An investigation into the efficacy of reflexology on acute pain in healthy human subjects

Carol Samuel

The thesis is submitted in partial fulfilment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY of the

January 2011

Abstract

Introduction

Reflexology incorporates the use of specific pressure techniques to the feet, hands or ears. There are many anecdotal claims for reflexology in the treatment of various conditions such as migraine, arthritis and multiple sclerosis but very little clinical evidence exists for reflexology in the management of pain per se. Pain is a worldwide concern and 10% of the UK population suffer from chronic pain, making demands on an already overstretched NHS service. Members of the public seek more control over their wellbeing and there is a growing trend towards complementary medicine. Reflexology, one of the many complementary medicine modalities available, may be a suitable adjunct to pain management by helping to reduce the number of medications and associated side-effects from continued drug use. This research therefore, enters at a time when the call for scientific evidence is sought and offers new evidence for the efficacy of reflexology in acute pain.

The principal aims of these experiments were to investigate the acute effects of:

i) Chapter 3 - standard reflexology on changes in basal physiological parameters, such as blood pressure (mmHg), heart rate (bpm), and core body temperature (°C). Fourteen healthy subjects were recruited to a crossover design study in which they participated in one 30 min session of standard reflexology and one 30 min session of sham Transcutaneous Electrical Nerve Stimulation (TENS) given one week apart. The results showed a significant decrease in heart rate (bpm) during and post standard reflexology when compared to a sham TENS (control).

ii) Chapter 4 - standard reflexology in an ice pain experiment. Outcome measures were recorded for (a) pain threshold (s) i.e. the time it takes for the subject to find the experience painful, (b) pain tolerance (s) i.e. the time it takes until the subject can no longer keep his/her hand in the ice water and c) heart rate (bpm) pre and post ice plunge. Sixteen healthy

volunteer subjects were recruited to this crossover design study to participate in one 45 min session of standard reflexology and one 45 min session of sham TENS (control) given one week apart. The results revealed a significant increase in both pain threshold (s) and tolerance (s) following standard reflexology when compared to the sham TENS (control). There was also a decrease in heart rates (bpm) following standard reflexology prior to and post ice immersions which were maintained for 60 min, although the effect was non-significant for the post ice immersion.

iii) Chapter 5a - standard and light reflexology in an ice pain experiment. Thirty healthy volunteer subjects participated in this study to compare the effects of standard and light reflexology with a 'no treatment' control. Outcome measures were recorded for pain threshold (s), pain tolerance (s) and post treatment pre and post ice plunge heart rate (bpm). Subjects participated in one 45 min session each of standard and light reflexology and one 45 min control session consisting of no treatment given one week apart in a Latin square design. The results showed a significant increase in pain threshold following both standard and light reflexology and significant increases in pain tolerance for standard but not light reflexology. Pre-ice plunge, post treatment heart rates (bpm) were significantly lower following both standard and light reflexology and there was a transient decrease in heart rate post-ice plunge, post treatment for light reflexology.

iv) Chapter 5b – An alternative statistical analysis on the effects of standard and light reflexology in an ice pain experiment. This chapter represents an alternative method of analysing the data where there are large inter-individual variations in responses. The results showed significant biphasic responses, e.g. nociceptive and anti-nociceptive to the effects of both standard and light reflexology when compared to a no treatment control. These results extend the observations made in Chapter 4 and 5a.

v) Chapter 6 - mechanical reflexology in an ice pain experiment. Twelve young and healthy subjects were recruited to participate in one 20 min session of mechanical reflexology and one 20 min session of sham TENS (control), give one week apart in a crossover design. Outcome measures were recorded for pain threshold (s), pain tolerance (s) and heart rate (bpm). The results showed no significant effects of mechanical reflexology treatment when compared to sham TENS (control) on either pain threshold or pain tolerance, although there were some transient benefits of mechanical reflexology on pain threshold during stimulation and on pain tolerance post stimulation.

vi) Chapter 7 - repeated standard reflexology treatments in an ice pain experiments In this experiment eleven healthy female subjects were recruited to participate in three consecutive weeks of 45 min standard reflexology and three consecutive weeks of 45 min sham TENS (control). The treatments were given in a crossover fashion and there was a minimum one week break between treatments and crossover. Outcome measures were recorded for pain threshold (s), pain tolerance (s), pre and post ice plunge heart rate (bpm) and blood pressure (mmHg). The results showed no significant differences between the two treatments, but there was a general trend for an increase in the mean pain threshold and tolerance following standard reflexology. There was however, some drop-off in the effect on pain tolerance. This result should be interpreted with caution due to the small number of subjects and the large inter-individual variations. Furthermore, there were no cumulative effects of treatment on either blood pressure or heart rate.

vii) Miscellaneous Chapter – pressure applications in reflexology. This study was carried out using the Tactilus® Freeform Sensor system to measure the effects of three distinct pressure modes of reflexology: a) static, b) standard dynamic and c) light dynamic on four different regions of the foot sole: i) medial edge, ii) arch, iii) heel and iv) the ankle on different foot types. The data showed variations in average maximum pressure values according to the foot type and area treated.

Conclusion

Manually applied reflexology increases pain threshold and tolerance which seems to be independent of any changes in autonomic function.

Contents

Declaration

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

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Glossary & Abbreviations

The terms used in this glossary relating to pain have been categorised by The International Association for the Study of Pain (IASP).

The following pain terminology is from "Part III: Pain Terms, A Current List with Definitions and Notes on Usage" (pp 209-214) Classification of Chronic Pain, Second Edition, IASP Task Force on Taxonomy, edited by H. Merskey and N. Bogduk, IASP Press, Seattle, © 1994.

PAIN	"Pain is an unpleasant, sensory and emotional experience associated with potential or actual tissue damage or described in terms of such damage".
PAIN THRESHOLD	The least experience of pain which a subject can recognize.
PAIN TOLERANCE	The greatest level of pain which a subject is prepared to tolerate.
NOXIOUS STIMULUS	A noxious stimulus is one which is damaging to normal tissues
ANALGESIA	Absence of pain in response to a stimulus which would normally be painful.
NOCICEPTOR	A receptor preferentially sensitive to a noxious stimulus or to a stimulus which would become noxious if prolonged
ALLODYNIA	Pain due to a stimulus which does not normally produce pain.
HYPERALGESIA	An increased response to a pain which is normally painful.
HYPOALGESIA	Diminished pain in response to a normally painful stimulus.
NOCICEPTION	The neural processes of encoding and processing noxious stimuli – in simple terms the perception of a painful stimulus.
ANTINOCICEPTION	A reduction in the responses to pain.
CAM	**C**omplementary and **A**lternative **M**edicine – Complementary medicine supports and works alongside orthodox medical practices, whilst alternative medicine is said to be that which lies outside of orthodox medical practices.
EXPECTANCY	The act or state of expectancy is for example, when changes in bodily health occur because we anticipate they will happen.
CONDITIONING	Repeated use of a specific stimulus in order to create a predictable and controlled response in another person or animal.
PLACEBO	A dummy medicine or activity containing no active ingredients; an inert treatment; anything of no real benefit which nevertheless makes one feel better. Also said to be

	a treatment that works because of the patient's belief in it, not because of the actual physical changes it may produce.
REFLEXOLOGY	A method of therapeutic stimulation by pressure application to reflex sensitive points usually on the feet, hands or ears. Reflexology assumes that the entire body is mapped onto these reflex points. As a result, the pressure applied is believed to affect more distant, internal organs.
RECEPTOR	Special places on nerve endings capable of responding to a chemical or physical stimulus from within the body or in the environment.
AMPA RECEPTOR	**a**lpha-amino-3-hydroxy-5-**m**ethyl-4-isoxazole **p**ropionic **a**cid is a non-NMDA-type ionotropic trans-membrane receptor for glutamate that mediates fast synaptic transmission in the central nervous system (CNS). It is responsible for the intensity and duration of a peripheral stimulus.
NMDA RECEPTOR	The NMDA receptor (**N**-**m**ethyl-**D**-**a**spartate) is a G-protein coupled receptor that acts as a second messenger in the spinal cord. It is the predominant molecular device for controlling synaptic plasticity and memory function. It mediates excitatory effects in the brain when they are stimulated by endogenous ligands such as glutamic acid.
SUBSTANCE P	A neuropeptide: functions as a neurotransmitter and a neuromodulator. It belongs to the tachykinin neuropeptide family. It is thought to stimulate inflammation and function as a sensory neurotransmitter in the central nervous system.
NUCLEUS ACCUMBENS	The Nucleus Accumbens are a collection of neurones found in the forebrain. They have an important role in reward, pleasure, motivation, addiction, aggression, fear, and the placebo effect.
ENDORPHINS	Endogenous opioid polypeptide hormones synthesised in the areas of the brain and concentrated in areas that modulate nociception. They are referred to as the body's own painkiller because of their resemblance to opiates and their ability to produce analgesia and euphoria.
B-ENDORPHINS	Small protein/peptides released into the blood from the pituitary gland and into the spinal cord from the hypothalamic neurons. B-endorphins act like an analgesic to dull the sensation of pain.
DOPAMINE	Dopamine is a catecholamine neurotransmitter found naturally in the brain and it is essential for the normal functioning of the central nervous system. It is associated with movement, attention, learning, and the brain's pleasure and reward system. It provides a 'feel good' factor.
CATECHOLAMINES	Catecholamines are one of a group of amines that are released by the adrenal glands in times of stress. They include adrenaline, noradrenaline and dopamine. They are responsible for the 'fight or flight' response to stress and

	function both as hormones and neurotransmitters.
ADRENALINE	Adrenaline is a neuromodulator of the peripheral nervous system which is also present in the blood. In times of stress it's activity in the sympathetic nervous system increases the heart rate, contracts the blood vessels and dilates the air passages so that the body may respond rapidly as in the 'fight of flight' response to stress.
NORADRENALINE	Noradrenaline is one of the catecholamines and acts as both a hormone and a neurotransmitter. Along with adrenaline it is released into the blood by the adrenal glands in times of stress. In the brain it acts as a neurotransmitter to produce an anti-inflammatory effect via the locus coeruleus.
NEUROMODULATOR	A hormone or chemical substance released from the neurone or synapse with the ability to regulate neuronal activity.
NEUROTRANSMITTER	Conveys electrical signals through hormonal or chemical substances with the ability to change neural activity, either to enhance or modulate such activity.
ACETYLCHOLINE	An amine of the autonomic nervous system, a neurotransmitter which is found in the peripheral and central nervous system. It is said to be of particular importance in those who suffer from Alzheimers disease because of its effect on learning and memory.
HISTAMINE	An amine that is released from mast cells causing an inflammatory response and vasodilation causing reddening of the skin.
IONOTROPIC RECEPTORS	A group of trans-membrane ion channels that are opened or closed in response to binding of chemical messengers
METABOTROPIC RECEPTORS	Membrane receptor subtypes without ion channels. They are linked to ion channels on the plasma membrane of a cell through transduction mechanisms.
RECEPTIVE FIELD	Area within which a stimulus can excite a cell
IPSILATERALLY	On the same side
CONTRALATERALLY	On the opposite side
NORMOTENSIVE	With normal blood pressure 120 / 80 mmHg
TSUBO POINT	A point on the skin where acupuncture needles or acupressure is applied.
ANOVA	**An**alysis **o**f **Va**riance – a statistical tool to compare the Means of experimental data sets.

Acknowledgements

It is my belief that people come into your life for a reason and that you are in the right place at the right time because fate has drawn you to it. We all of us have lessons to learn in this life, but without a doubt this has been one of the most challenging of my life's lessons so far. I have learned so much from this PhD journey, not only professionally but also personally.

Dr Sheelagh Campbell, my Director of Studies sadly passed away before I could complete the amendments, but she was here for me when I went through my viva and I was glad of her company. Her input, especially on the Miscellaneous Chapter of this thesis was invaluable. Sheelagh was able to provide me with an opportunity that I otherwise would not have had, and I will always be grateful to her for that. I cannot however write these acknowledgements without extra special thanks to Dr Ivor Ebenezer, without whose help and advice the experiments would never have begun and the thesis never have been finalised. What can I say for the endless hours of time, patience and perseverance he gave me, for his quiet words to others that I may continue this journey, for his endless commitment to me and my research which spurred me on time and again? He is a genuine man with a caring and understanding attitude to his students and I hope that I have found a friend for life.

Sam and Simone my fellow PhD students, your support and encouragement have been brilliant and I am blessed to be able to call you friends, thank you both. Dee, your insight saw all of this long before I even signed up for it; you were right, as you always are. Thanks to all those who gave up their time to take part in the research trials and to those who have supported me in the background with their knowledge, friendship and valuable advice.

I would like to say to my daughters Claire and Sharon; remember never give up, believe in yourself even when no one else does and fight for what you believe in. If *you* believe you can do it, you *can!* Most of all though, I must give my heartfelt thanks to my husband Sam; for us it has been the longest, most difficult journey in

our relationship. Without your love, your commitment and your faith in my abilities I could not have continued. I love you will never be enough.

Dedication

To Sherry my dearest friend and benefactor without whose gift I would not be here today, and to my husband Sam for this is as much your thesis as it is mine.

CHAPTER 1

COMPLEMENTARY AND ALTERNATIVE MEDICINE

1.1 INTRODUCTION

Complementary and Alternative Medicine (CAM) has become an increasingly popular form of healthcare and the subject of much debate over the past ten years (Foundation for Integrated Health, 2000). In their interpretation of CAM, Zollman and Vickers (1999) have proposed that it refers to a group of therapeutic and diagnostic disciplines that exist to a large degree outside of normal healthcare settings. Thomas *et al*. (2001) reported that 28.3% of the adult population have used one of eight popular therapies and list them as acupuncture, chiropractics, homoeopathy, hypnotherapy, medical herbalism, osteopathy, reflexology and aromatherapy. Of this predominantly female population, 46.6% were found to be lifetime users. They reported that the annual spend on CAM equated to £580 million, of which 90% was from private purchase; additionally CAM makes a measurable contribution to first-contact primary care. Complementary Medicine in the public domain remains an increasingly sought after health option (Lomas, 2006). The Prince's Foundation for Integrated Health (FIH), an organisation set up by the Prince of Wales in 1993 to promote the integration of CAM within the NHS with a view to making it available to everyone, reported that three quarters of the British public would like to see Complementary Medicine made available to them *via* NHS services (Foundation for Integrated Health, 2006).

Many people place both Complementary and Alternative Medicine in the same category, but the National Centre for Complementary and Alternative Medicine (NCCAM) in the USA has suggested a clear difference between the two. To clarify the terminology the centre has defined complementary medicine as a therapy, such as aromatherapy, that may be used alongside conventional medical practices, and Alternative Medicine as one used in place of conventional medical practice (NCCAM, 2007).

Chronic conditions are an ever-increasing reason why people consider CAM therapies. Current provision within the NHS is largely limited to palliative care

(Thompson, 2005) but a study carried out by Ong and Banks (2003), and confirmed in the Smallwood Report (Smallwood, 2005), has suggested that CAM may have beneficial effects for musculoskeletal pain, arthritic pain and other acute and chronic pain conditions, such as headaches and migraine. The Smallwood Report also indicated that components which make up the psychological aspects associated with pain, such as anxiety, stress and depression also appeared to benefit from CAM interventions. Long *et al*. (2001) carried out a survey of 223 professional CAM organisations in an attempt to relate the benefits of CAM therapies to medical conditions. The seven conditions agreed as being most beneficial for treatment were stress/anxiety, headache/migraine, back pain, respiratory problems including asthma, insomnia, cardiovascular and musculoskeletal problems. The survey reported that 64% of CAM users sought advice from either their GP or consultant prior to their visit to a CAM practitioner and 24% received CAM in addition to conventional medical advice.

A review carried out by Vickers (2000) reported that massage, which has previously been shown to reduce anxiety and improve sleep (Ferrell-Torry and Glick, 1993), is offered in most UK hospices; acupuncture is used for pain relief in rheumatology clinics and music therapy has been used for reducing pain and anxiety. In a 3-year study of 1290 cancer patients treated with massage therapy, outcome scores for pain, fatigue, nausea and depression were reduced by 50% (Cassileth and Vickers, 2004). Peace and Manasse (2002) have reported that pain ranks as the highest concern both physically and emotionally in cancer sufferers and evidence for the efficacy of CAM is increasing (Vickers, 2000). It is being used more and patients are being referred on a more regular basis with 40% of GPs now providing access to CAM practitioners through the NHS (Carter, 2003).

An increasing number of complementary practitioners are now funded directly by the NHS in hospital as well as in community settings (Andrews, 2004). In 2003 the Christie Hospital in Manchester was awarded the National Prince of Wales award for 'Good Practice in Integrated Healthcare' where complementary therapies are made available to patients (Mackereth, 2004). The hospital is the largest acute cancer treatment centre of its kind in Europe and has demonstrated that CAM can be integrated within the NHS service provision, allowing not only treatment for cancer

patients, but also for the carers and nursing staff at the hospital. Andrews (2004) suggested that orthodox medical practitioners now have a more positive attitude towards complementary medicine and the Royal College of Nursing indicates there are now a large number of nurse practitioners who are trained in CAM (Lomas, 2006). Perry & Dowrick (2000) reported that 13% of GPs had used complementary therapies to directly treat patients, 31% had made referrals and 38% endorsed complementary treatments. In the same report, GPs stated that 62% of treatments resulted in successful outcomes, whilst 21% reported adverse reactions. The latter were specifically related to medical herbalism, whilst hypnotherapy, reflexology and acupuncture showed the fewest adverse effects.

In a more recent project, McDade (2008) has reported on the findings of a pilot project in Northern Ireland where GPs provided access to CAM therapies *via* the Get Well (UK) service. The report found that in 65% of cases, GPs saw their patients less often following referral to a CAM practitioner and prescribed 50% less medication for chronic or acute conditions. Furthermore, 98% of the GPs surveyed said that they would recommend this type of service to their colleagues. CAM practitioners involved in the scheme reported an improvement in patient health of 77%, but identified the need for a series of educational interventions to provide GPs with a better understanding of their treatment provision. Patients referred under the scheme have recorded an 81% improvement in their physical health and 79% improvement in their mental health. Of those patients who were taking pain killers on a regular basis on referral, 55% said they used fewer pain killers after their CAM experience. Overall the report has recommended that CAM provision be made more widely available not only because of the improvements seen in patients' health, but also because of the potential economic savings as a direct result from prescribing and the use of primary health services.

Many CAM practitioners would like to integrate their therapies within the NHS. Ernst (2004a) suggested that 80% of pharmacists within the UK would like to undertake additional training in herbal medicine, whilst Perry and Dowrick (2000) indicated that 49% of GPs would like further training in CAM. Ernst (2005) has also said that the general public is more interested in illness being treated in its entirety and expect to be treated as a whole person. Lomas (2006) confirmed that patients want to have more control over their choice of treatment and feel that CAM

treatments should be made more readily accessible to the public at large. Hyland *et al.* (2003) found that 95% of CAM users, and 75% of the general public, supported access to CAM *via* the NHS.

1.1.1 House of Lords Report on CAM

In 2000, The House of Lords (HoL) Select Committee on Science and Technology issued the 'Sixth Report' (Parliament, 2000) detailing the need to foster high-quality research in the area of CAM. The report recommended that the NHS Research and Development Directorate and the Medical Research Council should create centres of excellence to conduct CAM research and that it should provide dedicated funding in this area. The report also stated that therapies making claims of effectiveness for specific ailments should be able to prove this above and beyond any placebo effect.

In the Report (Parliament, 2000) the therapies were split into three main groups.

a) Group 1

   This encompassed the most organised professions and included osteopathy, chiropractic, acupuncture, homeopathy and herbalism. These therapies are generally referred to as 'alternative' because they are often used independently of conventional medicine.

b) Group 2

   This group encompassed those therapies that most clearly complement conventional medicine. This group included reflexology, aromatherapy, counselling and hypnotherapy. These are referred to as the 'complementary' element of CAM.

c) Group 3

   The therapies in this group embrace philosophical approaches to healthcare and were deemed to lie outside scientific principles. They offer diagnostic approaches to healthcare but without scientific evidence. Therapies such as Traditional Chinese Medicine (TCM), crystal therapy and iridology were included in this category.

The Report caused some confusion amongst TCM practitioners whose therapy had been placed in Group 3, especially since the Report classified acupuncture and herbalism, both of which are aspects of the TCM philosophy as Group 1 therapies.
The Report aimed to provide guidance on progressing CAM over a five-year period. It also encouraged clear professional structures with uniform standards of education and training and supported the idea of a single regulatory body for each CAM therapy. Finally it encouraged scientific validation for CAM.

1.2 REFEXOLOGY

1.2.1 Reflexology an Introduction

The HoL Report (Parliament, 2000) has categorised reflexology as a system based on massage of the feet that *"purports to have invisible lines connected vertically throughout the body to all organs, and that each organ has a corresponding place on the foot"*. Reflexology incorporates the use of specific pressure techniques to the feet, hands or ears. It is one of a number of complementary therapies becoming more commonly used in healthcare. Amongst other therapies, reflexology is gaining importance, particularly for clinical conditions.

1.2.2 Historical Evidence

A pictograph found in the tomb of Ankmahor in Saqquara, Egypt, see Figure 1.1, is indicated in various reflexology text books (Byers, 1990, Issel, 1996, Wright, 2001) and has been described as the only remaining evidence that reflexology has existed for thousands of years.

Figure 1.1: A commercial reprint of the pictogram found at the tomb of Ankmahor, Saqquara, Egypt. The hieroglyphics beneath the pictogram are said to read "do not let it be painful" to which the attendant responds by saying "I shall do as you please" (Issel, 1996).

