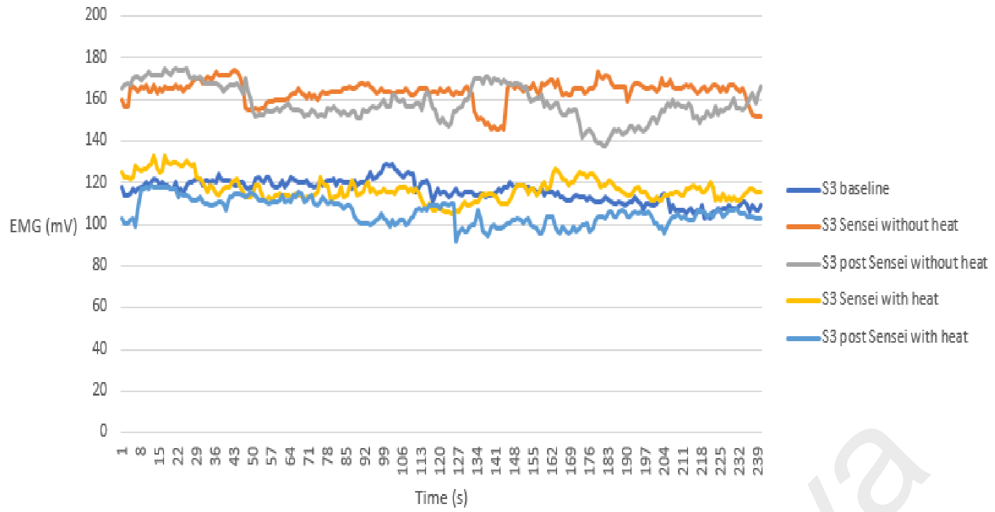

Figure 4.3: Graph of EMG activity over time for subject 3 during various activities

Table 4.3: Mean Absolute Value of EMG amplitude for subject 3 during various activities

Pre-massage baseline MAV	116.0792 mV
Sensei without heat MAV	163.8292 mV
Post Sensei without heat MAV	158.3083 mV
Sensei with heat MAV	116.9917 mV
Post Sensei with heat MAV	105.9708 mV

The MAV EMG for subject 3 is altogether different from both subjects 1 and 2. In subject 3, the MAV EMG increased from 116.0792mV pre-massage to 158.3083mV post massage without heat. The MAV EMG then decreased to 105.9708mV post massage with heat. This indicates that there was a degree of increased muscle tension for subject 3 after massage without heat. The muscle tension then reduced to below initial MAV level after massage with heat, indicating that for subject 3 the massage session with thermotherapy fares better than massage therapy alone.

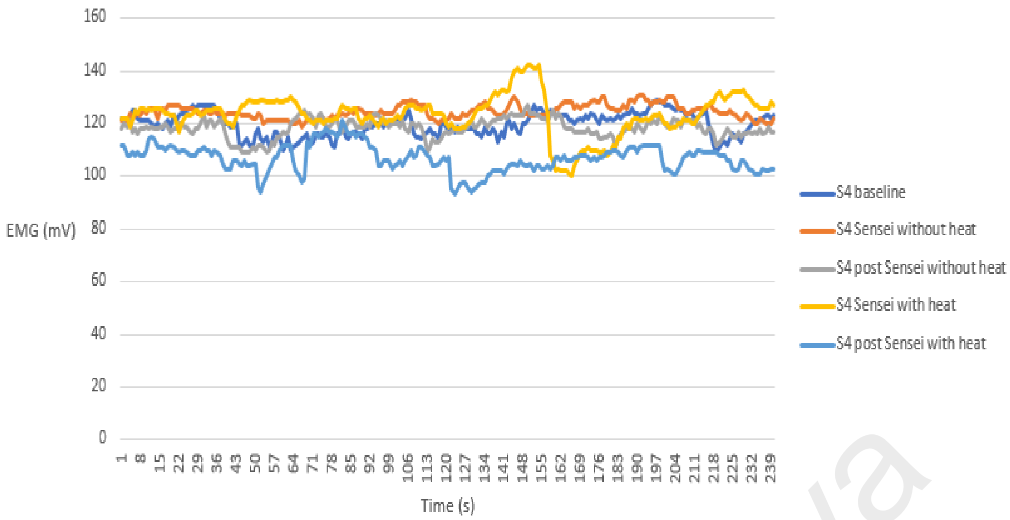

Figure 4.4: Graph of EMG activity over time for subject 4 during various activities

Table 4.4: Mean Absolute Value of EMG amplitude for subject 4 during various activities

Pre-massage baseline MAV	119.65 mV
Sensei without heat MAV	124.5708 mV
Post Sensei without heat MAV	118.3583 mV
Sensei with heat MAV	123.375 mV
Post Sensei with heat MAV	106.9375 mV

For subject 4, the EMG MAV showed very small difference from 119.65mV pre-massage to 118.3583mV post massage without heat. The value then reduced to 106.9375mV post massage with heat. For subject 4, only small differences were seen in terms of reduced muscle tension.