1.2.3 Eastern theories

Issel (1996) ascribes various Eastern theories to reflexology which appear to have developed from pictures inscribed on the feet of Buddha. Many religious texts indicate that the feet have been a focus of Asian religions as early as 100 A.D., particularly in the Buddhist sector. Buddha footprints (Sailer, 2001) have been found in many Eastern countries, two examples of which can be seen in Figure 1.2. Issel (1996) reported that the embellishments found on the sole of the foot were related to reflexology, however there is no definitive evidence of this and it is more likely that they refer to various religious accomplishments. Many footprints contain embellishments of complex diagrams often with up to 108 illustrations which appear to be generic to Eastern symbolism and depict the physical attributes of the Buddha (Sailer, 2001). The swastika seen on the toes of the feet in Figure 1.2 are generally associated with Nazi Germany but in Eastern religion the swastika originated from the Sanskrit word Svasti meaning 'to be fortunate'. Footprints of the Buddha traditionally symbolized the physical presence of the enlightened one (Harderwijk, 2006) and Buddhist texts report that the feet represent the grounding of the transcendent. In India they are a focus of respect where today worshippers are expected to go barefoot in temples, shrines and even in the home (Sailer, 2001).

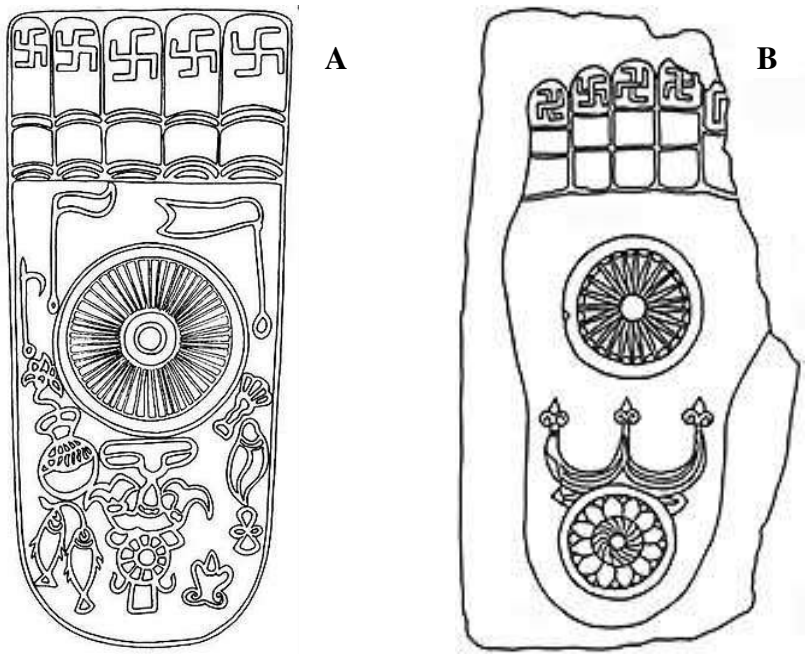


Figure 1.2: Two examples of Buddha footprints. a) Buddha Footprint, Sri Lanka and b) Gandharan Buddha Footprint, Pakistan (2001 (Sailer, 2001).

In China the feet were revered in a very different way. The art of foot binding was a custom in China as early as 618 A.D. (Hutchins, 2004). Figure 1.3 illustrates how this practice caused distortion of the bones of the foot and shows an extreme example of foot binding. The foot would not have been more than 9.9 cm long and was designed to fit shoes referred to as the 'Golden Lotus' (Lim, 2007). The binding procedure was carried out as a status symbol in order to attract a wealthy husband. The female feet were bound usually from the age of six in tight bandages which restricted their growth. In 1911 this practice was abolished with the start of the new Republic of China (Lim, 2007).

There is no recorded evidence for the use of foot pressure massage prior to the Song Dynasty (960 – 1127A.D.) when it was deemed to be a part of the TCM philosophy of acupressure (Fan, 2006). Fan (2006) reported that in the Northern Song dynasty during 1021 – 1101 A.D, the centre of the middle of both feet were massaged on a daily basis on an area referred to as the kidney 1 point. The area is located in the middle of the foot just beneath the metatarsal heads and in modern reflexology charts this area is labelled as the solar plexus. This was the first mention that foot massage was used as a way of maintaining good health.

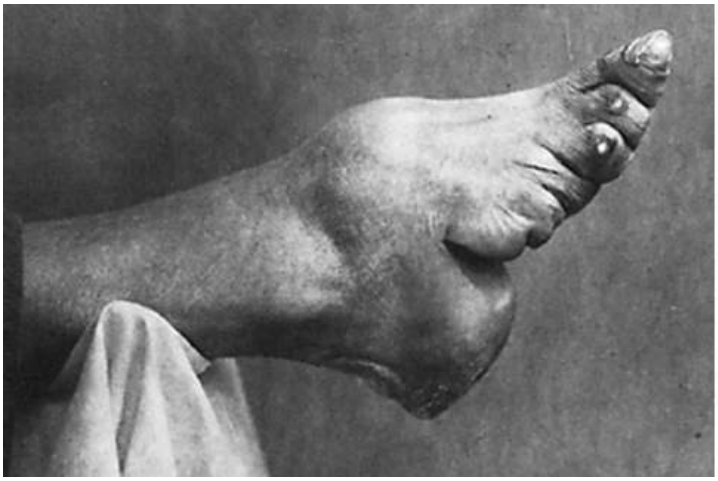


Figure 1.3: An extreme example of Chinese foot binding (Hutchins, 2004)

According to the Rwo Shur Health Institute International, foot reflex therapy originated in China 5000 years ago as part of acupuncture; furthermore they have suggested that it can be traced to the 'Hwang Tee Internal Text' where it is recorded as the 'Examining Foot Method' (Tay and Eu Hooi, 1988). Issel (1996) discovered that it was driven underground in China, during the cultural revolution whilst Dougans (2005) has suggested that any reflexologist stimulating the reflex points on the feet is also stimulating the six paired meridians that run through the feet. There are however a number of books available that record reflexology as a form of acupressure (Bendix, 1976, Blate, 1982, Wright, 2001) and this type of acupressure-like practice is still in use in many Eastern countries today.

In China, foot massage is performed on a regular basis and includes bathing the feet in herbal waters (Vickers, 2000, Ye *et al.*, 2005) prior to performing deep tissue knuckling movements. There is a growing demand for foot massage and Shanghai boasts as many as 30,000 foot massage workers, whilst in Hong Kong there are approximately 40,000 workers. Most of these are aged between 18 and 25 and originate from rural districts only moving to the cities for financial purposes (Bennedbaek *et al.*, 2001). Chinese foot massage bears only a minor resemblance to the treatment given in the UK today and reportedly uses reflex points in addition to the meridian acupuncture/acupressure points found on the lower limbs and feet.

1.2.4 Reflexology in relation to Eastern Medical Practices

Reflexology is thought by many to be a derivative or technique closely aligned to the practices of acupuncture, acupressure and auriculotherapy, all of which are said to originate from the Traditional Chinese Medicine (TCM) philosophy. Acupuncture is recognised as a system of diagnosis and treatment dating back to 100 B.C. White and Ernst (2004) declare that acupuncture works via channels known as meridians purported to be invisible lines that traverse the body. Acupuncture in TCM is based on the concept of yin and yang and the philosophy of the five elements (Maciocia, 1989), notably earth, wind, fire, metal and water. In the 1940s, Voll discovered electrical fields within the human body that claimed to prove the existence of the meridians (Ericsson *et al.*, 2003). The system is supposedly made up of 12 main meridians that are said to link the exterior of the body to its interior (Kaptchuk, 2000), each meridian being bilateral and thus existing on both sides of the median line of the body. They were named according to organs or functions to which they were related and are said to exist in pairs. For example, the meridians of the lung and large intestine are a pair, and the Chinese Medicine theory of yin and yang suggests these organs regulate one another. One meridian is said to go out to the extremities whilst the other runs back to the centre from the extremities (Frydenlund, 1996, Fan, 2006). The lung meridian (yin organ) for example, runs along the lateral border of the arm to the thumb, whilst the large intestine meridian (yang organ) runs along the medial aspect of the arm from the forefinger to the axilla (armpit). Unlike Western medicine, acupuncture and its many derivatives do not treat the organ systems *per se*, rather they address the dysfunction associated with the circulation of essential fluids and the flow of energy that is said to move constantly through the meridian network (Tedeschi, 2000).

Close to the surface of the body are areas of skin reported to be especially sensitive to electrical resistance or high electrical conductivity. These are known as skin impedance points, or more commonly as tsubo points (Tedeschi, 2000, Colbert *et al.*, 2007). Shah (1999) has reported that 80% of tsubo points are located near cutaneous sensory nerves. Chinese medical schools also have noted strong correlations with the location of nerves and tsubo points, for example, the heart meridian which runs along the ulna surface of the arm, correlates well with the ulna and medial cutaneous

nerves of the arm (Tedeschi, 2000). According to the theory of acupuncture if the flow of energy through the meridian system becomes blocked, it has an effect on the organ or system along its path. In acupressure and acupuncture, pressure and dry needling (the insertion of a solid needle) of a number of tsubo points is said to release the blockage and help restore the flow of energy along the meridian. More recent research has demonstrated the relationship between tsubo point stimulation and their corresponding brain areas (Cho *et al.*, 1998). There is now a growing body of evidence to support acupuncture as an alternative form of medicine particularly in the area of pain management (Grasmuller and Irnich, 2007, Pyati and Gan, 2007, Sun *et al.*, 2008, Wang *et al.*, 2008). It is a complex system in which the Eastern theory reviews Western ailments in a completely different way. Although there has been little evidence of physiological or anatomical proof of the meridian system, TCM associates the Western theory of referred pain, with an imbalanced or blocked meridian line (Kaptchuk, 2000). In Western medical practice the relationship between pain from the viscera and an area of skin arises from the visceral and somatic pain fibres using the same pathway to the brain. When there is pain in the viscera it can be perceived as being somatic in origin. For example, a common referral area for pain in the gallstones is the tip of the shoulder. In the Eastern meridian system the gallbladder meridian runs through the shoulder, so a person presenting with pain in the shoulder may be treated by acupuncture anywhere along the gallbladder line.

1.2.5 Auriculotherapy

Auriculotherapy another derivative of TCM is a method of stimulating the acupuncture points on the external ear. Ear acupuncture charts have been used in TCM for thousands of years (Dougans, 1996) but it wasn't until 1950 that Nogier (Gori and Firenzouli, 2007) produced a somatotopic representation of an inverted foetus in the ear and proposed that massaging, or electrically stimulating any area in the ear could provide pain relief. Clinical trials (Oleson and Flocco, 1993, Oleson, 2002) have endeavoured to demonstrate the accuracy of Nogier's ear chart, but a recent study by Andersson *et al.* (2007) concluded there were no correlations between patients' anatomical pain indicators and auricular reflex points. It did however suggest that in general, musculoskeletal pain was represented by tender

points (regions sensitive to touch) on the external ear. Tender points in therapies such as acupuncture, acupressure and reflexology are said to reflect altered physiology and pathological change in an organ or system (Washington *et al.*, 2003, Tiran and Chummun, 2005). Patterson (1976) and Oleson (2002) have demonstrated the successful use of auriculotherapy in drug addiction. Opiate receptors occupied by narcotic drugs are said to inhibit the natural activity of endogenous opioids. Oleson (2002) reported that narcotic addicts had raised met-enkephalin levels and that auriculotherapy could facilitate withdrawal by activating the release of previously suppressed endorphins. Usichenko *et al.* (2005) have demonstrated that patients who underwent total hip arthroplasty also benefited from auriculotherapy and following surgery were able to reduce post-operative pain medications by 36%.

The entire Eastern theory of medicine appears to be related to lines or zones that run through the body and it is this connection that many have suggested connects reflexology with Eastern medical practices (Dougans, 2005).

1.2.6 European theories and neurological relationships

The term 'zone therapy' appears to be the original term for reflexology and in many European countries this is still in use today (Marquardt, 1984). Adamus and A'tatis are credited with writing the first official book on 'Zone Therapy' in 1582 (Lerner and Witztum, 2005). In 1862 Sechenov postulated that a reflex response from a sensory stimulus may be inhibited within the forebrain or medulla (Haas, 1998), a theory later recorded as central inhibition. In 1870 Bekhterev introduced the term 'reflexology' (Lerner and Witztum, 2005) when working independently to Pavlov, he developed the conditioned reflex theory which he defined as a discipline to study the responses of external and/or internal stimuli.

In 1893 Head (1893) postulated a direct relationship between the viscera and the skin. He mentioned that when a portion of the skin became over-sensitive to pain it was a result of an internal disturbance, postulating that the sympathetic responses for that area were greatly increased. Head depicted this with a case study drawing in which he illustrated the cutaneous areas affected by the Herpes Zoster virus, as shown in Figure 1.4. The diagram showed that a part of the foot was also affected by

Herpes Zoster. This area, in terms of reflexology is thought to correlate with the reflex points of the pelvic area of modern reflexology charts, appearing to demonstrate the first 'zonal relationships'.

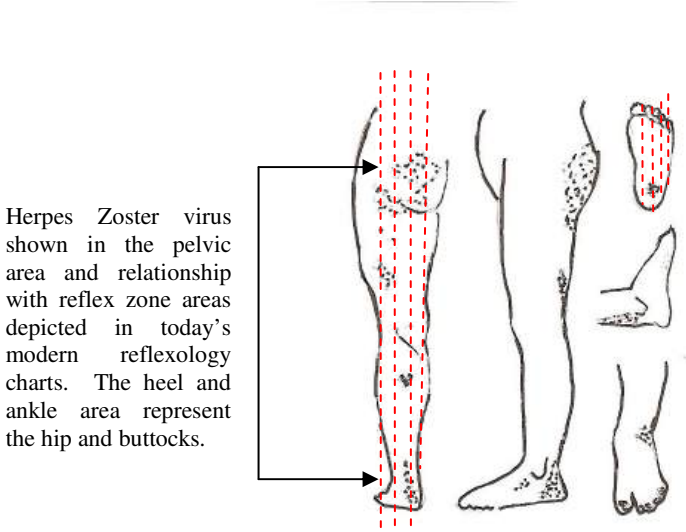


Figure 1.4: Cutaneous representation of Herpes Zoster, adapted from (Head, 1893). This is one of the first drawings to depict zonal relationships.

Head (1905) also recorded that patients who experienced pain in the lower back very often were unable to stand for any length of time due to pain in the foot, and that the bladder could be excited by stimulating the soles of the feet. The main contribution of Head to the neurological relationships of reflexology was his definition of dermatomes, which he outlined as areas of the skin supplied by spinal nerves. A diagram of these regions is shown in Figure 1.5. Head (1893) further suggested that pain from an internal organ was ill defined due to a lack of pain receptors in the viscera, but maintained that internal organs could project their afferent fibres to a site far removed from it. This early work was alluding to the phenomenon of referred pain where sensory fibres from the viscera stimulate the nerve routes of somatic nerves of a corresponding spinal segment and the brain receives a confused message leading to what is termed 'referred pain'(Marieb, 1998, Lett, 2000).

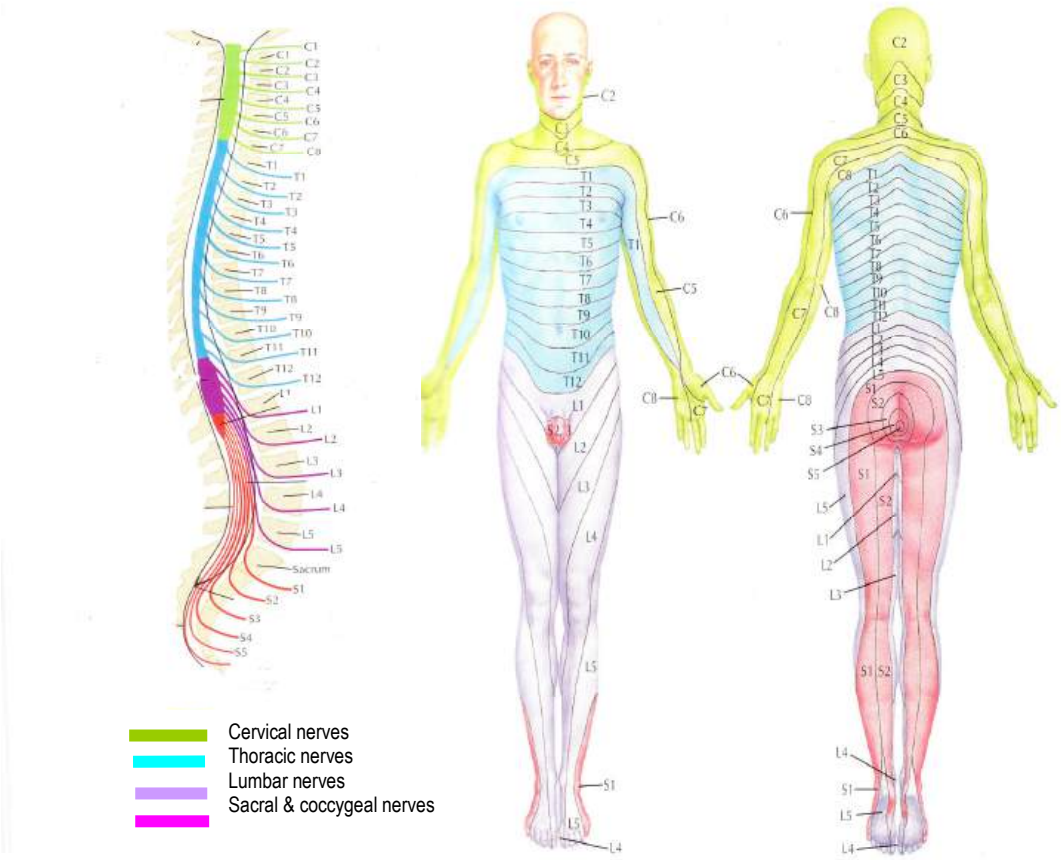


Figure 1.5: Adaptation of Heads zones. Defined areas of skin supplied by spinal nerves (Bear *et al.*, 2007).

In 1906, Sherrington (Kusurkar, 2004) improved upon the general understanding of the neurological system by identifying that the whole nervous system adjusted to a stimulus. He distinguished three sets of sense organs;

i. exteroceptors which are located near to the body surface and detect touch, pressure and temperature, receiving information from outside the body,

ii. interoceptors found in the epithelial cells, mainly in the viscera which are sensitive to pressure, pain and stretching and the internal body chemistry, and

iii. proprioceptors which are found mostly in the musculoskeletal system, making them particularly sensitive to stretch, movement, pressure and position in space (Kusurkar, 2004).

1.2.7 History of modern reflexology

According to Dougans (1996) Cornelius was the first to apply massage to 'reflex zones' on the body having learnt through his own ill-health that firm pressure on a tender point was more beneficial than a general massage. Sensitivity to pressure has been observed in other areas of CAM and is well recognised in myofascial trigger point therapy (Davies and Davies, 2004, Dommerholt *et al.*, 2006) and Osteopathy (Washington *et al.*, 2003). Bron *et al.* (2007) reported that trigger points are hyper-irritable regions found within skeletal muscle associated with nodules of hypersensitivity, and are palpable in a taut band of muscle. Such areas are characteristic of referred pain and are thought to become sensitive when an organ becomes diseased (Lett, 2000). Shah (1999) has proposed this same theory when discussing stimulation of acupressure points.

Marquardt (1984), Tay and Eu Hooi (1988) and Dougans (2005), have all suggested that reflexology evolved from the Chinese traditional therapies of acupuncture and acupressure. The Japanese art of acupressure is referred to as shiatsu and there appear to be many similarities in the way the treatments for acupressure, reflex therapy, reflex zone therapy, compression therapy, reflexology, auriculotherapy and shiatsu are performed.

Historically the development of zone therapy is connected with FitzGerald after he observed that pressure on various body parts could anaesthetise another area within the same 'zone' (Lust, 1928, Issel, 1996, Lett, 2000). The zones shown in Figure 1.6 bear a resemblance to the zones of hyperalgesia, now known as dermatomes, which were originally identified by Head(1893). There are reports that they correspond longitudinally to the ten segments of the fingers and toes (Lust, 1928). FitzGerald is said to have postulated that massage to an area within a zone could produce physiological improvement in an organ within the same zone, no matter how remote it was to the organ being treated. The Modern Institute of Reflexology (2008b) has recorded that although he was scientifically trained, FitzGerald could not explain how zone therapy worked and that he was aware there were no anatomical relationships between the nerves on the big toe and those on the thumb. He did however write that "*a pressure on a particular area of the right hand will excite pain*

in a corn or bunion or other painful conditions in the corresponding area of the toe" but scientific validation of this statement is not reported.

Lust (1928) wrote that FitzGerald used implements such as metal combs, pegs and elastic bands to produce feelings of numbness and instil physiological normality. Similarly in an expansion of Head's work, FitzGerald is said to have demonstrated that an application of pressure to an area of skin or mucous membrane within one of the ten zones could effect a change in an internal organ associated with that zone (Lett, 2000).

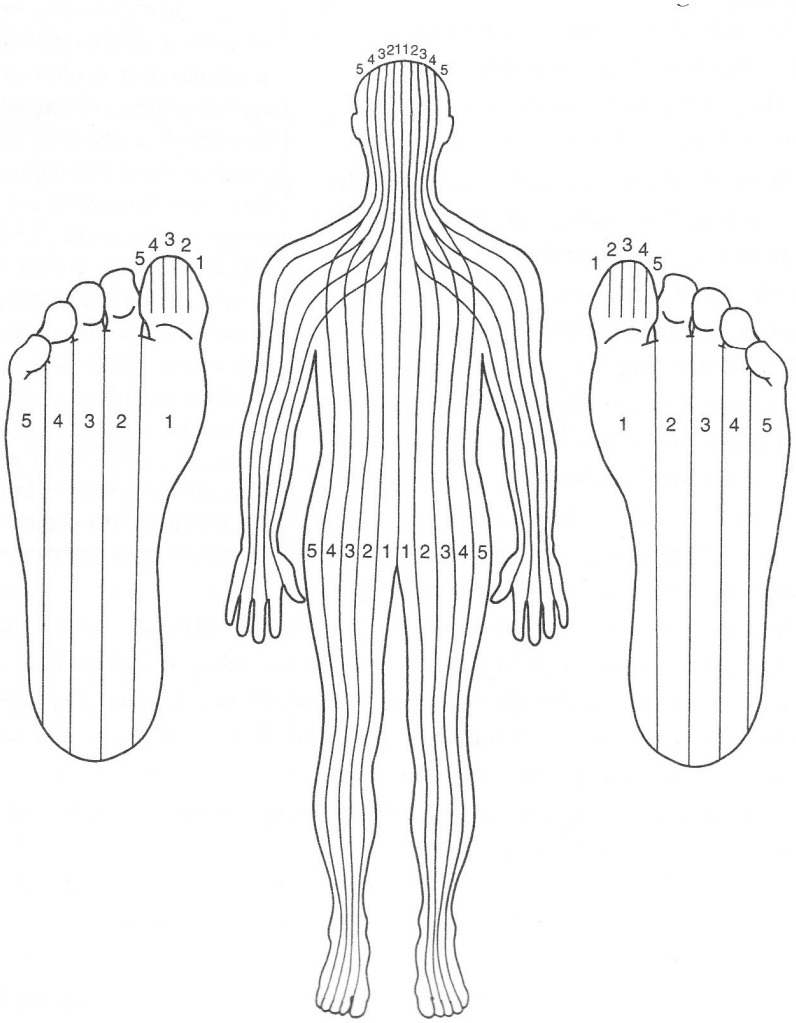


Figure 1.6: Schematic diagram of FitzGerald's zone map. The body is divided into longitudinal lines (zones), either side of the medial body. Reproduced with kind permission from Lynne Booth (Booth, 2000)

Riley is reported to have used zone therapy extensively in his practice as a body worker and was promoted as one of the greatest developers of this work (Issel, 1996) identifying reflex points on the back, hands, feet and ears. Unlike FitzGerald, Riley is said to have found no use for tools such as metal combs, pegs or elastic bands, but instead developed a technique known today as hook work (Byers, 1990). Ingham is said to have used Riley's techniques of applied pressure in her work as a physiotherapist (Norman and Cowan, 1988). She proposed that the application of pressure to tender areas on the feet was an important aspect of zone therapy. Ingham (1984) believed that tender areas contained crystal deposits similar to 'grains of sand' and that by applying a constant pressure on these tender areas, one could break down these crystals and increase blood circulation. Lett (2000) however described these as 'minute particles similar to sand or grit under the skin' and referred to them as part of the common tissue tonus. Ingham (1984) has stated that it was the pressure of the thumb coming into contact with the crystals at nerve endings that caused pain, which in turn was the result of an imbalance in the body with which the reflex point related. This is a hypothesis that is still held by many today, but there is no scientific evidence to support the suggestion that crystal deposits exist in the nerve endings, or that a painful reflex corresponds with an imbalance in an associated organ.

One of the known 'formal' crystal deposits in tissue can arise from either over production of uric acid which may cause gout, or a reduced ability by the kidneys to eliminate uric acid which may cause stone formation (Murray and Pizzorno, 1998). Schumacher (2008) reported that elevated serum levels of urate, which can result in the deposition of urate crystals into the joint space cause such inflammatory responses referred to as gout but there is nothing in his pathogenesis of gout that suggests they may be dispersed by any form of compression therapy. Dieppe (2008) confirms this by reporting that he had never observed uric acid crystals in the foot sole and they are only apparent in certain circumstances in the body which may be related to gout. He went on to say that it was preposterous to think that one could dissolve these crystals merely by rubbing. There is no evidence in any of the medical literature to support the theory of crystal deposits in the foot, nor that any such crystals can be eliminated by pressure or rubbing. Gout, stones and calcium pyrophosphate dehydrate crystal deposition disease, a form of rheumatoid arthritis

(Frediani *et al.*, 2005) are the only known forms of crystal deposits in the tissues of the human body and the presence of these is managed through conservative pharmacological means (Underwood, 2006) and not by any form of pressure management. Ingham's idea that pressure on the feet can grind down crystal deposits found in the ends of nerves (Ingham, 1984) is without any form of scientific basis and has no place in reflexology .

Froneberg has produced the most recent developmental work in reflexology (Lett, 2000). A technique known as nerve reflex point therapy was established for innervations of the spine and muscles (N. Pauly, personal communication, October 10, 2007). Froneberg postulated that the spine and the spinal cord were the central axis in the link between motor and visceral dysfunction and developed special nerve reflex points for the entire nervous system. In 1986 Pauly (2004) further developed this system with the addition of massage and manipulation techniques. The theory was more evidence-based and worked within the principles of pain science (Veldhuizen and Pauly, 2001). The principal objective of this therapy was to elicit a response within the central, peripheral and autonomic nervous system from vibro-tactile stimulation in the periost of the foot (N. Pauly, personal communication, March 31, 2009).

1.2.8 Reflexology Charts

The reflexology charts employed today originated from the work of FitzGerald when he divided the body into ten longitudinal zones (Issel, 1996). Riley's first book, 'Zone Therapy Simplified' was published in 1919 and historical evidence reported that the first drawings of reflex points on the feet were produced sometime between 1916 and 1920 (Issel, 1996). Riley is said to have introduced an additional eight horizontal lines to accompany FitzGerald's ten longitudinal lines. These horizontal lines segmented the feet so that the organ placement was easier to locate. A diagrammatic representation of these points is shown in Figure 1.7. Riley's early foot charts did not indicate the internal organs visually, as shown in the diagram, merely the organ locations were depicted by words.

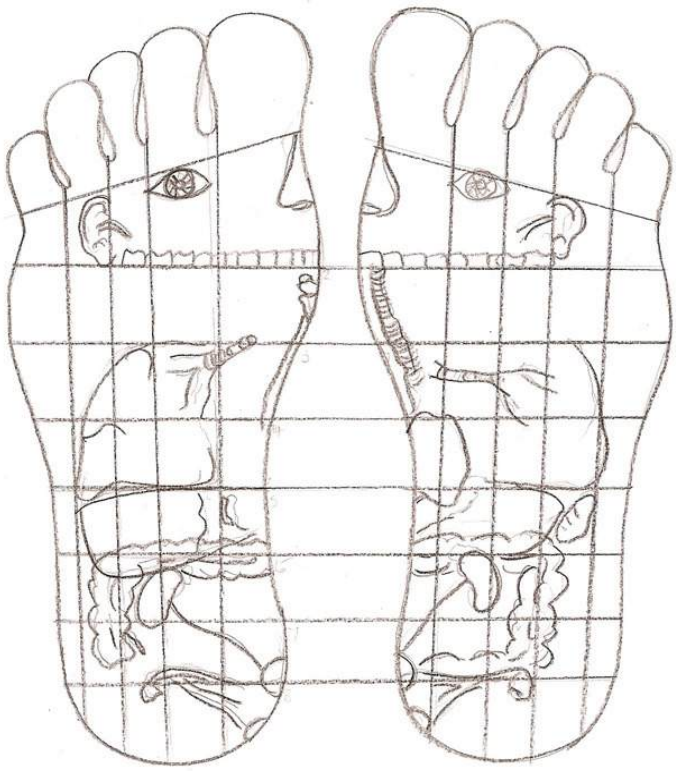


Figure 1.7: Diagrammatic adaptation of Rileys early drawing of the reflex points on the foot sole (Issel, 1996).

Ingham was credited with the refinement of Riley's original reflexology charts and there is some evidence from the drawings shown in Figures 1.8 and 1.9 that she had already proposed the location of reflexes for the neck, sinuses and some parts of the digestive system. Ingham's early charts have been revised and updated by her nephew and Figure 1.10 shows the anatomical locations of organs on the feet in the revised chart (Byers, 1990) in use today.

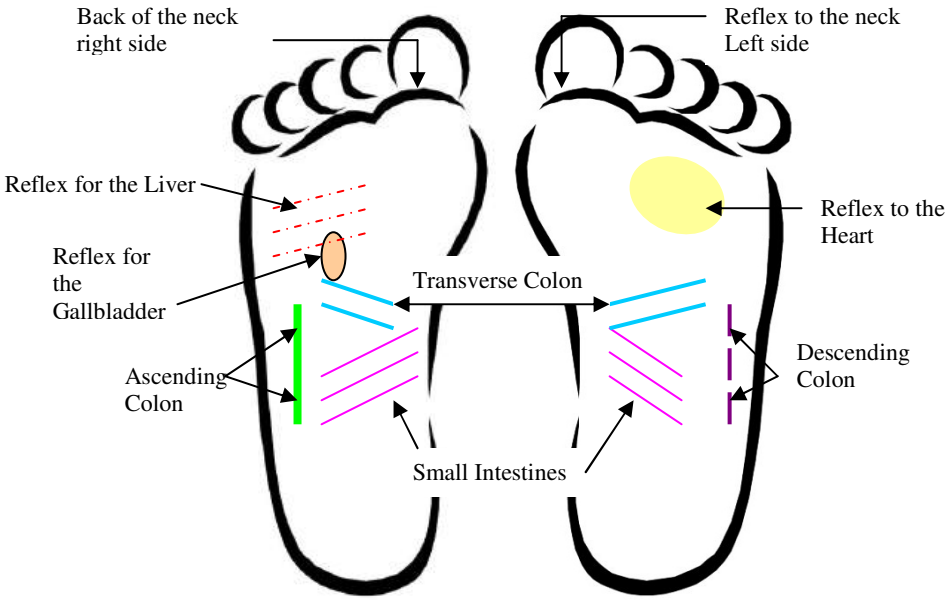


Figure 1.8: Schematic diagram of one of Ingham's original drawings. Diagram shows the representations for some of the internal organs on the foot sole. Adapted from an online image at (Modern Institute of Reflexology, 2008a)

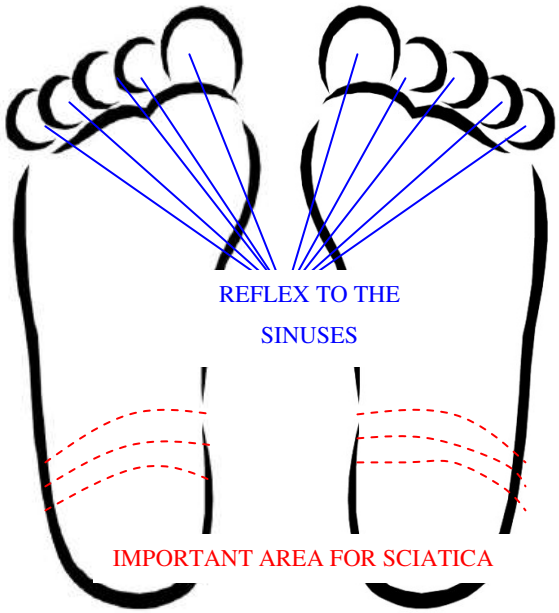


Figure 1.9: Schematic drawing for Ingham's depiction of the reflexes for the sinuses and sciatic areas. Adapted from an online image at (Modern Institute of Reflexology, 2008a)

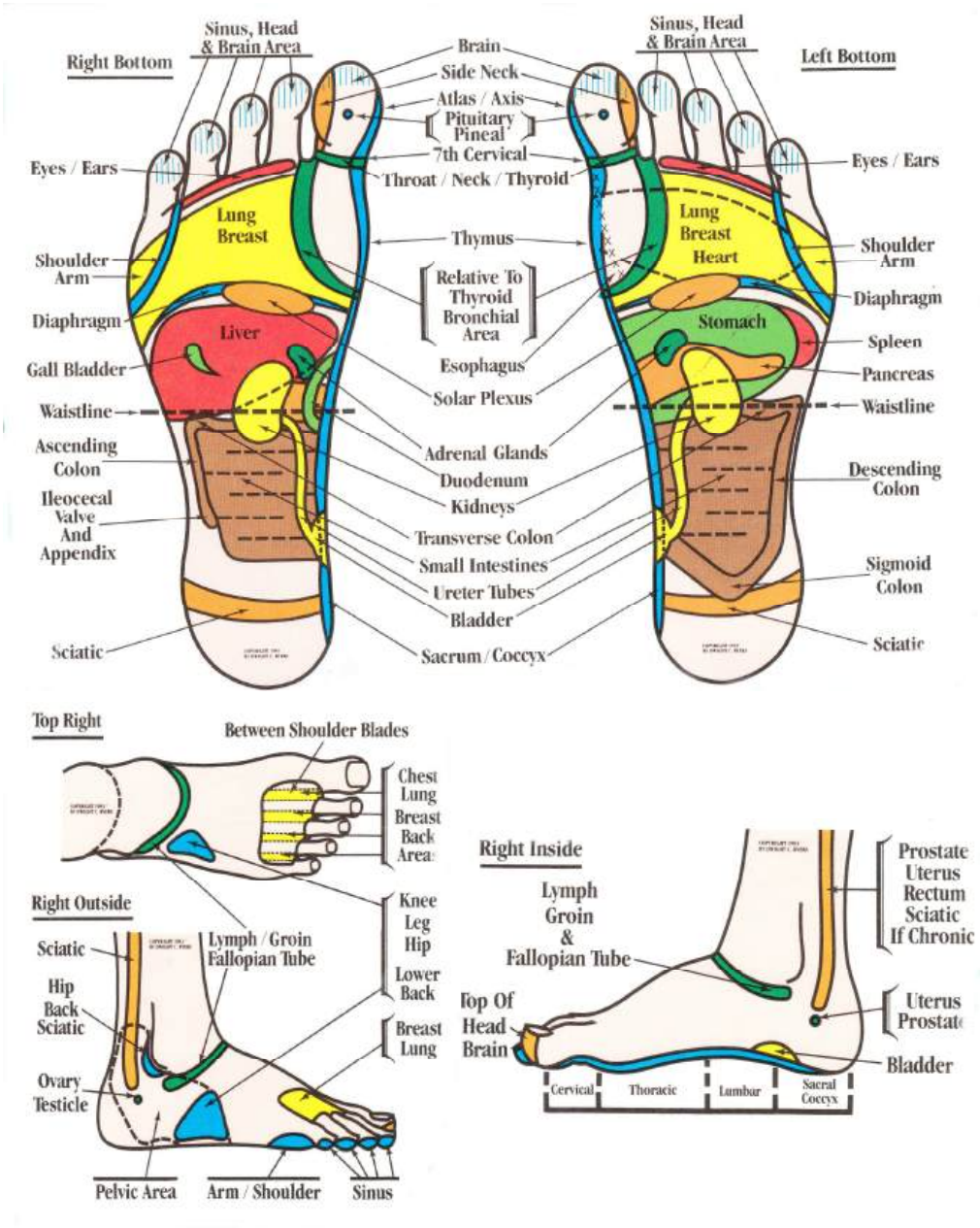


Figure 1.10: International Institute of Reflexology (IIR) foot chart. A cropped example of the chart used by the IIR showing anatomical representations of organ locations on the feet (Byers, 1990).

Marquardt (1984) further modified the reflex maps of the body on the feet. She provided greater precision to the work of reflex zone therapy by introducing transverse zones, refining work previously carried out by Riley (Lett, 2000, Issel, 1996). Marquardts three transverse zone areas are shown in Figure 1.11 and represent the upper, middle and lower torso with corresponding landmarks on the feet shown beneath the phalanges at the head of the metatarsals, at the fifth metatarsal tuberosity joining the cuneiform bones and at the start of the calcaneus.

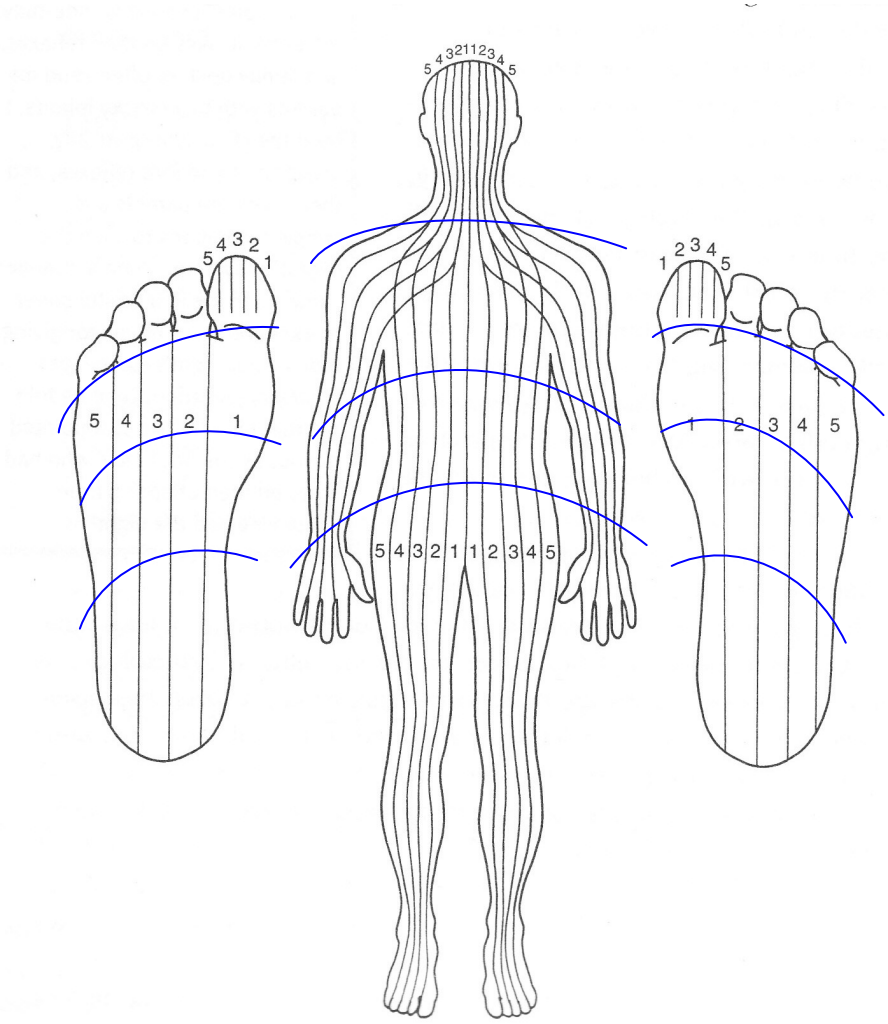


Figure 1.11: Schematic diagram of the transverse reflex zones, (shown in blue). Described in (Marquardt, 1984), adapted with kind permission from (Booth, 2000).

The transverse zones suggested by Marquardt are similar to the three cavities indicated in Traditional Chinese Medicine (Maciocia, 1989) although there is no evidence that this relationship was intentional. Figure 1.12 shows the anatomical locations suggested by Marquardt but there is still no direct evidence that confirms the accuracy of any of these charts.

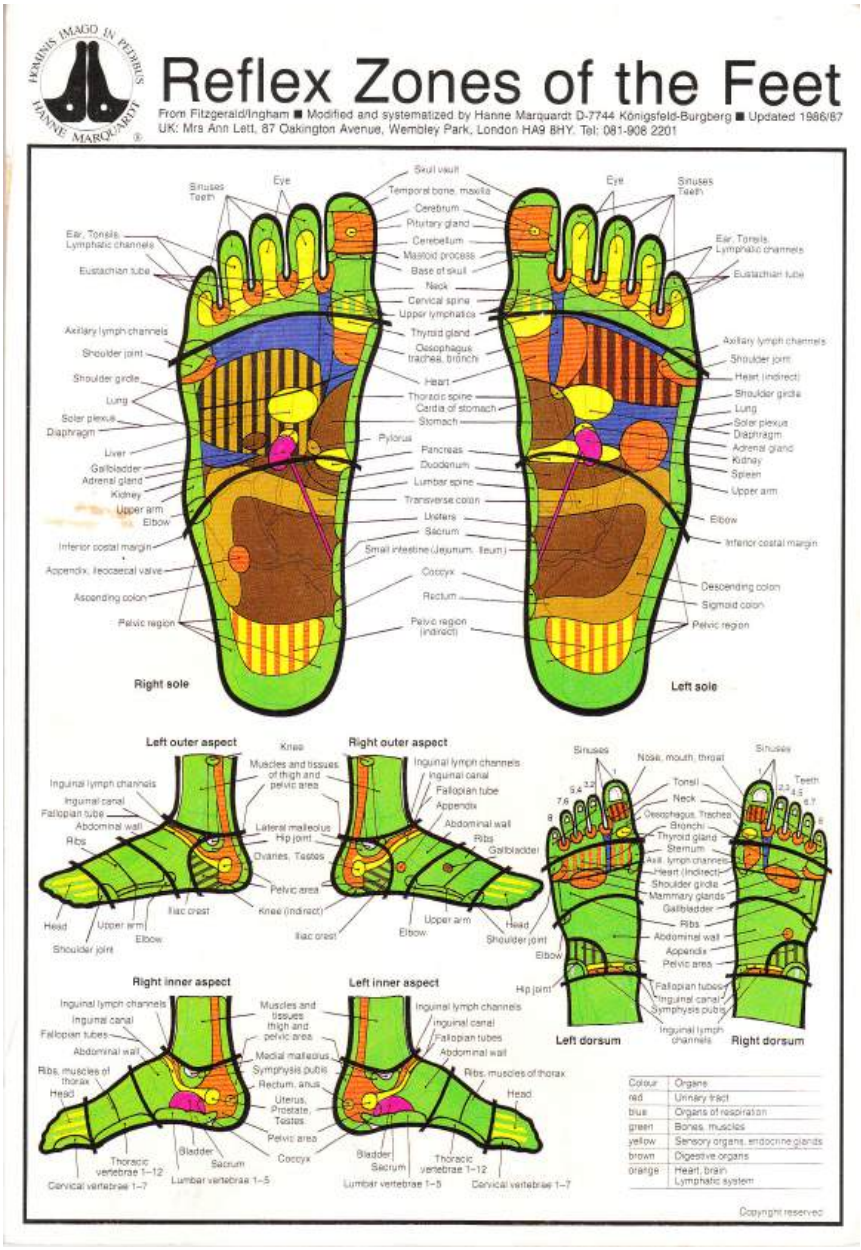


Figure 1.12: Marquardt's reflex zones of the feet. Updated in 1986/7 (Marquardt). Image gifted from Ann Lett.