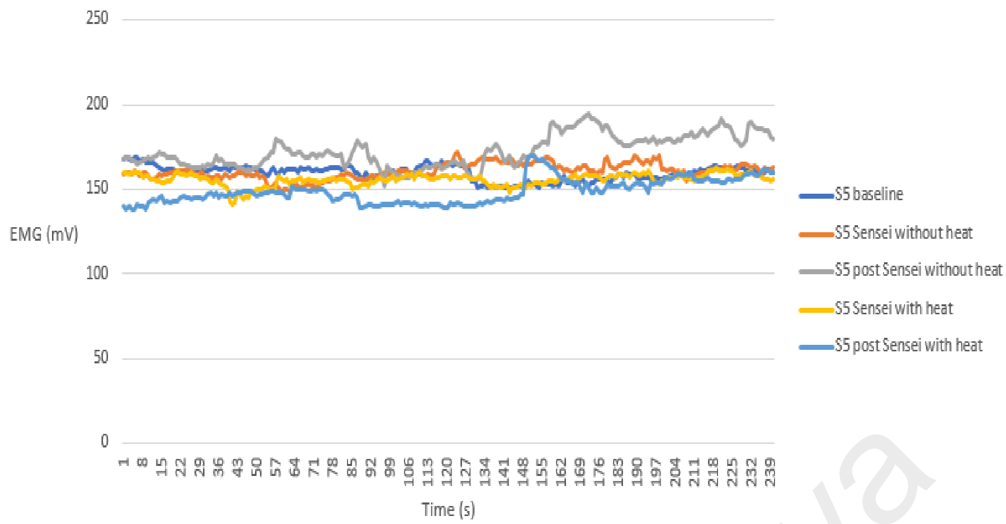

Figure 4.5: Graph of EMG activity over time for subject 5 during various activities

Table 4.5: Mean Absolute Value of EMG amplitude for subject 5 during various activities

Pre-massage baseline MAV	159.7125 mV
Sensei without heat MAV	160.8292 mV
Post Sensei without heat MAV	172.8625 mV
Sensei with heat MAV	155.758 mV
Post Sensei with heat MAV	148.7667 mV

The value for EMG MAV of subject 5 followed the same pattern as subject 3. The EMG MAV post massage without heat raised from 159.7125mV to 172.8625mV post massage without heat. Then, the EMG MAV decreased to 148.7667mV indicating reduced muscle tension when thermotherapy is combined with conventional massage mode.

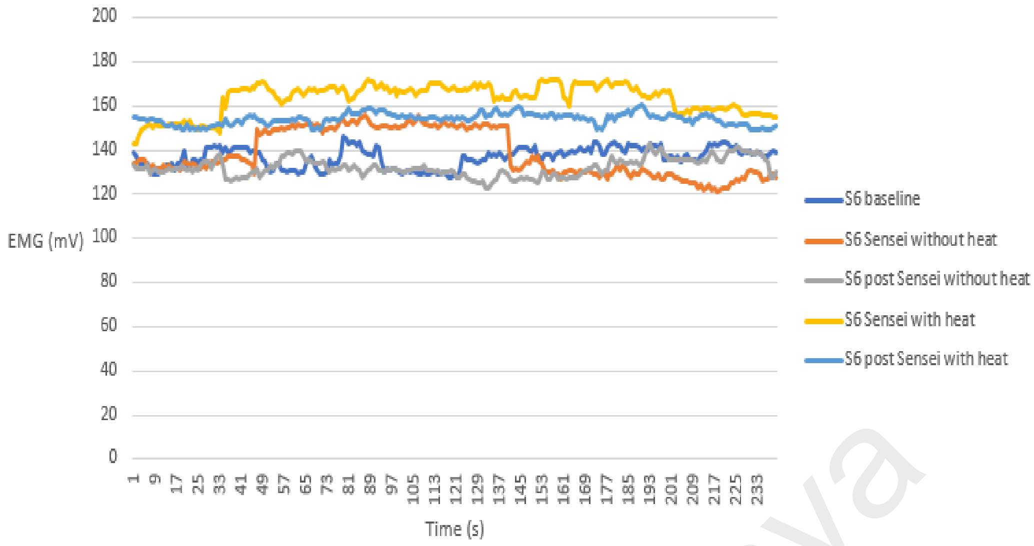

Figure 4.6: Graph of EMG activity over time for subject 6 during various activities