1.2.9 Questioning the accuracy of reflexology charts

Confirming what FitzGerald is reported to have said, anatomists have also suggested that there are no direct connections between the soles of the feet and the organs of the body (Ernst, 2004b, Barrett, 2008). The somatosensory map of the brain shown in Figure 1.13 indicates that the feet occupy quite a proportionate amount of space along the sensory cortex and whilst there is no clear evidence to be found in the literature, one reflexology text reports more than 7,200 nerve endings in the foot

(Byers, 1990), whilst another postulates 72,000 (Wagner, 1987). Many physiology textbooks depict Penfields homunculus or 'little man' showing the hands, feet and lips as major somatosensory regions within the brain (Marieb, 1998, Pocock and Richards, 2006, Bear *et al.*, 2007). Nakamura (1998) has confirmed that the distorted perception of the human sensory system is located in the post-central gyrus and arranged along the central sulcus. Figure 1.13 shows a diagram of the brain areas devoted to the area of sensitivity and control one has over each part. The map indicates that it is the hands and lips that have the most sensory receptors, but the feet also occupy a larger than average section of the somatosensory cortex.

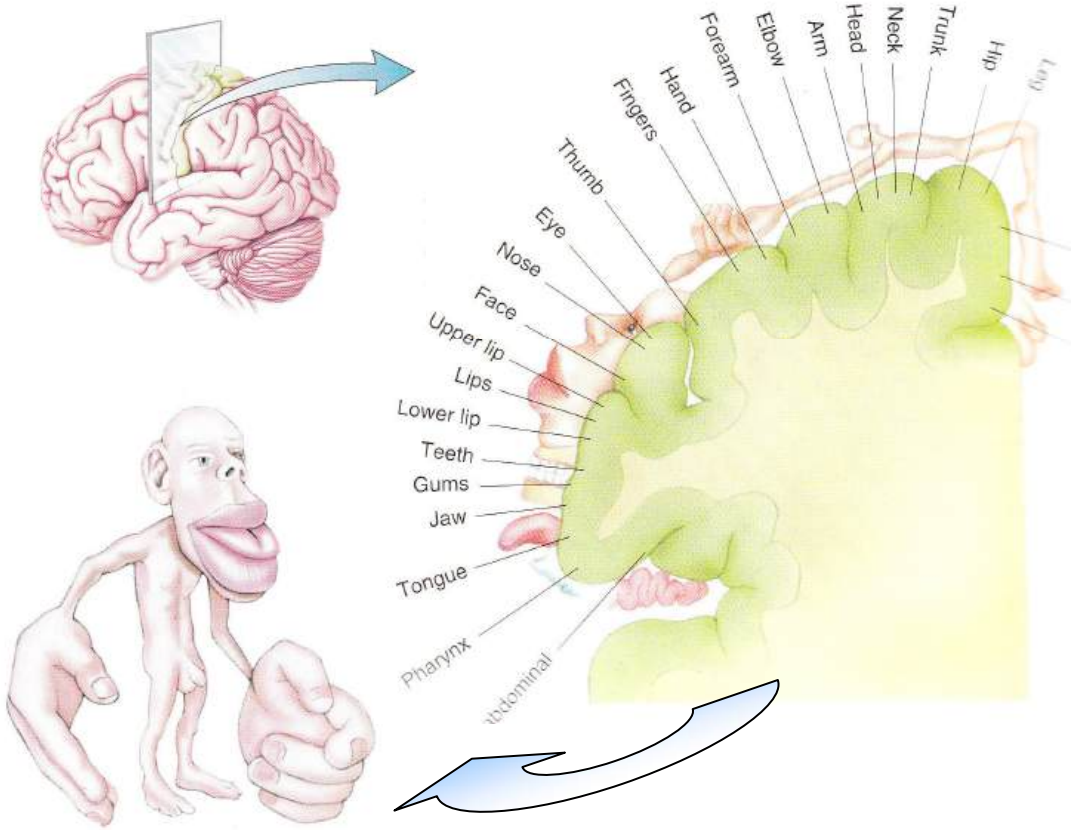


Figure 1.13: Representative diagram of Penfields homunculus. The diagram illustrates the somatosensory areas of the brain, the proportional brain areas and the representation of those areas on man. Adapted from (Bear *et al.*, 2007)

In 1994 Omura (1994) carried out a study using a patented method referred to as Bi-Digital O-ring testing to evaluate the accuracy of reflexology charts. This method of testing is classified as a form of applied kinesiology, or sometimes referred to as opposing muscle strength. The proposed hypothesis is that organs of the same molecular structure resonate with one another via electromagnetic fields surrounding

the body, but Barrett (2004) suggested that this work cannot be regarded seriously as there is no scientific evidence to support it. .

White *et al.* (2000) have investigated the accuracy of reflexology charts as a diagnostic tool. Three reflexologists, who were blinded to the patients' condition, examined eighteen patients, each with one or more of a number of specified conditions. The reflexologists were permitted to examine the feet, but were not permitted to treat the patients. The results provided no evidence to support reflexology as a diagnostic tool. However with an excess of 22,000 (Tanner, 2007) reflexologists in the UK alone, the small number of practitioners used and the use of a single treatment without any recourse to re-evaluate a reflex point, does not provide great credibility for this study.

In an blood-oxygen-level-dependent functional magnetic resonance imaging (BOLD fMRI) study by Tang *et al.* (2005b) the reflex point on the left foot at the base of the second and third toes, indicated as the eye/ear reflex on charts, was stimulated during scanning. BOLD fMRI uses the principle of haemodynamics and involves observing areas in the brain that become more active as a result of increased blood flow to a region of increased neural activity (Bear *et al.*, 2007). Results of the study did not indicate any significant activity in the visual cortex although there was a strong activation in the left insula region, an area associated with emotions, pain and visceral function, and the left frontal region of the brain, associated with memory and higher order function. Of interest however, is that the paper reported that these regions had previously been identified in acupuncture trials as successful points for stimulation in stroke patients with visual deficits. In another trial by Tang *et al.* (2006) the reflex points for the adrenal glands were stimulated with a 1cm diameter, semi-spherical massage cap, using a 2 kg pressure, and compared with electro-acupuncture stimulation to the kidney 1 point. Results of this study also located responses localized mainly within the insula region. The authors suggested that results from the trial confirmed that reflexology had the same function as acupuncture.

In a co-relational study where two separate examinations were carried out on 80 patients, Raz *et al.* (2003) proposed that reflexologists were able to reliably diagnose

at a systemic level (structural). Of the eighteen body structures examined, fourteen of those examined by reflexologists correlated with conventional medical diagnosis.

Zimlichman *et al.* (2005) used a Medex device to measure the electrical skin impedance of 24 pre-determined dermal zones on the feet and hands. The device measures changes in electrical potential and impedance of cells, thought to correspond to various disorders of internal organs (Medex Screen, 2009). Areas of skin with low electrical skin impedance have been used to locate placement of acupuncture needles and to apply acupressure techniques for many years (Tedeschi, 2000). Furthermore skin impedance at acupuncture points has been used as a diagnostic and therapeutic aid for more than 50 years (Colbert *et al.*, 2007). The purpose of the study was to establish if the results of the physician using the Medex system matched diagnosis performed by physicians without the equipment. The Medex device is termed a neuroreflexology based screening test. It is said to be based on the rationale that each internal organ has a representative dermal zone on the trunk and limbs, *vis a vis* reflexology. This hypothesis is not new and can be traced back to the early days of neuroscience when Head (1893) first postulated zones of hyperalgesia. According to the hypothesis any pathology of an organ or body system directly affects its corresponding dermal zone. The outcome of the study in which 150 people were observed with varying non-specific pathologies, demonstrated a significant correlation ($p<0.01$) between the dermal zones of the feet and hands and pathology in various organs and systems of the body.

Although there is little empirical evidence for reflexology as a form of diagnosis, the aforementioned studies may help expand the existing knowledge with regard to anatomical representation of organs on the feet as they are presented in modern reflexology charts.

1.3 THEORETICAL BASIS OF REFLEXOLOGY IN PAIN MANAGEMENT

1.3.1 Pressure and Sensory Receptors

The true mechanism of action of reflexology has not, as yet, been clinically demonstrated, but it appears to work *via* sensory receptors within the nervous system (Marquardt, 1984, Lett, 2000, Tiran and Chummun, 2005). The body as a whole responds to a number of chemical exchanges instigated by the movement of ions in and out of the cells. Reflexology is a touch based therapy and Tiran and Chummum (2005) have proposed that it produces peripheral vasodilation through which it may remove local toxins. Furthermore it was proposed that pain sensation is reduced in reflexology *via* the gate control mechanism (Tiran, 2002a, Stephenson and Dalton, 2003, Tiran and Chummun, 2005). The 'gate control' theory was first postulated by Melzack and Wall (1965) and proposed that the physical perception of pain was not a direct result of stimulating small pain receptors such as the Aδ and C nerve fibres in the skin, rather that pain was modulated by larger non-pain (Aβ) fibres that closed the transmission signal (gate) to the brain. These modulating receptors are said to interfere with the pain signal at the level of the spinal cord by releasing natural endorphins (Bear *et al.*, 2007).

1.3.2 Skin and Sensory Receptors

The feet are rich in receptors that are extremely responsive to a variety of environmental and sensory stimuli. Mechanoreceptors are a type of receptor embedded within the skin throughout the body (Pocock and Richards, 2006) and are modified ends of sensory nerve fibres (Ganong, 1997) which are distributed within the dermal layers:

a) In the superficial layer of the skin between the dermis and epidermis, merkel discs and some free nerve endings respond to continued light touch. They are slowly adapting receptors that produce prolonged repetitive nerve impulses over the entire duration of a stimulus, also known as tonic receptors.
b) Meissner corpuscles lay nearer the skin surface, just beneath the epidermal layer in smooth skin, at a distance of about 0.7 mm (Bear *et al.*, 2007) and are found on the palms of the hands and the soles of the feet. These touch

receptors detect change in texture and respond to light touch and slow vibration. They are rapidly adapting phasic receptors that have the ability to adapt to constant or static stimuli at a fast rate.

c) Ruffini corpuscles in the mid dermal layers of hairy skin respond to deep pressure and stretch and have an important role to play in proprioception. They are slowly adapting tonic mechanoreceptors.
d) Pacinian corpuscles lie deep within the dermis at a depth of approximately 2mm (Snell, 2001, Singh, 2006, Bear *et al.*, 2007), within the subcutaneous layers of skin. They are highly sensitive to deep pressure and respond best to vibration rather than to prolonged pressures. Pacinian corpuscles are the only other phasic receptor and they can respond to up to 600 stimuli per second (Snell, 2001) from a single skin indentation (Pocock and Richards, 2006), making them rapidly adapting mechanoreceptors that produce a nerve impulse at the beginning and end of the stimulus.
e) Free nerve endings are the only nerve endings exclusively able to detect pain in addition to touch, pressure and temperature (Snell, 2001) and are located throughout the body between the epithelial cells.

Mechanoreceptors vary in their size and position within the dermal layers, as shown in Figure 1.14 and are classed as either rapidly or slowing adapting. The adaptation rate refers to the speed at which the receptors respond to a stimulus and then return to their resting states. Rapidly adapting receptors propagate an action potential (nerve impulse) at the onset and offset of a stimulus, whilst the slowly adapting receptors propagate a steady flow of action potentials for the entire duration of the stimulus (Pocock and Richards, 2006).

The area in which a stimulus can excite a cell is known as its receptive field (Snell, 2001) and two types exist: -

i) Type I (Merkel and Meissner) have a small receptive field, and can detect finite detail within two small receptive areas, this is known as two point discrimination whilst,
ii) Type II (Pacinian and Ruffini) has a larger receptive field and only sense stimuli when it occurs directly within its receptive field.

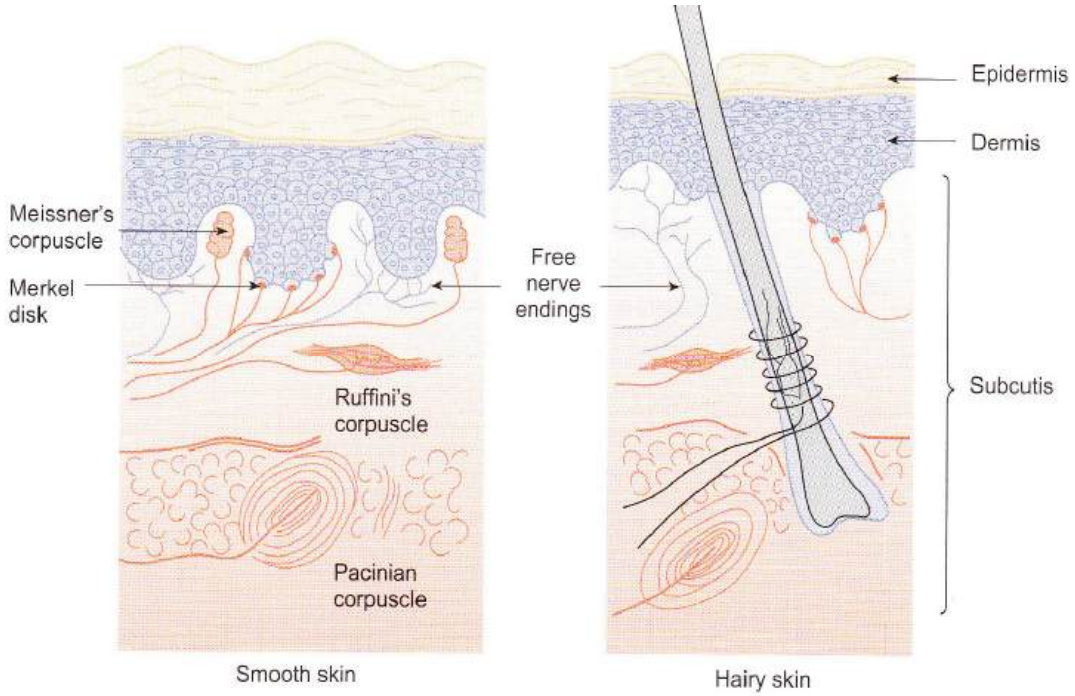


Figure 1.14: Skin receptors found in smooth (glabrous) and hairy skin. Merkels disk, Meissner's corpuscle, Pacinian corpuscle and free nerve endings. Source: (Pocock and Richards, 2006).

Kennedy and Inglis (2002) have suggested that mechanoreceptors in the soles of the feet may behave differently from those found in the glabrous skin of the hand, and that the foot may have elevated activation thresholds. Further they indicated that 70% of the skin receptors found in the sole of the foot are rapidly adapting with randomly distributed receptive fields, which are three times greater than those in the hand. They suggested that the wide dispersal of receptors in the foot sole was an indicator of their ability to sense contact pressures.

A large part of reflexology work is carried out on the plantar surface of the foot and the work of Kennedy and Inglis (2002) may be a useful identifier alluding to the hypothesis of its mechanism of action. The tendency for large receptive fields in the sole of the foot and the high proportion of pacinian corpuscles makes them ideal responders to the caterpillar on/off walking technique used during reflexology stimulation. Pacinian corpuscles generate depolarising potentials, known as receptor potentials. They are similar to an excitatory pre-synaptic potential seen at neuronal synapses (Ganong, 1997) except that they are non-propagating. As the pressure on the corpuscle increases they initiate an action potential in a sensory nerve. Activation of an action potential across the cell membrane activates neural afferent fibres to ascend the spinal cord to the brain. This sensory activation system initiates further

neuronal responses which may confirm the hypothesis proposed by Tiran and Chummum (2005) and Stephenson and Dalton (2003) for a gating effect, but scientific validation for the 'gating' mechanism in reflexology, currently remains elusive.

1.4 REFLEXOLOGY IN PRACTICE

Thomas (2001) reported that reflexology usage had increased from 0.4% in 1993 to 2.4% in 1998, and that 5.4% of this number were lifetime users of the therapy. Of the visits to aromatherapists and reflexologists 25% were related to musculoskeletal problems (Vickers, 2000, Long *et al.*, 2001, Smallwood, 2005). In Denmark, Launso *et al*. (1995) found reflexology to be the therapy most often accessed with 15% of the population using reflexology in 1994, whilst in the UK Wilkinson (2002) reported that 12% of the population accessed reflexology on a regular basis which represents an increase on the 1993 statistic of 9.6%. Perry and Dowrick (2000) stated that 8% of GPs believed there was no theoretical basis for reflexology compared with 50% who supported the theoretical basis of acupuncture and yet reflexology is considered a development of acupuncture and acupressure (Tay and Eu Hooi, 1988). Despite these data, considerable scepticism remains surrounding reflexology (Perry and Dowrick, 2000).

1.4.1 Assessing the patient for treatment

When a client makes an initial visit to a reflexologist all areas of the feet are assessed. The first visit is an exploratory one and enables the practitioner to develop a treatment plan. The most effective treatment plan requires the client to attend a minimum of six times, and whilst ten sessions, given twice weekly for five weeks is thought to be more beneficial (Lett, 2000), there is no scientific validation for this suggestion. The remit of the practitioner is not to diagnose a medical condition but to refer the client to an orthodox medical practitioner if they are not responding to the treatment or their condition worsens.

Reflexology is classified as a bodywork intervention (Parliament, 2000), and is predominantly a touch-based therapy. Touch is an extremely intimate experience

and one that stimulates a large array of chemical processes within the plasma membrane, including the release of endorphins (Stevensen, 1995, Pert, 1997). Touch adds a powerful therapeutic ingredient that emphasises a more open and intimate relationship between the client and therapist and it is thought to engender a safe, non-judgemental environment (Mackereth, 2005). Fishman *et al.* (1994) have demonstrated an increased level of relaxation and a reduction in the level of arousal following touch. This element of reflexology may also be the reason why so many clients feel able to disclose their personal anxieties in a treatment environment (Mackereth *et al.*, 2008) providing the perception of a sense of caring and comfort (Gleeson and Timmins, 2005) from the therapist.

Reflexology has been established as a useful treatment in palliative care (Lett, 2000, Hodkinson and Williams, 2002, Mackereth, 2005) and for people with mental health problems (Knowles and Higgins, 2002, Hodgson and Andersen, 2008) and during pregnancy and birth (Clausen and Moller, 1996, Lett, 2000, Tiran, 2002b, Mollart, 2003, McNeill *et al.*, 2006). It has also been implicated in the relief of pre-menstrual syndrome (Oleson and Flocco, 1993, Hansen *et al.*, 1995), menopausal symptoms (Williamson *et al.*, 2002) and the stress and anxiety of life-limiting conditions (Quattrin *et al.*, 2006, Stephenson *et al.*, 2007).

1.5 SCIENTIFIC EVALUATION OF REFLEXOLOGY

The benefits of reflexology have previously been attributed to the relationship therapeutic relationship (Pollo *et al.*, 2003) and the placebo effect of treatment (Hewer, 1983, Tiran, 2002a, Goffaux *et al.*, 2007), but there is now a growing body of evidence to suggest that efficacy may be related to a variety of physiological changes within the body (Tiran, 2002a, Tiran and Chummun, 2005). It is certainly well known that the large myelinated Aβ nerve fibres, relating to touch, ascend the spinal column much faster than the smaller Aδ and C-fibres relating to pain (Ganong, 1997) and that massaging a painful area can rapidly enhance the descending pain signals to suppress the pain sensation (Haldemann and Hooper, 1999).

There is much discussion in the literature on the relationship between stress, anxiety and pain levels (Riley *et al.*, 1999, Keefe *et al.*, 2004, Keefe and Porter, 2007) and

previous studies have analysed the effects of reflexology in these areas (Stephenson *et al.*, 2000, Stephenson *et al.*, 2003, Stephenson *et al.*, 2007). The examples shown in Table 1.1 list the developments in the way the therapy is being used and researched within clinical practice. Many CAM research studies lack sufficient power (Booth, 1997), are void of any type of control (Launso *et al.*, 1999), and lack randomisation (Hayes and Cox, 2000) or blinding (Stephenson *et al.*, 2007) which affects the scientific evaluation of data that may have been attributed to the treatment. However it is notably difficult to introduce controls in many touch-based therapies, as the physiology of touch alone can engender both physiological and psychological change (Gleeson and Timmins, 2005, Bufalari *et al.*, 2007, Malville *et al.*, 2008). It may be possible to blind the subjects in some instances, but this is more difficult with the practitioner involved in administering a procedure (Carroll *et al.*, 1996).

Table 1.1 provides details of scientific evaluation of clinical studies in reflexology and their outcomes. The condition for which the study was established, the amount and type of reflexology administered as well as controls are summarised in the table.

Table 1.1: Summary of selected studies for reflexology, reflex zone therapy and foot massage in clinical treatments

Condition	Experimental Design	Treatment	Control	Outcome measures	Results	Comment	Ref
Primary inertia during labour	RCT (n=99)	Foot reflex therapy for 30mins x 2 with 30min gap between treatments	Usual care	Syntocinon drip usage. Cervical dilation ratio	66% of control group received syntocinon drip compared with 45% in reflex group ($p<0.04$). Reflex group had > change in cervix dilation $p<0.002$	Study demonstrates an ability to progress labour and may prove beneficial in cases of primary inertia (dilation <3.7cm) = failure to progress labour.	(Clausen and Moller, 1996)
Baroreceptor reflex sensitivity, blood pressure and sinus arrhythmia	Single blind study, randomly assigned (n=24)	Reflexology or foot massage	No treatment	Baroreceptor reflexes (BRS), blood pressure (BP) and sinus arrhythmia (SA).	60% reduction in BRS compared to 50% in control, non-significant.	Treatments not sufficiently different to provide accurate results. Needs repeating with larger numbers and a non-effective control treatment.	(Frankel, 1997)
Various orthopaedic related conditions, such as arthritis	Case study n=7	6 wks of vertical reflexology administered 1/wk. + subjects were able to self-administer vertical hand reflexology on an ongoing basis.	None	Decrease in pain, increase in mobility	60% improvement lasting > 2mths after final treatment.	Differs to conventional reflexology. Performed on dorsal surface of foot/hand only. Lacks a control, and could be the result of general interaction, rather than treatment effect. Average age of the cohort (80 years).	(Booth, 1997)

Condition	Experimental Design	Treatment	Control	Outcome measures	Results	Comment	Ref
Recovery after total knee replacement	Preliminary study (n=29)	Morrell reflexology 3x/wk until discharge Placebo group received reflexology to unrelated area, e.g. avoided knees	No treatment	VAS pain scores, analgesic consumption.	No difference between treatment group and placebo group. No differences in analgesic consumption or any increase in recovery rate in any group. There was an increase in patient comfort, probably due to the relaxation response.	The light touch of Morrell reflexology may have been insufficient to trigger descending pain pathways. This research was ongoing with a larger cohort but to date nothing further has been published.	(Evans *et al.*, 1998)
Migraine/ tension headache	Exploratory/ Prospective study (n=220)	Regular reflexology by chosen therapist for 6 months	None	Headache diaries, questionnaires & qualitative interviews	23% experienced no further recurrence of symptoms, 55% experienced relief and. 19% stopped meds.	Patients' change in lifestyle could have affected outcomes or could have been the result of the natural course of condition.	(Launso *et al.*, 1999)
Renal blood flow	RCT double blind (n=32)	Treatment group received a total of 8 minutes of reflexology to left kidney reflex.	Placebo group received reflexology to eye/ear reflex.	Colour Doppler sonography	Reflexology has the ability to effect a change in blood flow through the kidneys.	Reflexology stimulation to the foot sole may have been sufficient to increase blood flow regardless of the area treated.	(Sudmeier *et al.*, 1999)
Stress reduction	Quasi-experimental repeated measures (n=25)	2 - 3 sessions of 5-mins foot massage per patient	None	Heart rate, peripheral oxygen saturation, mean arterial blood pressure and respiration	Significant decrease in heart rate, respirations and mean arterial blood pressure.	Results were transient and may be attributable to the relaxation response or simply additional care.	(Hayes and Cox, 2000)

Condition	Experimental Design	Treatment	Control	Outcome measures	Results	Comment	Ref
Anxiety and pain in breast and lung cancer	Quasi-experimental pre/post crossover (n=23)	A 30 minute treatment session in which 15 minutes was dedicated to reflexology to the specific pain site, 10 minutes to relaxation techniques and 5 minutes to general foot massage.	No treatment	VAS for anxiety and short-form McGill pain questionnaire (SFMPQ) for measuring pain and pain intensity.	Significant reduction in anxiety for reflexology group $p<0.01$ in breast cancer group and $p<0.02$ in lung cancer group.	Not clear what happened during the 30-minute control, therapist was not present, so results could have been attributed to the contact time during reflexology and personal attention. Opioid analgesia may also have been a complicating factor.	(Stephenson *et al.*, 2000)
Chronic low back pain	Pragmatic RCT (n=243)	1 hour of weekly reflexology for 6 weeks using the Morrell reflexology technique (light touch)	Usual GP care (control) and relaxation (placebo)	Questionnaires on general health, pain, functioning, coping and mood, completed before/after treatment and at 6mths follow-up	No significant differences on primary outcome measures of pain and functioning. Pain reduced across all groups but there was a tendency for greater reduction in pain for reflexology group.	Reflexology did not follow a specific treatment protocol and was therefore open to variances in the ability of the therapist to affect the best treatment outcome. As pain is extremely subjective other factors could have influenced outcomes.	(Poole, 2001)
Multiple Sclerosis	Prospective RCT (n=71)	11wks reflexology and calf massage for 45 minutes.	Non-specific calf massage only	Parasthesia intensity, urinary symptoms, muscle strength and spasticity at start of study, following 6wks of treatment, at 11wks and at 3 month follow-up.	A significant decrease in intensity of parasthesia was noted in reflexology group $p<0.04$ and remained at 3month follow-up. Significant difference in urinary symptoms and spasticitiy $p<0.03$.	No significant improvement detected in the control group, so this was a useful study for those seeking CAM therapies for MS. There was a high attrition rate with only 53 completing the study, which could have impacted on the results.	(Siev-Ner *et al.*, 2003)

Condition	Experimental Design	Treatment	Control	Outcome measures	Results	Comment	Ref
Anxiety in cancer patients receiving chemo-therapy	Exploratory pre test/post test comparative group (n=30)	One 30 minute reflexology session administered on $2^{nd}/3^{rd}$ chemotherapy cycle	No treatment	Speilberger State Trait Anxiety Inventory (STAI)	Significantly lower post-test state anxiety $p<0.05$	This study was preceded by a pilot study offering further observations on study methodology. It is confusing, and succinct data would help provide the reader with a better evaluation of outcome.	(Quattrin *et al.*, 2006)
Non-specific low back pain	Pilot study. RCT – patients and outcome assessor blinded (n=15	Precision reflexology x 1/wkly for 6 wks	Sham reflexology avoiding spinal reflexes	VAS for pain (primary) McGill pain quest, Roland Morris disability & SF-36 questionnaires (secondary outcome)	Improvement in VAS and McGill pain quest. No difference in RM disability or SF-36	Sham reflexology in the form of foot massage may have contaminated results due to physiological effects of touch. Biochemical assessments may have helped provide more accurate results.	(Quinn *et al.*, 2007)
Mild to moderate dementia	Experimental, repeated measures, cross over design. (n = 21)	5 mins of progressive relaxation (PMR) followed by 30 mins reflexology (1/wk for 4 weeks)	5mins PMR & 30mins friendly visits (1/wk for 4 wks)	Physiological distress measured by salivary α-amylase & observed pain.	Significant effect for reflex group on salivary α-amylase ($p<0.049$) & observed pain ($p<0.031$).	A small study but results are promising and of clinical relevance.	(Hodgson and Andersen, 2008)
Relief of phantom limb pain	Pilot study (n=10)	Five phase treatment with phases 2, 4 & 5 providing one foot/one hand reflexology	None	Pain diaries over a 30-week period.	Improvement in pain perception and intensity of phantom limb. Improved pain duration and lifestyle affect.	67% of patients continued to self treat and benefit from this treatment. A sound study using patients as practitioners and thus avoiding contamination of results due to therapist interaction.	(Brown and Lido, 2008)

1.6 REFLEXOLOGY FOR PAIN MANAGEMENT

It is not yet understood how, or if, reflexology addresses the management of pain though current opinion suggests that it works on the neurological system through the release of endogenous opioids (Stephenson and Dalton, 2003, Mackereth, 2005, Tiran and Chummun, 2005). It has been argued that the stress response is an important factor in pain conditions and that modulating pain is vital to reduce natural killer cell activity in the metastasis of cancer (Page and Ben-Eliyahu, 1997) and perhaps other immune-suppressing diseases (Melzack, 1999). There is a paucity of data for pain as a specific outcome measure in reflexology research with many simply assessing the effects on anxiety. However anxiety is an important factor related to the stress response which can have a direct affect on the immune system (Khansari *et al.*, 1990, Henry, 1992, Pocock and Richards, 2006) and this in turn may affect pain (Melzack, 1999).

CAM therapies generally, have proven to be of especial benefit to patients with life limiting conditions such as cancer (Wright *et al.*, 2002, Ross *et al.*, 2002). The literature documents that many of the associated symptoms of cancer aggravate a person's pain experience, including fear and anxiety (Wright *et al.*, 2002). Gambles *et al.* (2000) evaluated the effects of a hospice based reflexology service, using qualitative audit on patients' perceptions. Of the 46 questionnaires given out to patients, 34 were returned. Female patients accounted for 33 of the 34 patients, confirming literature reports that females are the main users of complementary therapies (Ernst and White, 2000). The study reviewed the effects of a 4-6 week treatment schedule on palliative care patients. Of the patients questioned 91% of them highlighted relaxation as the primary benefit and mentioned reduced stress and anxiety levels in their statements. Although not indicated as an outcome measure, patients reported a positive effect for pain relief, and also for the patient-therapist relationship. A positive effect on pain perception has also proven to improve coping strategies (Wright *et al.*, 2002). Gambles *et al.* (2000) reported that touch helped to improve the psyche of the patient and enabled them to cope better with their problems and circumstances. Hertenstein *et al.* (2006) claimed that humans can communicate several distinct emotions through touch, and Gambles *et al.* (2000) have also demonstrated this as an important aspect of patient care, particularly in

palliative care. It is difficult to assess whether the outcomes from this study were attributable to the reflexology or to touch and time spent in a supportive environment. Patients reported a more satisfying encounter with their complementary practitioner than with their GP, emphasising perhaps that time in a one to one relationship was an important factor in this study. Reflexology administered to this treatment group allowed practitioners to perform as they would in a normal clinical environment. This format offered the complete package of care (Mackereth, 2005) and allowed patients to relieve themselves emotionally, mentally and physically. This qualitative study made no attempt to measure anxiety, depression, or pain before or after treatment, neither was it controlled. It would have benefited from a control group of either relaxation or perhaps empathetic listening to see if results would differ. It was based on the subjective opinion of patients who underwent reflexology treatment and this may have opened it up to selection bias. Self-involvement in pain control can make a vast difference to coping with the issues of pain (Keefe *et al.*, 2004). Many participants of reflexology studies choose to take control, either knowingly or unknowingly. The cognitive evaluative aspect of pain relates to past experiences and how it affects daily life and functions (Melzack and Wall, 1965) and the ability to control ones pain experience can determine the current perception of pain. It may have transpired that as patients found many positive benefits to the reflexology treatments, these influenced their subjective statements. Blinding of the analysis of responses would also have improved the validity of the outcome. Results of questionnaires were returned to the centre in which patients received their treatment and patients may have wanted to provide positive feedback where they benefited from relationships with service providers. Thomas *et al.* (2001) reported that a positive and supportive consultation resulted in improved outcomes, which may also have influenced subjective responses.

In a quasi experimental trial by Stephenson *et al.* (2000) the effects of reflexology on 13 patients with lung cancer and 10 with breast cancer were reviewed. Outcome measures for anxiety were recorded on a visual analogue scale, a 10 cm line with verbal anchors at each end, stating “not anxious at all” to “the most anxious I have ever been”. The other outcome measure of pain utilised the short-form McGill pain questionnaire (Melzack, 2005). This questionnaire uses commonly voiced sensory and affective descriptors of pain, together with an intensity scale to measure the

overall severity of the pain experience, and a visual analogue scale to measure the present pain intensity. This crossover design ensured patients became their own control and one of the benefits of such a design was that fewer subjects were required to obtain the same power, with every subject receiving both experimental and control conditions (Senn, 1993). Half this group received reflexology on their first visit, whilst half received no treatment, alternating this sequence on their second visit. The nature of the illness dictated that patients continued to take analgesics, likely to be a complicating factor in the outcome measurements but an unavoidable necessity in a patient group such as this. Of their 30-minute treatment time, 15-minutes of reflexology was administered to areas of reported pain or specific cancer sites; patients not reporting pain were given reflexology on associated organs or body parts in which cancer had previously been defined. The first 10-minutes of the session was given to relaxation techniques and the remaining 5-minutes used to stimulate (Marquardt, 1984, Lett, 2000) the entire surface of the feet, thus ensuring all areas of the body had been covered. Outcomes indicated that patients demonstrated a reduced anxiety following reflexology treatments, and patients with breast cancer experienced significantly less pain. However Stephenson reported that the practitioner was not present during the control period, suggesting that results could have been due to the additional time and tactile stimulus (Gleeson and Timmins, 2005) rather than the reflexology itself.

Stephenson *et al.* (2007) carried out a controlled hospital experiment on patients with a variety of different cancers. Of the 86 patients studied, 42 patients were assigned partner-delivered reflexology, whilst 44 patients were assigned to a control group in which their partner read selected texts to them. It is not clear from this report how the patients were assigned to these groups. The reflexology group received treatment provided by their partners in one 30-minute session. Partners were trained in the technique by Stephenson, herself a trained reflexologist. As in previous studies by this author (Stephenson *et al.*, 2000, Stephenson *et al.*, 2003) 10-minutes of the treatment was dedicated to relaxation of the feet prior to reflexology stimulation, 15-minutes was assigned to reflexology applied to patients' self-reported pain area and organs or body parts where cancer sites or pain were located. Additional helper areas as indicated in Byers (1990) reported to assist the immune system were also used and a final 5 minutes at the end of the treatment session was

devoted to reflexology of the entire foot. Measurement tools included the brief pain inventory, the short form McGill pain questionnaire and a visual analogue scale for anxiety. Patient partners were provided with documentation about the reflexology protocol together with a list of signs and symptoms of deep vein thrombosis, a known contra-indication to treatment. Stephenson reported no significant baseline differences were found between the groups regarding the length of time since diagnosis of cancer, pain medication, or pain and anxiety levels. Baseline characteristics signified that the experimental group had cancer pain for an average 42.5 months (± SD 82.6) whilst the control group had their pain on average 24.5 months (± SD 30.4). The reflexology group demonstrated a 34% reduction in pain scores compared to 2% in the control group. However such a large SD in the experimental group shows great variation in the baseline characteristics between the groups. According to the author (personal communication) this was because there were many different types of cancer patients in the group. The difference in results could therefore be attributable to the type of cancer and how the two groups were split (Valeberg *et al.*, 2008). Cancer patients experience a variation in pain depending on the site of the cancer, time since diagnosis, whether or not there has been any surgical intervention, whether or not they have undergone chemotherapy and also simple day to day living difficulties (Burrows *et al.*, 1998). The total group score for anxiety indicates a 62% decrease in anxiety from baseline to post intervention for the reflexology group, compared to 23% in the control group. The intervention effect was strongest in the subgroup of patients with moderate to severe levels of pain and anxiety. Keefe *et al.* (2004) have suggested that caregivers can have a huge influence on the patients' pain perception, and perhaps the involvement of the partners/caregivers in providing a touch-based therapy influenced that perception. Certainly there appears to be a link between touch and the feeling of comfort and caring. Gleeson and Timmins (2005) have reported that it promotes relaxation and a feeling of being cherished. It is not clear whether patients in the reading group received any form of tactile stimulus, which may also have influenced results. The usefulness of reflexology provision by caregivers however may prove an important factor in the overall well-being of patients of such vulnerable groups. In terms of reducing levels of anxiety and in providing a special non-verbal means of communication that can in itself express so many emotions (Hertenstein *et al.*, 2006).

In a more recent study Hodgson and Andersen (2008) examined the efficacy of reflexology in individuals with mild-to-moderate dementia. Outcome measures included salivary α-amylase (sAA) as a measure of physiological distress together with a checklist of non-verbal pain indicators to assess a reduction in observed pain. This type of non-verbal checklist was designed to measure pain behaviours in cognitively impaired elders (Feldt, 2000). This crossover study randomised patients into two groups. Those assigned to the first group received 4 weeks of reflexology treatment for 30 minutes each time, followed by 4 weeks of friendly visits. Those in the second group received the same treatments in the reverse order, friendly visits followed by reflexology. Both the reflexology treatment and the friendly visits were conducted by the same single therapist to avoid needless effects that may have resulted from multiple therapist intervention (Poole, 2001, McNeill *et al.*, 2006). Each 30-minute session of either reflexology or friendly visit was initiated with a 5-minute progressive relaxation exercise. Data was collected by observers blinded to treatment conditions on the day of the intervention and over the entire 8-week course of treatment. Mackereth (2005) had used salivary cortisol as a measure of stress in previous studies and advocates its use as a clinical biomarker in this regard. Hodgson and Andersen preferred to measure sAA (Rohleder *et al.*, 2004). The adrenal medullary system releases catecholamines (noradrenaline and adrenalin) in response to a number of stressful situations, and measuring the salivary enzyme, alpha amylase, is deemed an effective measure of psychosocial stress (Rohleder *et al.*, 2004, Nater *et al.*, 2006). Twenty-one patients completed the study and results indicated a statistically significant improvement in pain ($p<0.031$) and in sAA ($p<0.049$). Whether or not the order of treatment, an interesting and perhaps relevant fact, had any effect on outcome measures, was not discussed. Tables of mean and standard deviations for each treatment group would have shown changes relating to the order of treatment and may have produced evidence of benefit to future research. Mackereth (2005) demonstrated that order of treatment can have a within session effect on salivary cortisol levels but not overall and that state anxiety, which is related to anxiety of the current situation, had a cumulative effect over the duration of the study, thus supporting the usefulness of reflexology as a treatment in the management of stress and anxiety related conditions.

A single-blind study by Tovey (2002) assessed the effects of six 30-minute reflexology treatments on 34 patients suffering from irritable bowel symptoms (IBS). The group was selected from predominantly white patients distributed across four general practice clinics. Patients were randomly allocated to receive either foot reflexology to specific areas of the feet, or foot massage. Symptoms commonly associated with irritable bowel syndrome such as abdominal distension, pain, constipation and diarrhoea were assessed daily using a 5 point scale. Participants to the study completed the questionnaire of symptoms two weeks prior to participating, throughout the intervention, for two weeks post intervention and then at follow-up, three months after the final intervention. Abdominal pain was the principal outcome measurement used in this study, whilst secondary measures included other symptom variables, as previously indicated. Results of the study demonstrated no significant difference in effect between the two groups on any of the outcome measures. The results are not surprising as foot massage has shown to be an effective treatment in the reduction of stress and anxiety and in promoting relaxation, making it an ineffective control (Grealish *et al.*, 2000, Hayes and Cox, 2000, Quattrin *et al.*, 2006). One of the other reported symptoms of irritable bowel syndrome, notably sleep disturbance, was not measured and this oversight may have proved an important point. Poor sleep patterns are thought to increase the symptoms of irritable bowel (Murray and Pizzorno, 1998) and there is evidence to suggest that reflexology may help improve sleep. Other factors that may aggravate irritable bowel include stress, a diet high in sugar and food allergy or intolerance (Murray and Pizzorno, 1998). The holistic approach generally taken by reflexologists would have supported change in these lifestyle factors. Reflexology is a 'package' of care, not a stand alone treatment and in cases of IBS it is important to address the entire persona. Tovey (2002) does recognise however that the results are from one homogenous group and that further studies should extend the range of participants to include both a variety of patient groups and those newly diagnosed with IBS, who perhaps may be less difficult to treat. The use of an alternative control arm, perhaps a placebo of sham TENS and a 'no treatment' group may also have yielded a different outcome.

Poole (2001) studied the effects of reflexology on the management of chronic low back pain (CLBP), a notoriously difficult condition to treat and one of the most

costly medical conditions in the country (Moore *et al.*, 2003, Quinn *et al.*, 2007). The research was carried out using a pragmatic randomised controlled trial. Pragmatic designs seek to assess the effectiveness (capability of a desired effect) of an intervention as opposed to the efficacy (ability to produce a desired effect) of an intervention in routine clinical practice. A group of 243 patients was randomised to receive reflexology, relaxation or standard care. The six reflexology sessions were administered by five therapists using the Morrell technique, which employs a light pressure. Therapists operated according to their own standard practice for the treatment of CLBP during six, one hour sessions given at weekly intervals. Over the same duration in the primary muscle relaxation group, four other therapists guided the participants through a series of relaxation exercises that focused attention on tensing and then relaxing various muscle groups in succession. Assessments were carried out *via* completion of self-report questionnaires which included the SF-36 and Oswestry low back pain disability questionnaire, Beck depression inventory II and pain visual analogue scales, all of which were completed prior to commencement of treatments, on completion of treatments and at six months follow-up. Although results from this study indicated no significant difference between groups on either pain or functioning, there was a significant reduction in pain over time for all groups, which was greatest in the reflexology group. This effect has been confirmed in an experiment by Veldhuizen and Pauly (2001) using nerve reflex point therapy to attenuate low back pain, whilst Quinn (2007) who used reflexology and compared it to a control of foot massage did not report a significant effect. According to the zones of hyperalgesia depicted by Head (1893, Head, 1905) and indications given by Pauly (2004), pain can refer from the viscera to the cutaneous tissue, including spinal areas. In the study by Quinn *et al.* (2007) only those reflex points deemed to be related to the spine and surrounding musculature were stimulated in the reflexology group, whilst the control group received a treatment similar to standard reflexology but omitted the spinal reflexes, suggesting a contamination of reflex points that could have influenced outcomes.

1.7 PAIN AN INTRODUCTION

1.7.1 A Brief History

In primitive times pain was considered a curse of the devil or evil spirit and treatment, in a not dissimilar way to today's treatments, consisted of rubbing, or perhaps exposure to cold or heat (Loeser, 2001). Religion played a large part in pain and when priests took on the role of the physician they speculated that pain came to those who had sinned, the fate of whom was determined by sacrificial animals. In Egypt, pain was associated with the spirits of the dead, who were said to arrive at night entering the body through an open orifice such as the nose or ear. Physicians used herbal remedies and spells to induce vomiting, urination, sneezing and sweating in order to eradicate the evil spirits from the body (Fairley, 1978, Loeser, 2001).