Table 4.6: Mean Absolute Value of EMG amplitude for subject 6 during various activities

Pre-massage baseline MAV	136.7958 mV
Sensei without heat MAV	138.4625 mV
Post Sensei without heat MAV	132.2792 mV
Sensei with heat MAV	163.4542 mV
Post Sensei with heat MAV	154.1208 mV

For Subject 6, there was initial decrease from pre-massage EMG MAV of 136.7958mV to 132.2792mV post massage without heat, indicating reduced muscle tension. However, when thermotherapy was incorporated, the EMG MAV increased to 154.1208mV. This indicates that for subject 6, massage therapy with heat contributes to more muscle tension or muscle fatigue. This can also be due to the subject being unfamiliar with the sensation due to the heat, thus not properly relaxed.

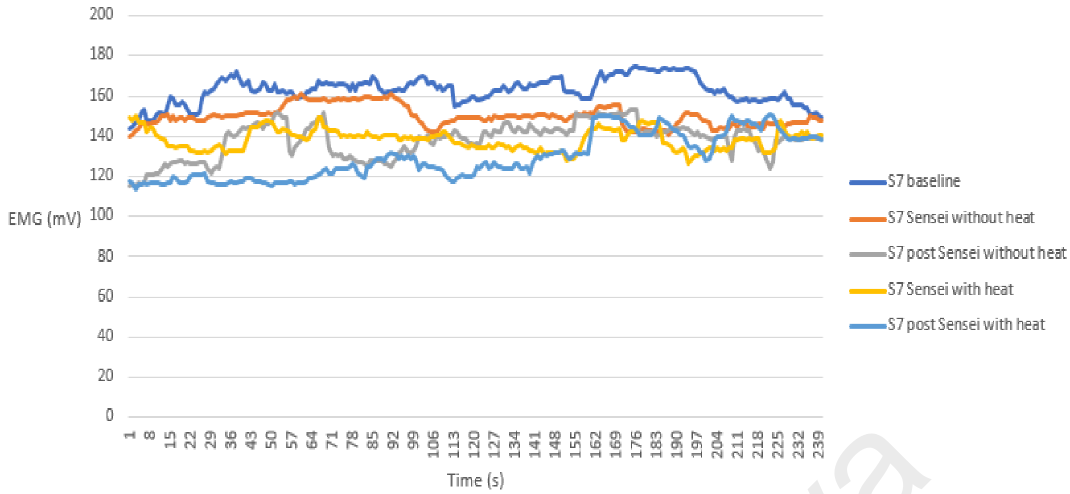

Figure 4.7: Graph of EMG activity over time for subject 7 during various activities

Table 4.7: Mean Absolute Value of EMG amplitude for subject 7 during various activities

Pre-massage baseline MAV	162.975 mV
Sensei without heat MAV	149.9875 mV
Post Sensei without heat MAV	138.1417 mV
Sensei with heat MAV	138.3583 mV
Post Sensei with heat MAV	129.3958 mV

Subject 7 follows the same pattern of MAV shift as subject 1, in which there is decrease from pre-massage EMG MAV of 162.975mV to 138.1417mv after massage without heat. When heat is added together with the massage therapy, the EMG MAV reduced to 129.3958mV. For subject 7, the combination of massage with thermotherapy is seen to be effective in reducing muscle tension.