According to Egyptian medical history the heart was classified as the centre of sensation (Fairley, 1978) and in India, the Charaka Compendium stated that all joy and pain was experienced in the heart, where it was referred to as the seat of consciousness. In China, all matters relating to health were equated with qualities of natural phenomena based on the elements of wood, fire, metal, water and earth (Maciocia, 1989). They proposed that an imbalance in the body was created by a blockage or excess in one of the unseen lines (meridians) that coursed through the body. Such a blockage was initiated by one of the elements resulting in disease and/or pain. Relief from such conditions could be gained through the application of acupuncture and/or moxa (mugwort) when used at any of the specific points of location along a meridian line, known as tsubo points (Kaptchuk, 2000).

In the 4th century B.C. the elements of earth, air, fire and water were variously linked to blood, muscles, bone, tendons and nerves (Bennett, 1999). During this period Plato designated the brain as the centre of perception, as did the Greek, Alcmaeon (Doty, 2007), but his proposal was argued against by Aristotle and Empedocles, who believed that all pain sensation was located in the heart (Crivellato and Ribatti, 2007). Aristotle held that the heart was the centre of perception. He introduced a fifth element which he named 'ether' and suggested it traversed the body during breathing, going directly to the lungs and heart and subsequently to the remainder of

the body *via* the blood vessels as 'vital pneuma' (Bennett, 1999, Bennett and Hacker, 2002).

Whilst Galen retained the idea of the elements, he suggested that it was the brain and not the heart that was the centre of perception believing that the 'vital pneuma' was transported to the brain, from the heart, to be used by the nerves for conduction (Bennett, 1999). When he performed dissection on pigs he elaborated on the sensory theory and emphasised the importance of the central and peripheral nervous systems. Galen established the more detailed anatomy of the cranial and spinal nerves and the sympathetic trunks (Loeser, 2001, Bennett and Hacker, 2002).

Hippocrates considered the father of medicine, believed that pain was felt when one of the four humours, (yellow bile, black bile, phlegm and blood) was either in decline or excess and that the brain an organ he considered a gland, was the centre of thought and sensation. Herophilus dissected human cadavers and confirmed Galen's idea that the brain was part of the nervous system with nerves for both motor and sensory functions (Crivellato and Ribatti, 2007).

Aristotle believed that the soul was the principle of life and that the mind and body were one. This concept remained until the 17th century when Descartes suggested that a person was essentially a 'thinking thing'. He proposed that thinking encompassed our sensory awareness and suggested that it was impossible to experience sensation without our conscious thought (Bennett and Hacker, 2002).

Descartes believed in a more mechanistic philosophy. He proposed that the body could be activated by heat occurring in the heart, *via* the passage of small particles (animal spirits) derived from the blood, passing through nerve endings to enter muscle (Bennett, 1999). Descartes dualism theory proffered that the mind and body were two separate things. He postulated a hard-wired route for pain in which delicate threads from the periphery conducted the pain signal to the pineal body in the brain, an area he considered to be the seat of reason (Wall, 1999a). He suggested that the brain played only a passive role in pain, and that pain was directly proportional to the amount of tissue damage, i.e. sensation. In his sketch, shown in Figure 1.15, Descartes compares the ringing of a bell with delicate threads sewn through the

body, claiming that when such threads were set in motion, their ends pulled at the brain to set the body in motion.

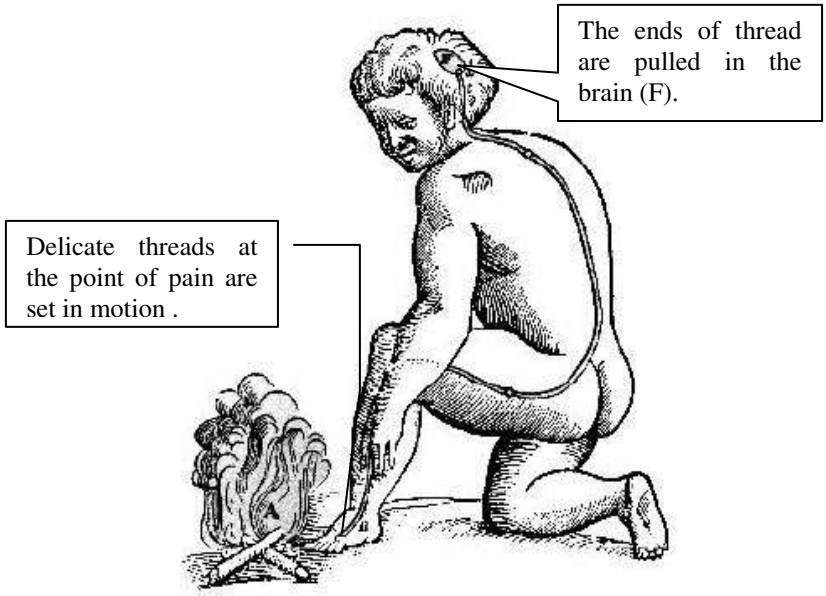


Figure 1.15: Descartes model of pain. Image obtained from (Kerber). Descartes suggested that delicate threads sewn through the body pull at a bell in the brain in response to peripheral pain to create a withdrawal reflex (Brooks and Tracey, 2005).

Descartes believed that the body moved through an act of will and that movement required both excitatory and inhibitory effects (Bennett and Hacker, 2002). His notion that the human mind interacted with the pineal gland as the centre of sensation was later proved wrong. In 1672 Willis concluded that the psychological aspects of sensation were to be found in the cortex and not the ventricles as proposed by Descartes. There followed a number of neuroscientific studies that further confirmed and firmly placed the seat of sensation in the brain. Despite the increased knowledge, Descartes dualism theory still pervades current thinking (Rose, 2009).

The existence of both motor and sensory nerves was first proposed by Galen but it was only at the beginning of the 19th century that the sensory and motor systems were divided into posterior and anterior roots (Bennett and Hacker, 2002, Levine, 2007). In 1911 Head and Holmes wrote about sensory disturbances from cerebral lesions (Henson, 1977). They suggested that the pain centre was located in the thalamus and that the cortex applied inhibitory control to the thalamic pain centre an idea that for many still holds true today (Fields and Basbaum, 1999). It is, however,

the sensory cortex that is considered the pain centre, whilst the integration of pain takes place within the thalamus (Dickensen, 2008).

1.7.2 Pain transmission

In simple terms, sensory pain messages pass from pain receptors (nociceptors) where there is injury, through the spinal cord to the brain stem and then onward to various areas in the brain for recognition. In reality however, the process is far more complicated.

Ascending pain pathways

Pain, thermal and crude tactile sensations, ascend the spinal cord *via* the anterolateral system, a collection of pathways incorporating the spinothalamic, spinoreticular, spinomesencephalic, spinotectal and spinohypothalamic tracts, see Figure 1.16 (Patestas and Gartner, 2006). The more discriminative aspects of touch, vibration and muscle/joint sense ascend through the posterior white columns of fasciculus gracilis and cuneatus, collectively referred to as the dorsal column medial lemniscus (Patestas and Gartner, 2006, Tsuji *et al.*, 2006). Fibres from the sacral, lumbar and lower thoracic regions which represent some of the dermatome regions for the nerves from the feet (L3 - S2) ascend the columns in the fasciculus gracilis. Whilst ascending fibres from the upper thoracic and cervical spine which include the dermatome regions for the hand (C6 – 8), ascend in the fasciculus cuneatus (Snell, 2001), the two white columns are separated by a septum but converge to ascend the brainstem together, terminating in the ventral posterolateral (VPL) nucleus of the thalamus (Almeida *et al.*, 2004). Axons from the VPL then leave the thalamus *via* the internal capsule or corona radiata before ascending to the primary somatosensory cortex (Snell, 2001).

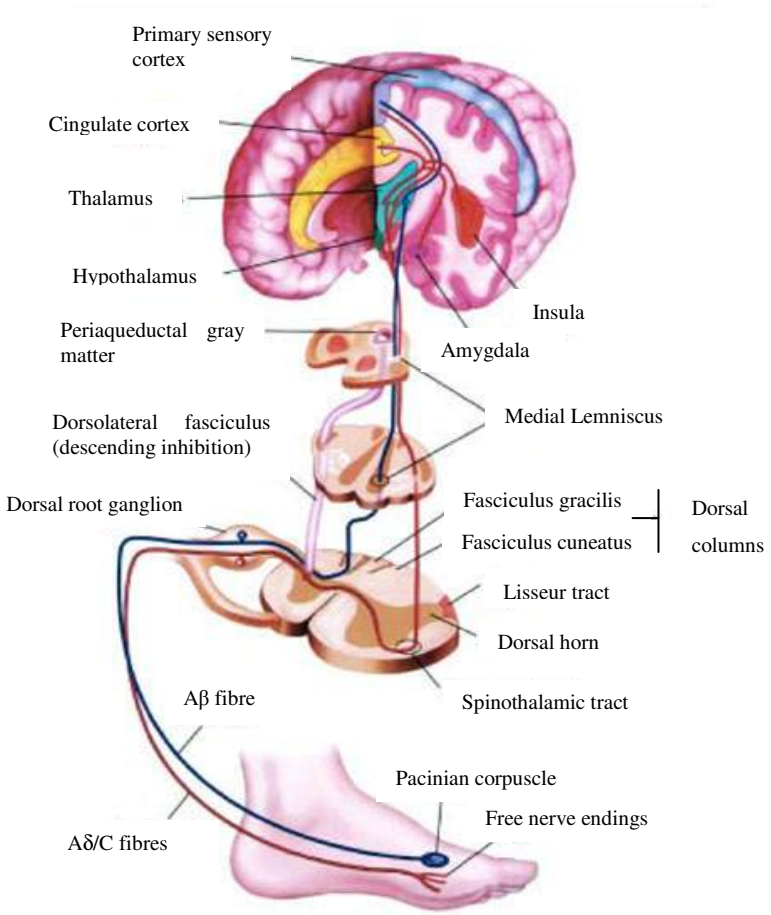


Figure 1.16: Schematic diagram of a sensory stimulus. The diagram indicates both ascending and descending pain pathways. The fast conducting Aδ and the slower c-fibres are transmitted to the dorsal horn before ascending the anterolateral tracts of the spinal cord. Image obtained from (Mayo Clinic, 2005).

When noxious events occur on free-nerve endings (nociceptors) of cutaneous tissue and there is tissue damage, they stimulate terminals of primary afferent neurons (Aδ and C-fibres) to which they are attached. This causes the release of neurotransmitters such as glutamate, histamine, prostaglandins, bradykinins and adenosine tryphosphate (ATP) into the damaged area, causing inflammation and swelling through activity on blood cells (Dickensen, 2008). The small Aδ nerve fibres are wrapped in a light sheath of myelin and transmit their pain signal at between 12–30 ms^{-1} which produces the initial pain focus giving a short, sharp, pricking sensation. The smaller C-fibres are free of myelin and conduct at rates of 0.5-2.0 ms^{-1} producing a diffuse, slow, burning type of pain (Almeida *et al.*, 2004, Bear *et al.*, 2007). Both the Aδ and C-fibres terminate in the dorsal horn of the spinal cord and transmit impulses along the anterolateral tract (Urch, 2007). They

enter the dorsal horn at the level of lamina 1 in the tracts of lisseur and quickly ascend toward lamina II where the C-fibres synapse on inter-neurones in the substantia gelatinosa, activating the release of the neuropeptide substance P together with the excitatory neurotransmitter, glutamate (Serpell *et al.*, 1998, Yaksh, 1999, Urch, 2007). If the stimulus is strong enough, the Aδ fibres synapse on second order neurons in the dorsal horn before crossing over to the opposite side. They ascend along the lateral surface of the spinothalamic tract directly to the thalamus without further synapsing (Almeida *et al.*, 2004). On their way to the thalamus the much slower C-fibres may synapse on collateral branches within the periaqueductal gray (PAG). Neurons from PAG then synapse in the dorsal raphe nucleus to release 5-HT, and on locus coeruleus to release noradrenaline. This produces a pre-synaptic inhibitory effect in the spinal dorsal horn (Snell, 2001, Almeida *et al.*, 2004). Not all noxious messages reach the brain; some cause a local reflex arc such as when one treads on a pin tack and withdraws the foot rapidly. This type of pain signal travels along sensory nerves to the dorsal horn and synapses with motor neurons to enable one to rapidly withdraw the foot from the pain stimulus.

The spinoreticular pathway carries some information from the slower C-fibres and the sensation of light touch and pressure from the periphery in fast conducting low threshold Aβ myelinated nerve fibres (Almeida *et al.*, 2004). The stimulus passes directly to the limbic system and hypothalamus. Sensations of touch on the right side of the body ascend the dorsal column ipsilaterally to the brainstem where they cross, providing information from the right side of the body, to the left side of the brain (Tsuji *et al.*, 2006). Axons from the limbic system and hypothalamus project into the periaqueductal gray to relay the pain messages from the Aδ and C-fibres. This pathway is important in the descending inhibitory control of nociception *via* activation of brainstem structures (Almeida *et al.*, 2004).

Descending pain control

There are a number of different pain inhibitory systems involved in the modulation of pain. The one that has stood the test of time is the 'gate control theory' developed by Melzack and Wall (1965). The gate control theory proposed a hypothetical 'gate' at the level of the spinal cord where large A-fibres interrupt the pain signal to the

brain, illustrated in Figure 1.17. When normal somatosensory stimulation from low-threshold mechanoreceptors (i.e. large myelinated Aβ fibres or touch fibres) is greater than that of the smaller nociceptive Aδ and C-fibres, inhibitory interneurones in the dorsal horn of the spinal cord are activated, closing the gate to noxious signals. However, when a noxious stimulus is transmitted along the small fibres or when the small fibre activity is greater than the large fibre activity, the projection neurone is stimulated and the inhibitory interneuron is blocked. The activity of the small fibres further stimulates the projection neuron releasing glutamate and substance P into the substantia gelatinosa enhancing the pain signal to the brain and thus the gate remains open.

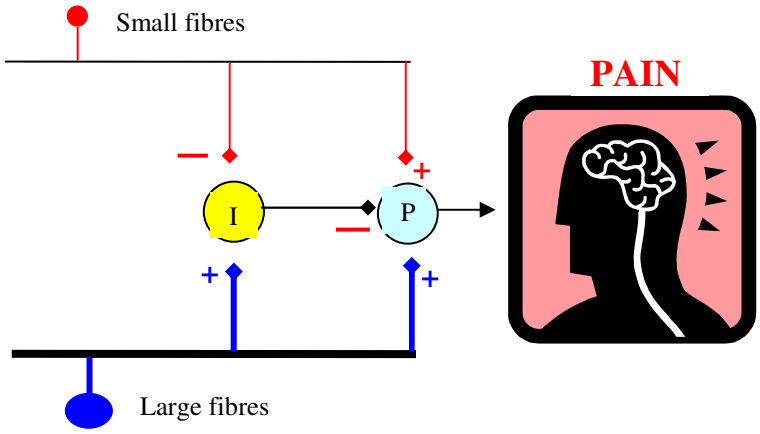


Figure 1.17: Illustration of the Gate Control Theory of pain. I = inhibitory interneuron, P = Projection neuron. When low-threshold traffic from mechanoreceptors of large myelinated fibres is greater than the smaller nociceptive fibres (Aδ/C-fibres) the inhibitory interneuron blocks the nociceptive transmission to projection neurons. When nociceptive traffic from the smaller neurones is greater than low-threshold mechanoreceptors, the projection neurone is stimulated and the pain signal reaches the brain.

Descending inhibition is further activated within the supraspinal architecture (Heinricher *et al.*, 2009) and in particular within the region of the periaqueductal gray (PAG) of the midbrain (Markenson, 1996). The PAG is an area rich in opioid receptors. Efferent projecting neurones from the PAG are interconnected to medial areas of the prefrontal cortex, the hypothalamus, limbic system, anterior cingulate cortex and the amygdala (Berger, 2005, Heinricher *et al.*, 2009). Fibres pass from the PAG to the dorsal raphe nucleus and then join axons of the dorsolateral funiculus of the spinal cord to synapse on interneurones in the substantia gelatinosa. Here they release serotonin (5-HT) and noradrenaline (NE) to inhibit ascending pain signals in

pre and post-synaptic terminals (Serpell *et al.*, 1998, Furst, 1999, Urch, 2007). Figure 1.18 illustrates this descending system. Dogrul *et al.* (2009) implicated a number of 5-HT receptor subtypes in descending pain pathways, indicating a bi-directional influence *via* activation of different 5-HT receptors within the spinal cord. In particular they have demonstrated that spinal inhibition is mediated by 5-HT_7 receptors, whilst facilitation mediates enhanced pain *via* spinal 5-HT_3 receptors (Suzuki *et al.*, 2004, Dogrul *et al.*, 2009).

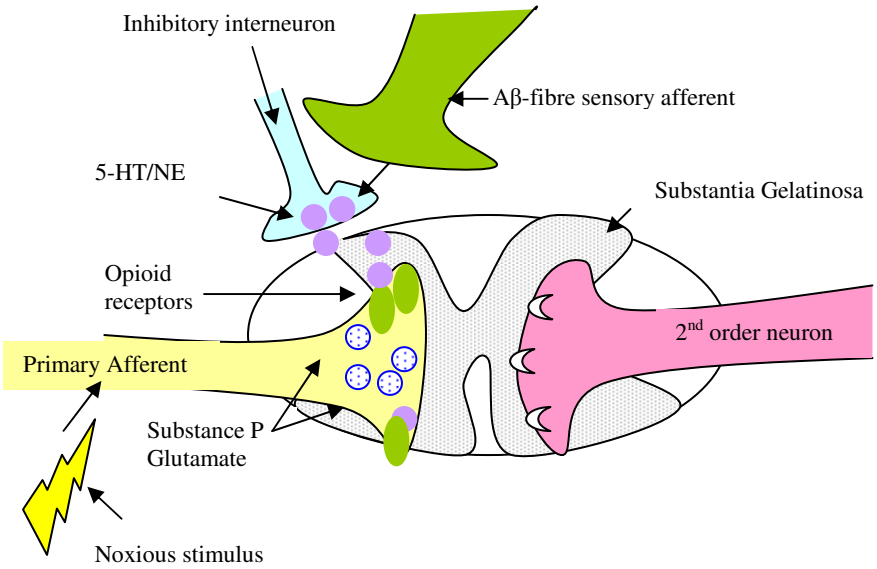


Figure 1.8: Schematic drawing of pre-synaptic inhibition in the substantia gelatinosa at the level of the spinal cord. The inhibitory interneuron can be excited by either the descending pathway, or from large-myelinated Aβ-fibres. In both cases the interneuron will release endogenous opioids to block the pain signal. Adapted from (Bear *et al.*, 2007).

Diffuse Noxious Inhibitory Controls

Another mechanism involved in the descending inhibitory pathway is termed 'diffuse noxious inhibitory control' and involves a form of counter-irritation (Villaneuva, 2009). This type of inhibition has been used for centuries and involves the spino-bulbo-spinal loop, a complicated mechanism involved in nociceptive feedback systems. Normal descending inhibition is based upon a top-down assembly, DNIC is reported to utilise a bottom-up approach that involves descending projections passing through the dorsolateral funiculus and terminating in the dorsal horn at all levels of the spinal cord, feeding from the endogenous modulatory system (Pud *et al.*, 2009). However Tracey and Dunckley (2004) have indicated that there is

very little input from the PAG or rostral ventromedial medulla. This method of 'pain inhibiting pain' is triggered from any body area outside the excitatory receptive field of pain and is known to differ depending on the magnitude of the stimulus, the type of stimulus, and the nerve fibres involved (Fujii *et al.*, 2006). It is thought to be a possible mechanism in the effects of acupuncture analgesia (Carlsson, 2002) and may be implicated in hypnosis (Sandrini *et al.*, 2000). It involves the use of a conditioning stimulus that generates the effect and a test-pain stimulus. It is calculated by the difference in pre and post values after the conditioning stimulus has been initiated (Tousignant-Laflamme *et al.*, 2008, Pud *et al.*, 2009).

Brain regions involved in pain transmission

There are three main cortical areas activated in pain transmission; the primary somatosensory area (SI), which lies directly behind the central sulcus, the secondary somatosensory area (SII), and the cingulate gyrus found in the medial aspect of the brain (Almeida *et al.*, 2004). However, recent evidence suggests that multiple networks converge to provide a parallel input depending on the stimulus type (Apkarian *et al.*, 2005) and that different fibre types may excite different brain responses (Weiss *et al.*, 2008). The SI region of the cortex is situated in the parietal lobe and is thought to be the area responsible for the conscious perception of pain, its location within the body and its quality and magnitude (Bushnell *et al.*, 1999). The anterior cingulate cortex (ACC) synthesises the affective component of pain unpleasantness (Bufalari *et al.*, 2007) and the anterior insula is thought to evaluate the cognitive and emotional aspects associated with pain unpleasantness, *via* its neural connections with the amygdala. The thalamus has multiple projections and is the main relay involved in the transmission of pain signals (Apkarian *et al.*, 2005, Urch, 2007).