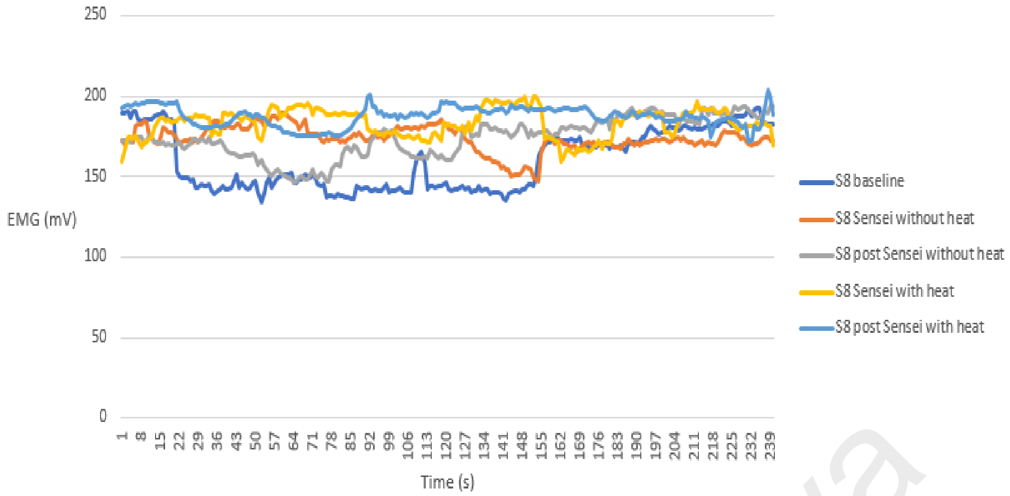

Figure 4.8: Graph of EMG activity over time for subject 8 during various activities

Table 4.8: Mean Absolute Value of EMG amplitude for subject 8 during various activities

Pre-massage baseline MAV	159.7417 mV
Sensei without heat MAV	174.1958 mV
Post Sensei without heat MAV	174.375 mV
Sensei with heat MAV	183.8042 mV
Post Sensei with heat MAV	187.8833 mV

Subject 8 was the same as Subject 2 in that the EMG MAV increased from 159.7417mV pre-massage to 174.375mV post massage without heat. It then increased further to 187.8833mV post massage with heat. This indicates that for subject 2, muscle tension is increased with massage, and increased higher when incorporated with thermotherapy.

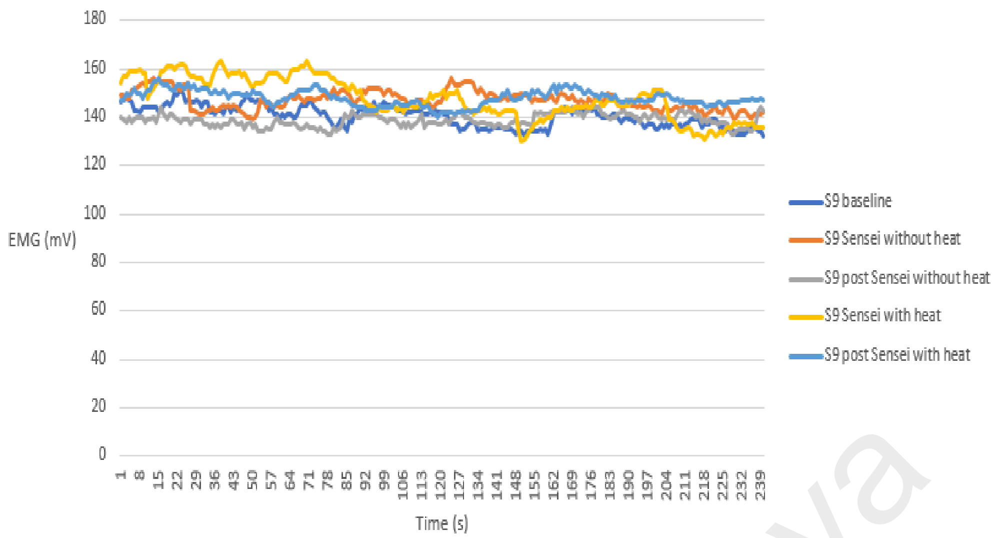

Figure 4.9: Graph of EMG activity over time for subject 9 during various activities

Table 4.9: Mean Absolute Value of EMG amplitude for subject 9 during various activities

Pre-massage baseline MAV	140.3875 mV
Sensei without heat MAV	147.0625 mV
Post Sensei without heat MAV	138.7292 mV
Sensei with heat MAV	147.7125 mV
Post Sensei with heat MAV	147.875 mV

Subject 9, like subject 6, had an initial reduction in EMG MAV from 140.3875mV pre-massage to 138.7292mV post massage without heat. This then increased to 147.875mV post massage with heat, indicating an escalation in the degree of muscle tension.