The brain's cortex is organised into layers of vertical columns about 300 – 600μm wide. They are composed of white matter containing afferent, efferent and association neurones and are further divided into areas known as Brodmann areas, each of which represents a different function of the body (Bear *et al.*, 2007). SI is a layered structure that receives its neuronal input from the ventral posterior nucleus of the thalamus, shown in Figure 1.19. The main somatosensory area is known as Brodmanns area 3b and it is very responsive to somatosensory stimuli but not to

other sensory stimuli. Its main function is in relation to touch in general (Nicolelis *et al.*, 1998, Ghazanfar *et al.*, 2000). Finite evaluation of sensory stimuli requires input from areas 3a for position, 1 for texture and 2 for size and shape (Tsuji *et al.*, 2006). Without this additional input the cortical areas of 3a/b would not be able to establish the direction in which a stimulus is moving. The vertical layers of S1 columns are further sub-divided into alternating columns that receive responses from rapidly and slowing adapting nerve fibres of varying receptive fields (Bear *et al.*, 2007). Recent evidence suggests that the SI regions hold a somatotopic map of the pain system similar to that employed by the somatosensory homunculus. Locations for nociceptive neurones were established slightly posterior to areas 3b, 1 and 2 (Tsuji *et al.*, 2006)

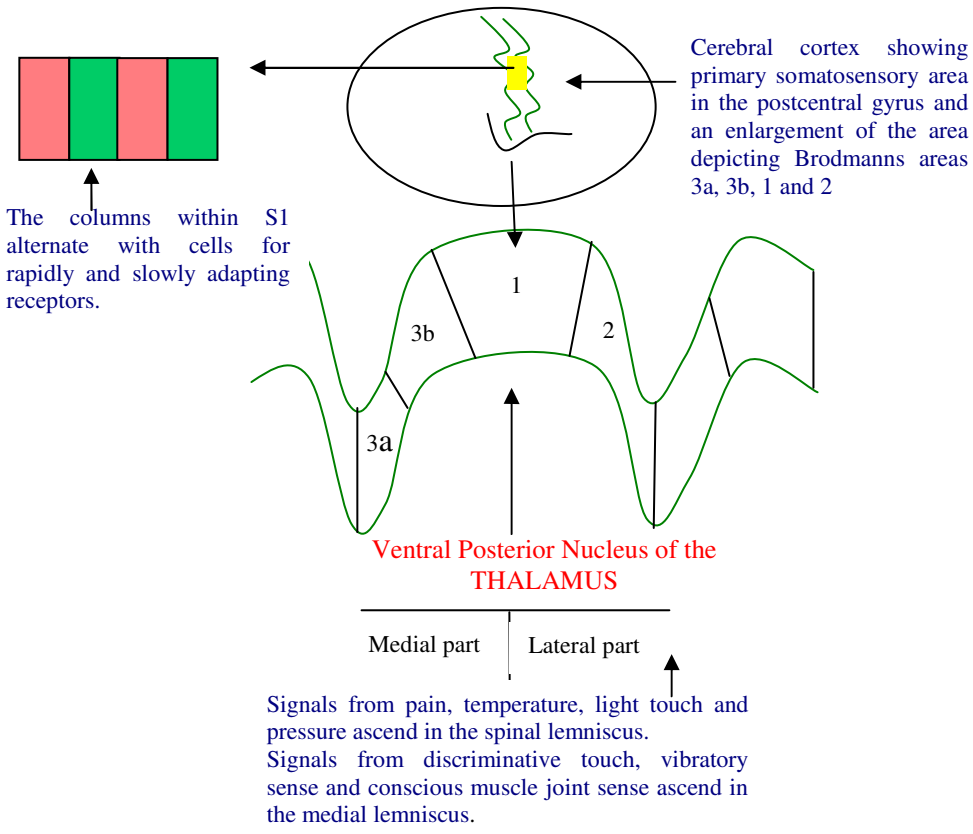


Figure 1.19: Sensory information pathways. Includes a depiction of a section of the primary somatosensory cortex indicating Brodmanns areas 3a – position, 3b – touch, 1 – texture and 2 size and shape which work together to form the primary somatosensory area S1. Adapted from (Bear *et al.*, 2007)

Afferent fibres ascending the thalamus project collateral branches to the hypothalamus and limbic systems (Almeida *et al.*, 2004, Tsuji *et al.*, 2006). Sub-corticol and corticol areas of the brain are involved in the sensory-discriminative and cognitive-evaluative attributes of the pain experience (Almeida *et al.*, 2004). The sensory-discriminative aspect interprets the type and quality of the sensation, for example; whether the pain is from pressure, heat, cold or some other event. The cognitive-evaluative aspect is the interpretation of the pain itself; how one feels about it and the intensity overall (Melzack, 1975a).

The hypothalamus, as part of the sub-cortical brain, conveys neuronal projections to the periaqueductal gray (PAG) of the midbrain (Behbehani *et al.*, 1988) and plays a major role in the descending modulation. PAG contains an abundance of opiate receptors (Pert, 1997) from which it releases endogenous opioids into the locus coeruleus and dorsal raphe nucleus. Noxious stimuli activate an arousal mechanism in the reticular formation so that one becomes more conscious of a painful sensation and arousal can be modulated by the ascending tracts within the reticular formation. Figure 1.20 illustrates the brain regions involved in the transmission of a noxious stimulus.

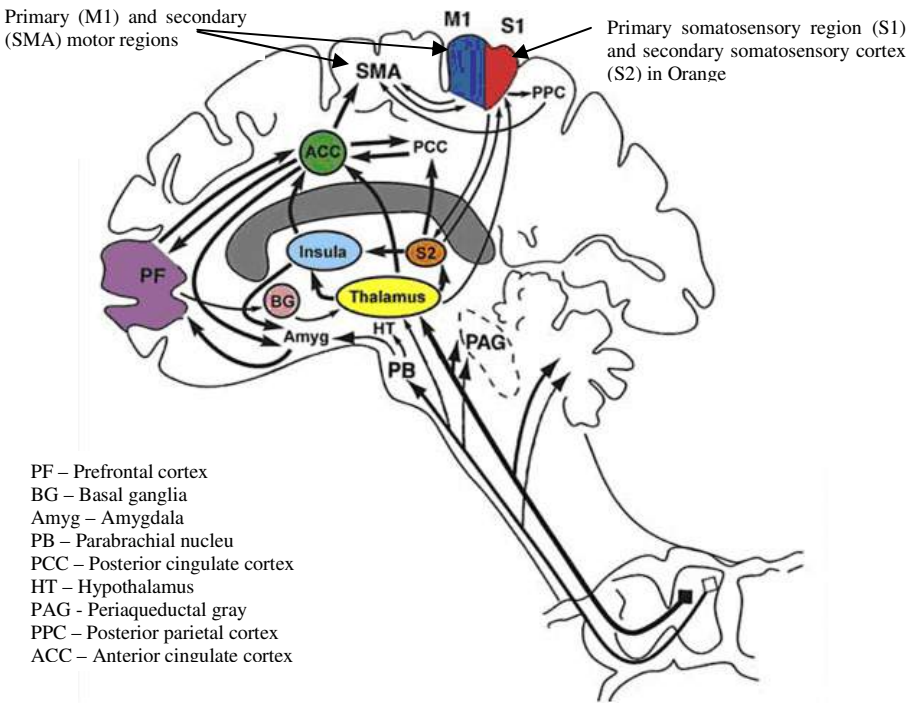


Figure 1.20: Schematic drawing of the regions of the brain involved in pain perception and their interconnecting pathways of ascending pain transmission, taken from (Apkarian *et al.*, 2005).

In conjunction with the hypothalamus and cingulate gyrus, the limbic system regulates the autonomic responses to pain *via* its influence on the endocrine system (Ganong, 1997, Bear *et al.*, 2007). Factors associated with the regulation of emotions, fear and motivation, long-term memory, behaviour and control involve other regions of the limbic system, notably the amygdala and hippocampus (Bear *et al.*, 2007, Butler and Finn, 2009).

Pain and pleasure are highly interconnected within the dopamine and endogenous opioid systems of the brain and nucleus accumbens (NAc) (Bufalari *et al.*, 2007, Urch, 2007, Leknes and Tracey, 2008) The mesolimbic and mesocortical dopaminergic systems are involved in emotional responses that are based on motivation and reward (Esch and Stefano, 2004, Ford and Finn, 2008, Becerra and Borsook, 2008). During noxious stimulation NAc releases endogenous opioids in the hypothalamus helping to raise the pain threshold (Leknes and Tracey, 2008). In World War I soldiers were known to continue in battle even though they may have been mortally wounded. Some have indicated that this response is the result of stress analgesia (Wall, 1999a), whilst others argue that the pain/pleasure reward system is involved (Leknes and Tracey, 2008).

Two stimuli are needed to induce an unconditioned response to stress analgesia, a noxious stimulus (an actual or potential tissue damaging event) and an aversive stimulus (a stimulus one tries to avoid) (Butler and Finn, 2009). A second type; conditioned stress-induced analgesia is triggered through fear conditioning. There is now strong evidence that conditioned stress induced analgesia is under supraspinal control and is mediated by mu and delta opioid receptors (Ford and Finn, 2008). It is likely that fear conditioning enabled the soldiers of World War I to continue their battle. Injury meant they had a greater chance of staying alive, whereas if they were uninjured and still on the battle field, there was a very high chance they would be killed (Wall, 1999a). Such a stressful event is complex but is thought to involve the pain/pleasure/reward circuitry within the brain (Esch and Stefano, 2004).

There are many areas involved in the perception and interpretation of pain, but to date, it is not clear whether the same brain regions are involved in both chronic and acute physiological pain (Apkarian *et al.*, 2005, Apkarian *et al.*, 2009, Neugebauer *et*

al., 2009) and ongoing research continues to provide more detailed evidence (Apkarian *et al.*, 2009).

1.8 TYPES OF PAIN

Pain is generally classified as either acute or chronic, but within these categories it may also be classified according to its origin and type. As an example somatic pain comes from skin, muscles and joints, whilst visceral pain comes from the internal organs within the thorax and abdomen and is poorly localised due to a low density of nociceptors in the viscera (Serpell *et al.*, 1998). Somatic sensation is further classified into pain that is superficial or pain that is deep, relating to both the area of pain and the sensation felt.

Physiological Pain

Physiological pain provides a useful mechanism that acts as a warning of actual or potential tissue damage (Serpell *et al.*, 1998) and is usually transient (acute) in nature (Loeser and Melzack, 1999). This type of pain rarely involves tissue damage and often triggers a flexion reflex that enables one to rapidly withdraw from the offending stimulus. It is often, but not always accompanied by increases in autonomic functions such as heart rate, blood pressure and temperature. This type of pain may be elicited by pressure, thermal extremes, scrapes, bumps and bruises and is often seen in young children. Acute physiological pain is fast acting and is transmitted *via* the small lightly myelinated Aδ primary afferent fibres and the smaller un-myelinated c-fibres to the dorsal route ganglia within the spinal cord (Serpell *et al.*, 1998).

Pathophysiological Pain

Physiological pain of pathological origin is by contrast the result of tissue damage and often also cell death (necrosis). This type of pain may be experienced from post-operative surgery where there may also be nerve damage, arthritis where there may also be inflammation, or from the growth of cancer cells where there may be both nerve damage and inflammation (Dickensen, 2008). Pain of this type is diffuse in origin and poorly localised originating from free-nerve endings that travel along the slower and smaller C-fibre afferents, termed second or slow pain (Serpell *et al.*,

1998, Weiss *et al.*, 2008). A noxious stimulus generally activates the release of the amino acid glutamate whilst intense stimulation includes the release of neuropeptides such as substance P and calcitonin-gene-related-peptide (CGRP) (Bird *et al.*, 2006, Adelson *et al.*, 2009). The release of these neurotransmitters may further stimulate mast cells to release histamine, leukocytes to release prostaglandins and macrophages to release cytokines into the blood stream. The area may become red, swollen and warm to the touch as a result of inflammatory processes initiated by an increase in bradykinins, which further enhance the pain sensation (Markenson, 1996, Serpell *et al.*, 1998, Wall, 1999a, Wang *et al.*, 2005). Such sensitised areas create more neurochemicals to release because the free nerve endings (sensory nociceptors) become more sensitive. In peripheral areas a bombardment of stimuli, generate greater neurotransmitter release (Dickensen, 2008). Chronic pain, unlike acute pain appears to serve no real purpose, since by its very nature one is usually unable to avoid it and the damage is already served (Markenson, 1996).

Neuropathic Pain

Neuropathic pain is known to be one of the most difficult pain conditions to treat (Severn, 2002b, Neugebauer *et al.*, 2009). Watkins and Maier (2004) have suggested that 50% of all neuropathic pain cases are associated with infection or inflammation, rather than with peripheral or central nerve trauma, with which it is generally associated. It is a state of hypersensitivity associated with an increase and alteration in the sensory nerve transmission system (Pasero, 2004). Neuralgia, diabetic neuropathy, spinal cord injury, demyelination and surgical scar pain are just some of the clinical conditions associated with neuropathic pain (Severn, 2002b, Dickensen, 2008). It is a severely painful condition that may be described with words such as burning, searing and shooting and there is often a feeling of numbness. The condition may result in allodynia, hyperalgesia and/or hyperpathia. Neuropathic pain increases over time so that even the lightest brush across the skin can set off extreme pain. Aβ fibres are normally associated with tactile sensations, but because the pathology of the pain causes peripheral and central sensitisation, which produces an over sensitivity to any type of contact, the large-mediated A-fibres can also trigger a painful response. One in three patients obtain inadequate relief from treatments that are currently available for neuropathic pain and a

combination of drugs is often required to modulate this painful experience (Suzuki *et al.*, 2004).

Central sensitisation, long term potentiation and wind-up

The terms central sensitisation, long term potentiation (LTP) and wind-up appear to be extensively interconnected with one another. However, many suggest there is difference between the three terms but that they each rely on the activation of the N-methyl-D-aspartate (NMDA) receptor (Dickensen, 2002, Dickensen and Suzuki, 2005, Sandkuhler, 2007). In the condition referred to as central sensitisation, concurrent prolonged pain signals transmitted by primary afferent c-fibres, in peripherally damaged tissue, results in an amplified response to normal tactile stimulation, see Figure 1.21. These stimuli would not normally be perceived as painful and are due to an increase in the excitatory receptive field surrounding the damaged tissue. There is an increased release of neuropeptides into the synaptic cleft that produces long slow potentials. Such potentials are prolonged in the dorsal horn by NMDA receptors (Petrenko *et al.*, 2003). In many neuropathic conditions central sensitisation, creates an irreversible change in the synaptic transmission both centrally and peripherally (Pasero, 2004). NMDA receptors are activated by the excitatory neurotransmitters glutamate and its co-agonist glycine, normally an inhibitory transmitter in the central nervous system (Petrenko *et al.*, 2003, Wang *et al.*, 2005). At resting membrane potential the receptors which contain ion-channels are blocked by Mg^{++}, but simultaneous stimulation which increases depolarization in postsynaptic terminals, can open the channel to release the Mg^{++}. If the stimulus is strong enough, the NMDA receptors can unblock the ion channel and release Mg^{++}. This is followed by an influx of Na^{+} and Ca^{++} ions which produces further depolarisation and long slow temporal summation. As long as the potential does not return to baseline, subsequent inputs summate with the first to produce an increased response. Metabolic changes take place through the increase of Ca^{++} ions acting as second messengers releasing more Na^{+} from the alpha-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid (AMPA) receptors and the intracellular space into the membrane and initiating more receptors in the spine (Watkins *et al.*, 2001). Subsequent stimuli will be stronger than they were before the NMDA receptors were activated and the synapse becomes more sensitive (Sandkuhler, 2007, Ikeda *et al.*, 2009).

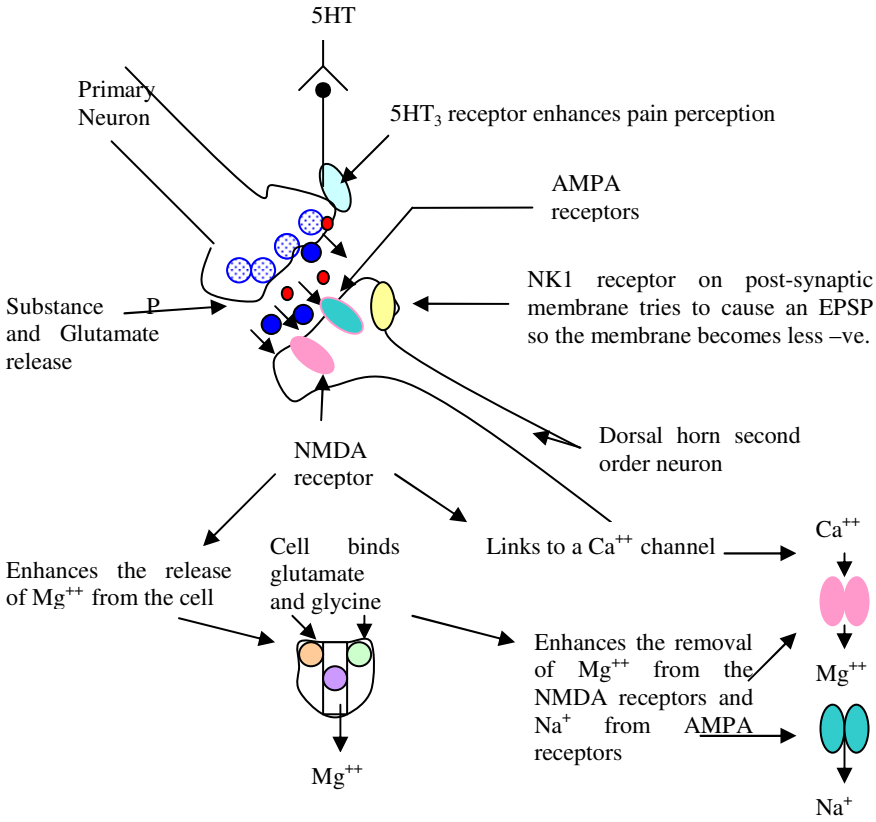


Figure 1.21: Schematic representation of central sensitisation. Repetitive brief pain stimuli release increased amounts of neuropeptides into the synaptic cleft. NMDA receptors on the post-synaptic terminal are blocked by Mg^{++} ions. The simultaneous release of the neurotransmitter glutamate and the inhibitory transmitter glycine onto the NMDA receptor depolarizes the cell membrane and releases the Mg^{++} into the post-synaptic terminal. The increased activity further increases depolarization and Ca^{++} ions flood the cell membrane, releasing Na^{+} from AMPA receptors and further stimulating the release of Mg^{++}. Adapted from (Watkins *et al.*, 2001)

Both LTP and central sensitisation are thought to relate to the processes involved in neuropathic pain signalling (Sandkuhler, 2007, Ikeda *et al.*, 2009). Neugebauer *et al.* (2009) have reported that neuropathic pain involved atrophy of between 5 – 10% of the grey matter of the pre-frontal cortex and thalamus. This can have a detrimental affect on decision making and general cognitive function, which may account for the depressive nature of chronic neuropathic pain (Neugebauer *et al.*, 2009). Long term memory is a function of the hippocampus and like LTP it relies on synaptic transmission. LTP is described as an increase in the communication system of pre and postsynaptic neurons (Sandkuhler, 2007). Simultaneous stimulation of afferent neurons is known to initiate a memory that improves postsynaptic cell sensitivity to

neurotransmitters released by presynaptic cells. A conditioned stimulus of both high and low frequency are known to produce burst-like stimuli that induce long term potentiation in the spinal synapses of c-fibres. Such stimuli provoke the release of substance P from the neurokinin receptors on these neurons, escalating the sensitivity of a noxious event (Sandkuhler, 2007). In a similar fashion to central sensitisation, LTP operates through the NMDA receptor and increased levels of Ca^{++} in the postsynaptic terminal are an essential part of LTP propagation (Sandkuhler, 2007).

In the phenomenon referred to as wind-up, dorsal horn neurones are augmented by repetitive c-fibre stimulation causing an increase in temporal summation (Baranauskas and Nistri, 1998, Suzuki *et al.*, 2003). Wind-up produces an increasing sensitivity of the large A-fibres such that both hyperalgesia and allodynia are present and subsequent to the widening of the receptive field which produces exaggerated responses to noxious stimuli *via* excessive release of substance P at the level of the spinal cord (Baranauskas and Nistri, 1998).

Psychological aspects of Pain

Pain affects millions of people worldwide with significant implications on quality of life and on the resources of the medical profession (Niv and Kreitler, 2001) (Donaldson, 2009). In today's society it appears to be a general consequence of long life and increasingly on ill health, but it can have devastating effects on pain sufferers and their family. Pain is not a simple sensory experience but also an emotional, social and cognitive one, in which it affects attitudes, beliefs and appraisal of pain. It is described by the International Association for the Study of Pain (IASP) as an unpleasant sensation that may be linked to potential or actual tissue damage, and which may possess both physical and emotional experiences. Pain though, is often difficult to describe, and sometimes the terminology used cannot, and does not, provide justice to the real pain experience. There are currently no objective measurements available for pain, no blood tests or dipstix tests, which means it is an extremely personal phenomenon and is defined by whatever the person experiencing it, says they are feeling (Bandolier, 2003, Donaldson, 2009). Pain of chronic nature can affect sleep patterns and behavioural patterns, often seen in patients with depression, and it severely affects the immune system (Markenson, 1996, Page and Ben-Eliyahu, 1997, Tang, 2008). In 1975 the development of the

McGill pain questionnaire made patients' descriptions of pain much easier to understand, and included sensory (descriptive), affective (motivational) and evaluative (cognitive) descriptors (Melzack, 2005). Memory, emotions and even expectations all have an enormous effect on pain perception (Meagher *et al.*, 2001, Coghill *et al.*, 2003, Wiech *et al.*, 2008) and many patients attach their own meaning. For example a recent observation of a friend or family member having a heart attack can be escalated beyond normal. When the observer suddenly experiences chest pains; it is not unusual for them to automatically reach the conclusion that they too are experiencing a heart attack, when in fact it may be simple muscle tension from poor posture. Such is the power of pain that the focus of it is so consuming and any logical reasoning abandons rational thought processes.