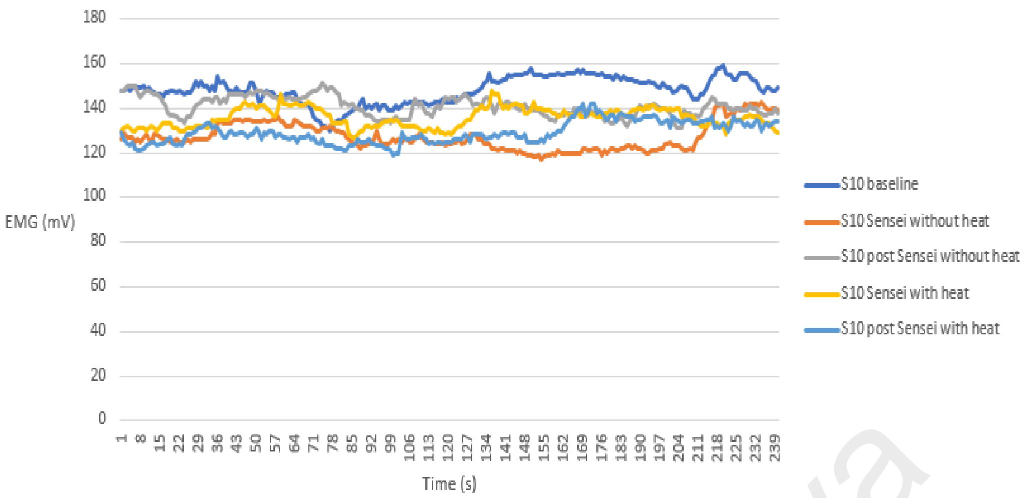

Figure 4.10: Graph of EMG activity over time for subject 10 during various activities

Table 4.10: Mean Absolute Value of EMG amplitude for subject 10 during various activities

Pre-massage baseline MAV	148.0875 mV
Sensei without heat MAV	127.1917 mV
Post Sensei without heat MAV	140.883 mV
Sensei with heat MAV	135.7458 mV
Post Sensei with heat MAV	129.0292 mV

Subject 10 followed the finding of subject 1 where the pre-massage EMG MAV reduced from 148.0875mV to 140.883mV post massage without heat. With the addition of thermotherapy, the EMG MAV further decreased to 129.0292. For subject 10, the combination of massage with heat showed greater efficiency in reducing muscle tension as compared to massage alone.

To further simplify the findings in relation to MAV shift in each phase of EMG recording, the table below sums up the data found. The differences were taken by subtracting pre-massage EMG MAV from post massage EMG MAV. A negative value, in which the EMG MAV post massage is lower than the

EMG MAV pre-massage, indicates a degree of reduced muscle tension. A positive value, in which the EMG MAV post massage is higher than the EMG MAV for pre-massage, indicates a degree of increased muscle tension.

Table 4.11: EMG MAV shifts for subjects during OGAWA Sensei mode without heat and with heat

Subjects	EMG MAV shift during OGAWA Sensei mode without heat (mV)	EMG MAV shift during OGAWA Sensei mode with heat (mV)
1	-37.0958mV	-48.525mV
2	+11.2292mV	+21.8875mV
3	+42.2291mV	-10.1084mV
4	-1.2917mV	-12.7125mV
5	+13.15mV	-10.9458mV
6	-4.5166mV	+17.325mV
7	-24.8333mV	-33.5792mV
8	+14.6333mV	+28.1416mV
9	-1.6583mV	+7.4875mV
10	-7.2042mV	-19.0583mV

From figures 4.1 to 4.10 and the corresponding table of average, it is noted than in eight out of ten subjects, the massage mode with heat yielded bigger EMG MAV shift compared to the massage mode without heat. To summarize, in both subjects 3 and 5, a positive MAV shift of EMG were recorded after massage without heat; possibly reflecting muscle tension after the subjects were subjected to the massage. This was subsequently followed by a smaller amplitude shift in negative values for subjects 3 and 5, reflecting muscle relaxation after a session of massage with heat. In contrast, it is noted that subjects 6 and 9 had a negative amplitude shift after massage without heat; implying muscle relaxation; which is followed by a positive MAV shift after massage with heat, implying muscle tension. It is also interesting to note that subjects 2 and 8 both had positive MAV shift after massage without heat and an increase of MAV shift after massage with heat reflecting an increased muscle tension for both subjects. In this study, only subjects 1, 4, 7 and 10 followed the expected result for this study with negative MAV shift after massage without heat and increased negative MAV shift after massage with heat; indicating a degree of muscle relaxation that rises with the presence of heat.

The findings were statistically analyzed using paired t-test on SPSS version 20. For the first null hypothesis tested which was that there is no significant difference between the EMG MAV for pre-massage and post massage without heat, the p value was insignificant at 0.942. The null hypothesis is therefore accepted. The second null hypothesis; in which there is no significant difference between EMG MAV for pre-massage and post massage with heat; the p value was also insignificant at 0.462. The null hypothesis is also accepted. Comparing the two post massage EMG MAV, in which null hypothesis is that there is no significant difference between EMG MAV of post massage without heat and post massage with heat, the p value was 0.369. The null hypothesis is accepted.

4.2 Participants' satisfaction

Table 4.12: Subjects' satisfaction level based on Likert scale and subjects' preference

Subject	Sensei mode without heat	Sensei mode with heat	Preference
1	4	4	c
2	3	4	a
3	4	4	c
4	4	5	a
5	4	3	c
6	3	4	a
7	4	5	a
8	4	5	a
9	3	4	c
10	4	5	a

From the table above, six out of ten subjects preferred the Sensei mode with heat compared to the conventional Sensei mode without heat. Four participants marked Sensei mode with heat as being 'very satisfactory' with only one participant marking it as 'neither satisfactory nor unsatisfactory'. It is noted that the EMG recording do not necessarily represent the participant's perception. By EMG recording, subjects 1, 3, 4, 5, 7 and 10 all had reduced muscle tension after having underwent the massage session with heat compared to the massage session without heat. However, only three out of these six subjects claimed that they preferred the massage mode with heat while the other three found both modes to be equal.

In contrast, subjects 3 and 9 both showed increased positive EMG MAV shift from massage session without heat to massage session with heat. This is not reflected in the participant perception survey in which subject 3 preferred the massage mode with heat whereas subject 9 found both modes to be equally satisfactory.

Considering the null hypothesis that there is no significant difference in participants' perception of satisfactory level between massage without heat and massage with heat, the p value was found to be insignificant at 0.024. The null hypothesis is therefore accepted.

Overall, the effects of the OGAWA Master Drive massage chair on trapezius muscle were present but insignificant. This contrasts with the previous study that was done in 2006 by Zullino et al, in which the gastrocnemius muscle of the lower limb was used as a general measure of muscle tension. Despite having chosen the trapezius muscle as the target muscle due to its location and the focus of the massage mode picked (Sensei - which emphasized on shoulder and spine), the result of the study might be different if other muscles were examined too. The sample size of 10 participants were also too small to be of significance. This is due to the time constraint faced as each recording took approximately an hour for each participant. Apart from that, further analysis such as using Joint Analysis of EMG Spectrum and Analysis (JASA) can help determining the cause of EMG changes whether due to force or due to muscle fatigue (Cifrek et al, 2009).

CHAPTER 5: CONCLUSION

5.1. Conclusion

This study evaluated the effects of OGAWA Master Drive massage chair on trapezius muscle using the electromyogram (EMG) sensor. Ten participants were subjected to 15 minutes massage session focusing on neck and shoulder using the Sensei mode with and without heat. Five EMG recording sets were taken in 4 minutes for each participant for baseline, during Sensei mode without heat, post massage without heat, during Sensei mode with heat and post massage with heat. The Mean Absolute Value (MAV) for EMG were taken for all sets and compared. It was found that in eight out of ten subjects, the massage mode with heat yielded bigger EMG MAV shift than that of without heat. Four out of ten subjects showed increased EMG MAV shift from baseline average EMG, reflecting muscle tension post massage session with heat. The difference was statistically insignificant ($p>0.005$). Six out of participants preferred having the massage with heat. The participant satisfaction level difference between the two massage modes was not significant ($p>0.005$). Despite the insignificant result of OGAWA Master Drive massage chair effect on the trapezius muscle activity based on the EMG recording, more than half of the participants preferred the massage mode with heat. This may provide a new research area in thermotherapy for patients with chronic neck and shoulder pain. With better innovation in the field of automated massage chairs, patients may find themselves to be more compliant to massage therapy and thermotherapy as they become more easily available in the comforts of their home.

5.2. Study limitations

The main drawback of this study is the lack of a universal surface electromyogram (EMG) baseline for control. Instead, individual values had to be used for comparison between before and after massage sessions. Also, the sample size was too small. The study could have been improved by further minimizing possible sources of noise. One suggestion is to repeat the study using invasive electrodes for higher accuracy. The participants should also be monitored prior to the study to ensure that they did not exert their shoulders to avoid error in EMG reading. Further studies with bigger sample size should be done to investigate the effect of thermotherapy on muscle tension. This should also include the older age group as they are more vulnerable to neck and shoulder pain. Additional analysis using Joint Analysis of EMG Spectrum and Amplitude (JASA) should also be done to determine the cause for EMG change.

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