The psychological aspects of pain, include but are not limited to expectation, emotion and attention, each of which has an effect on the descending neuronal activity of the brain (Markenson, 1996, Goffaux *et al.*, 2007). Social, cultural and emotional dimensions of pain relate to the 'whole' pain experience. Pain clinics are increasingly adept at providing a service that encompasses all aspects of such an experience (Bendelow and Williams, 1996, Archard and Collett, 2004). Many patients however are still not receiving adequate pain control and this has its own set of consequences, not least of which are sleeplessness (65% of pain sufferers) depression (49%), fear and stress (Phillips, 2009, Donaldson, 2009). Patients often have preconceived expectations of pain, particularly if they have had previous experience of pain themselves, or have cared for someone who has experienced a similar type of pain (Cioffi, 1991, Coghill *et al.*, 2003). Preconception is associated with negative expectations and where pain control is difficult to achieve it can induce negative attitudes (Wiech *et al.*, 2008). Keefe *et al.* (2004) suggested that adjustment to pain can take two paths. The first pathway, which increases the effect of persistent pain, relates to catastrophizing, a tendency to focus on pain from a negative perspective. Increased fear and anxiety and a feeling of being completely helpless in ones pain management; are all factors that increase the incidence of persistent, disabling pain (Archard and Collett, 2004, Tang, 2008). On the other hand, self help measures using different coping strategies with a willingness to change and accept the condition, all produce a decrease in pain and the disabling qualities that may be associated with it (Rose, 2009). These attributes though, are

not seen in all pain patients and Wade *et al.* (1992) provided evidence that personality traits can play a major part in the cognitive appraisal of pain. Highly anxious people can create pain where there is neither pathological nor physical evidence for it (Ahles *et al.*, 1987). There are an increasing number of approaches to pain in today's society with a growing number of pain clinics offering or providing the patient with services that enable them to make informed choices about their level of care (Donaldson, 2009). However, there is no consistency in pain management across the UK and many primary care facilities lack sufficient funding to be able to offer a variety of services. Those that do, are unable to keep up with the number of referrals (Donaldson, 2009).

Biopsychosocial model

One of the more recent approaches to pain management is the biopsychosocial model. It is based on the idea that ill-health has both a social and cognitive process which cannot be separated (Fillingim, 2005, Quintner *et al.*, 2008). The model proposes that the body has an effect on the mind and that the reverse is also true, so that an individual's response to a painful stimulus is based on their emotional reaction to, and subsequent appraisal of that stimulus (Melzack, 1999, Rose, 2009). Cognitive behavioural therapy was designed to work alongside the biopsychosocial method by helping patients to break the pain cycle (Donaldson, 2009). Patients are taught how to be aware of negative thinking patterns that may link with their pain experience. Adaptive techniques are demonstrated to help them overcome any negative thoughts (Turk and Okifuji, 1999).

Psychoneuroimmunology

The relationship between inflammatory pain and immune suppression has been the remit of scientific researchers for many years (Pert, 1997, Aggarwal *et al.*, 2006, Irwin and Miller, 2007, Irwin, 2008, O'Connor *et al.*, 2009). Recent evidence has provided a much clearer insight into the mechanisms and the possible biochemical interactions that occur between the neurological system, the endocrine system and the immune system, collectively referred to as psychoneuroimmunology (PNI) (Rabin *et al.*, 1989, Page and Ben-Eliyahu, 1997, Masek *et al.*, 2000).

Watkins & Maier (2004) reported that 50% of all neuropathic pain conditions were associated with infection or inflammation of peripheral nerves. Omoigui (2007a, Omoigui, 2007b) has proposed that all types of pain are based on complex inflammatory profiles and that the origin of all pain is based on inflammation and the inflammatory response.

All cells respond to injury, infection and ageing by way of inflammation and the release of a variety of chemical substances (Omoigui, 2007a, b). Where tissue damage is involved multiple inflammatory mediators are released, including bradykinin, 5-HT, adenosine triphosphate, prostaglandins and potassium, to name but a few (Dray, 1995, Wang *et al.*, 2005, Schug, 2007). Inflammatory mediators activate local pain receptors (Aδ and C-fibres) that in turn activate a further inflammatory cycle to generate more nerve signals by enrolling heat sensitive receptors such as the vanilloid receptor (VR). The VR receptor subtype has been identified in small diameter dorsal route ganglia as part of the inflammatory process (Szallasi and Blumberg, 1999, Davis *et al.*, 2000, Amaya *et al.*, 2003). When there is an increase of VR receptor activity Ca^{++} permeability is increased across the cell membrane, subsequently desensitizing the area to further activity (Caterina *et al.*, 1997).

One of the factors associated with stress and chronic pain is lack of sleep, and Irwin (2008) has shown that sleep disturbance can regulate immune cells and their function. Sympathetic activation is propagated by stress and involves the endocrine system (Ahles *et al.*, 1987, Al Absi and Petersen, 2003). Stress increases the release of adrenocorticotropic hormones (ACTH) that create metabolic and hormonal changes further escalating the pain cycle (Ahles *et al.*, 1987, Henry, 1992). Chronic pain is known to induce depression which increases stress levels (Irwin and Miller, 2007). The continual cycle of stress and pain influences immune suppression through the exaggerated release of pro-inflammatory cytokines and chemokines (Aggarwal *et al.*, 2006, Irwin and Miller, 2007, Irwin, 2008, O'Connor *et al.*, 2009) which in turn decrease the number of natural killer cells that play a major role in the rejection of tumours and cells infected by viruses (Irwin, 2008). Such a decrease in

these cells has shown to increase metastasis in cancer patients (Page and Ben-Eliyahu, 1997, Melzack, 1999, Aggarwal *et al.*, 2006).

Gender difference in Pain

Proposals regarding a gender affect in pain medicine are plentiful (Bragdon *et al.*, 2002, Wiesenfeld-Hallin, 2005, Fillingim, 2005), and suggestions have been made that women respond disproportionately to the pain experience based on a number of different factors, including hormonal fluctuations (Sherman and Le Resche, 2006), social expectation and differences in psychological traits such as anxiety and depression (Derbyshire, 2008). Emotionally linked pain generates greater suffering and women are generally thought to be more affected by their pain experience than men (Eccleston, 2001, Rollman *et al.*, 2004) with a tendency to catastrophize their pain (Bragdon *et al.*, 2002). Women are also said to seek more supportive networks and this may be one of the reasons they also tend to seek out complementary or alternative therapies. This makes them ideal candidates for experimental studies, especially since women are said to have reduced tolerance for experimentally induced pain compared to men (Jackson *et al.*, 2005, Greenspan *et al.*, 2007).

1.9 PAIN MEDICATION

Drugs are used in pain management in a variety of ways. Some are known to decrease the pain associated with inflammation, such as non-steroidal anti-inflammatory drugs, whilst others such as local anaesthetics, alter nerve conduction. Some drugs such as opioids and antidepressants modify pain and have a central effect on the emotions (Greene and Harris, 1993, Berger, 2005), whilst others act locally on the area of pain (Schug, 2007). The choice of drug combinations may vary according to type, location and attitudes about pain relief. Previous experience of a drug may bias the patient toward a specific drug especially if their previous experience of that drug was positive; this is also true where the patient may have had an adverse experience of a particular pain-relieving medication. The general rule however is to provide pain relieving analgesics at the lowest level appropriate to the patient's pain, and then to move up the potency level until the required relief is obtained (Dickensen, 2008, Greene and Harris, 1993, Schug, 2007).

One of the earliest known pain medications is opium and remnants of the opium poppy dating as far back as 6000 B.C were discovered in some of the Neothilic-era burial grounds of Europe (Berger, 2005). Its use has been recorded in Mesopotamia for various ceremonies and ancient texts record that Galen made use of opium for pain in 331 B.C. (Brownstein, 1993). Avicenna wrote in his text 'Canon of Medicine' "*…if it is desirable to procure a deeply unconscious state, so as to enable the pain to be borne which is involved in painful applications to a member, ….administer fumitory, opium, hyoscyamus (half dram dose of each)…add this to wine and take as much as is necessary for the purpose"* (Dunn, 1997). Hippocrates was said to have acknowledged it as a useful narcotic and styptic in treating uterine infections during the fourth century B.C. (Fairley, 1978). In the 15th century Paracelsus combined it with alcohol to form tincture of laudanum and in 1806 Serturner isolated the active ingredients of opium, naming it morphine after the Greek god of dreams, Morpheus (Brownstein, 1993, Pert, 1997, Berger, 2005). Its use was limited to oral intake until the development of the hypodermic needle in 1853 (Brownstein, 1993) prior to which it had been ingested or infused in various ways.

The evolvement of medicinal chemicals producing analgesic or anaesthetic properties became established in 1800 when Sir Humphrey Davy discovered that nitrous oxide (N_2O) could decrease physical pain. However, it was not until more than 40 years later that Horace Wells produced surgical anaesthesia for the extraction of a tooth using N_2O (Clark, 1938). Although the description for the synthesis of ether was produced by Cordus in 1546, a note believed to have been written by Michael Faraday in 1818 was published claiming ether had toxic effects that were similar to N_2O (Clark, 1938, Dodd, 2009). The first public use of ether was given by Morton in 1846 when he demonstrated the use of ether in human surgery, although there was much controversy surrounding the matter of its discovery (Clark, 1938). Simpson had previously used ether to relieve the pain of childbirth. In 1847 he and his colleagues successfully used chloroform for major operations. Simpson was the first to use chloroform for obstetric surgery, but its use in childbirth was opposed by the churches until it was administered to Queen Victoria during her childbearing. It then became an acceptable form of analgesia (Dodd, 2009). The discovery of the anaesthetic properties of ethyl chloride as well as chloroform was eventually credited

to Flourens (Clark, 1938). Advances in the use of drugs for managing pain *per se* did not come until the 19th century when the mechanisms of physiology were studied in greater detail. The 20th century saw great developments in pain medications which not only targeted specific types of pain but also endeavoured to reduce the side-effects associated with them. Pain relieving medications are known to extol their effects by blocking either Na or Ca channels (Dickensen, 2008). The British Pharmacopoeia have a large number of different pain relieving substances at its disposal today, some of which are mentioned below.

Opioid drugs

Opioids work by binding to opioid-receptors (mu - μ, kappa - κ, and delta - δ) within the CNS (Berger, 2005, Dickensen, 2008). Some μ-opioid receptors are found in the cell body of c-fibres occupying peripheral nociceptors at the site of tissue damage. They have also been found in dorsal route ganglions where they reside in the cell body of spinal neurons of substantia gelatinosa (Berger, 2005, Dickensen and Suzuki, 2005). They function through G-protein-couple-receptors which control the release of K^+ and Ca^{++} across the nerve cell membrane, *via* voltage-gated ion channels (Berger, 2005).

Following a noxious stimulus μ-opioids hyperpolarize the nerve cell membrane by increasing the release of K^+ pre-synaptically. A reduction in Ca^{++} ions in the cells membrane inhibits c-fibre transmission (Dickensen and Suzuki, 2005). Post-synaptically opioids inhibit the release of neurotransmitters along the anteriolateral tracts of the spinal cord through the inhibition of Ca^{++} from the cell membrane. This prevents the vesicles containing the neurotransmitters from spilling their contents into the synaptic cleft (Berger, 2005). Opioids are classified as either pure or partial agonists. The pure agonists include morphine, diamorphine and pethidine, whilst buprenorphine and meptazinol are partial agonists (Greene and Harris, 1993, Berger, 2005). The effect of partial agonists is weak in comparison to true agonists and their use is indicated mainly for short-term acute pain episodes, often associated with postoperative pain conditions (Schug, 2007).

Opioid medications have a good track record for relieving pain, but are fraught with unwanted side-effects, some of which can be life-threatening (National Institute on Drug Abuse, 2008). High doses of morphine for example have been linked to respiratory depression (Berger, 2005). As the principal component of opioid drugs, morphine is given for chronic severe pain and may be used orally, intramuscularly, intravenously or through the use of transdermal fentanyl patches (Berger, 2005, Dickensen, 2008). The down side to opioid medications is that with continued use, the patient may become tolerant to them and so requires an ever-increasing dose to achieve the same initial effect. They are known to induce nausea and vomiting and their suppression on the peristaltic movement of the gut can induce constipation (Jamison *et al.*, 2003).

The feelings of euphoria associated with opiates are one of the perceived benefits, reducing the anxiety and fear that may accompany severe pain episodes. The sedative effect of opioid analgesia has proven beneficial to those suffering chronic, unrelenting pain but also produces a negative effect for those who want to participate in the activities of life and are affected by clouded judgements (Jamison *et al.*, 2003). Codeine and dihydrocodeine are weak opioids that can be taken in combination with paracetamol to increase their effect (MeRec, 2006, Schug, 2007, Dickensen, 2008).
The effects of morphine are mediated by C-fibre activity in the peripheral nervous system (Stein and Yassouridis, 1997) and recent research has focused on drug development to target this area and avoid the unwanted side-effects from CNS opioid drugs (Berger, 2005). Many have reported that immunosuppression reduces the availability of opioid containing cells (Page and Ben-Eliyahu, 1997, Budd and Shipton, 2004, Rittner, 2005, Stein and Lang, 2009) and the neural connections of immune functions are an ongoing subject of interest to the proponents of PNI (Watkins *et al.*, 1995, Page and Ben-Eliyahu, 1997, Budd and Shipton, 2004, Watkins and Maier, 2004).

Anti-inflammatory and non-opioid drugs

Non-steroidal anti inflammatory (NSAID) drugs include drugs that can be purchased over-the-counter such as aspirin, paracetamol and ibuprofen and the prescription NSAID's cyclo-oxygenase (COX) inhibitors such as co-proxamol and co-codamol shown in Figure 1.22. They are largely used to treat mild to moderate pain associated with inflammatory processes (Latham, 1991, Greene and Harris, 1993, Bertolini *et al.*, 2001) and act on the peripheral nervous system to impair the production of prostaglandins which is increased by activation of COX-2 (Bertolini *et al.*, 2001, Schug, 2007). Prostaglandins are natural compounds responsible for producing the inflammatory pain sensation and pyrexia (increased temperature).

Figure 1.22: A selection of over-the-counter medications. A multitude of drugs are used for the suppression of pain and inflammation, including topical gels, heatpads and NSAIDs (photograph by C.Samuel).

NSAID's and COX inhibitors are known to produce side-effects related to the gastric mucosa through their action on the COX-1 enzyme. The COX-1 enzyme is responsible for inflammatory prostaglandin release in the gastrointestinal tract and maintenance of renal blood flow (Bertolini *et al.*, 2001, Schug, 2007, Brune, 2008, Dodd, 2009). Prolonged use of these drugs in high doses has been associated with liver toxicity (MeRec, 2006). Evidence of fatal toxicity caused by inadvertent overdoses with the NSAID co-proxamol prompted the Medical Healthcare products Regulatory Agency (MHRA), in January 2005, to announce its removal from prescribing practice. All licences were withdrawn from manufacturers of the drug by the end of 2007 (MeRec, 2006). This is not the only NSAID to have been withdrawn. COX-2 inhibitors were also withdrawn after evidence proved they were

a high risk for cardiovascular events such as stroke and heart attacks (Motsko *et al.*, 2006, Chen and Ashcroft, 2007), leaving those with unrelenting inflammatory pain to seek alternatives.

Tricyclic anti-depressants and anti-convulsants

Neuropathic pain is difficult to control and analgesics such as opioids and NSAID's often fail to control this type of pain. The target of medications for neuropathic pain is the ion channels where the chemical messenger is generated (Dickensen, 2008). Such drugs include gabapentin and pregabalin that work to block the Ca^{++} channels responsible for the transmission of pain signals from the periphery to the spinal cord. Ketamine an NMDA antagonist has proven to successfully block 'wind-up' in the spinal cord by acting at peripheral sites to prevent sensitisation (Warncke *et al.*, 1997, Dickensen, 2008).

Antidepressants are sometimes used in conjunction with muscle relaxants (Greene and Harris, 1993, Dickensen and Suzuki, 2005, Berger, 2005) to provide a multi-functional method of interacting with pain. Sensory pain signals to the midbrain and brainstem results in activity that may alter mood and emotions. Serotonin and norepinephrine are neurotransmitter amines released at pre-synaptic terminals in response to a stimulus; any that stay in the synaptic cleft longer than necessary are taken up by transporter proteins to terminate their action, a process referred to as uptake 1. Tricyclic anti-depressants and selective serotonin re-uptake inhibitors (SSRIs) inhibit uptake 1 so that serotonin and norepinephrine remain in the synaptic cleft for longer than normal. This in turn increases the levels in the extracellular fluid so that there is more availability for binding on post synaptic receptors. Their effect is to enhance mood which is a benefit for those people who are experiencing long-term chronic pain conditions (Berger, 2005, Schug, 2007, Dickensen, 2008). Anticonvulsants such as carbamazepine are used as a second line of treatment after antidepressants to block Na^{+} channels, which prevent the repetitive firing associated with many neuropathic pain conditions (Grady, 2002a, Dickensen, 2008).

Local Anaesthetics

Local anaesthetics act on peripheral nerves by blocking Na^{+} channels responsible for transmission of action potentials and ascending pain signals (Bianconi, 1998,

Strong *et al.*, 2002, Edgcombe and Hocking, 2005, Dickensen, 2008). Lignocaine is one of a number of different agents that can be administered topically, intravenously and *via* spinal epidural and is the most versatile (Hayes, 2008). Others include bupivacaine and prilocaine (Edgcombe and Hocking, 2005). Intravenously they are administered close to the area that requires the nerve block so that some of the drug may be absorbed into the systemic circulation (Edgcombe and Hocking, 2005). Local anaesthetics are more commonly used for dental surgery, childbirth or day surgery cases of short duration (Greene and Harris, 1993) but can also be used to break the cycle of chronic pain (Severn, 2002a). They are not without their side-effects and have been associated with systemic toxicity such as hypotension, bradycardia and respiratory depression (Edgcombe and Hocking, 2005).

1.10 FUTURE OF PAIN MEDICATION

There are many morphine-like drugs on the market, but all seem to accumulate some kind of side-effects with prolonged use (Kalso *et al.*, 2004). All addictive drugs are subject to both physical and psychological dependence (Strong *et al.*, 2002) and withdrawal symptoms are often more painful when the drug is stopped abruptly, leaving the patient with cravings and temporary mental disturbance. More recently evidence supports the use of different drugs for male and females based on the evidence that women respond better to opioid medications than men (Fillingim and Gear, 2004). In addition, Greenspan *et al.* (2007) have suggested that the potency and efficacy of certain drugs may be affected by the fact that women carry a higher percentage of body fat than men and that adherence to medications may be subject to effectiveness and associated side-effects that differs between male and females. Pain treatment remains inadequate despite increasing knowledge on causes of pain and how it can be controlled. Together with unwanted side-effects (Kalso *et al.*, 2004) this may be one of the reasons why more use is made of Complementary and Alternative (CAM) methods of pain management (Berman, 2003).

1.11 THE ROLE OF CAM IN PAIN MANAGEMENT

Many people in chronic pain often turn to CAM therapies out of desperation looking for an instant cure, whilst others are happy to find a level in which they can manage their pain with a mix of both conventional and complementary methods (Berman, 2003). There is a growing body of knowledge to support many CAM therapies in the management of pain (Stevensen, 1995, Quinn *et al.*, 2007) and in general there has been an increase in the use of CAM therapies (Zollman and Vickers, 1999, Ernst and White, 2000, Thompson and Feder, 2005). The majority of patients want to take an active role in managing their pain (Smallwood, 2005) and it has been suggested that a person in control of their pain has a better chance of recovering from it (Park and Fulton, 1991, Keefe *et al.*, 2004). The gate control theory is postulated as the mechanism of action in many methods of pain control, not least of which are Transcutaneous Electrical Nerve Stimulation (TENS) and acupuncture (Greene and Harris, 1993, Serpell *et al.*, 1998).

Transcutaneous Electrical Nerve Stimulation (TENS)

TENS is often used in the treatment of chronic pain (Hansson and Ekblom, 1983), and a recent pilot study has shown that when used with acupuncture, TENS can improve quality of life and pain relief for sufferers of chronic low back pain (Itoh *et al.*, 2009). However a systematic review by Khadilkar *et al.* (2009) did not support the use of TENS in chronic low back pain. In acute pain episodes it is often used during labour (van der Spank *et al.*, 2000, Chao *et al.*, 2007). Its mode of action is through the inhibition of high threshold pain fibres, *via* large Aβ nerve fibres which interrupt the pain signal to the brain (Carroll *et al.*, 1996, Wall, 1999a, Chesterton *et al.*, 2003, Koke *et al.*, 2004). TENS machines are frequently used in physiotherapy centres in conjunction with other electrophysical agents and some pain clinics, as well as for personal use (Strong *et al.*, 2002). The machines used for personal use have two rubber-based pads that are placed local to the area of pain and connect *via* electrodes to a small battery-operated unit. The unit produces a low-frequency, pulsed biphasic electrical stimulus often referred to as a pulse frequency, which can be adjusted by the patient according to their need (Johnson, 2007). Research on the use of TENS generally, has shown that its efficacy depends on the electrode placement, the frequency used (Chesterton *et al.*, 2003, Koke *et al.*, 2004, Claydon *et*

al., 2008), stimulus duration, and number of daily treatments (Hansson and Lundeberg, 1999), although a systematic review by Chen *et al.* (2001) argues that pulse frequency does not influence its analgesic effect. The small home use equipment provides the patient with a system of pain management that is totally within their control. TENS is thought to be a safe method of pain management with few, if any side-effects, save for minor skin irritations from placement of the pads. There are limitations on use however, especially in pregnancy where it is advised for use only at the onset of labour, and in those fitted with cardiac pacemakers the equipment should be avoided.

Acupuncture

Acupuncture has been in use for more than 4000 years (White and Ernst, 2004) and there has been an increase in the research surrounding its effectiveness in pain management (Ashton *et al.*, 1984, Pariente *et al.*, 2005, Grasmuller and Irnich, 2007). Whilst the mode of action is still debated in some circles, Pomeranz (1996) provided evidence that it induces the release of endogenous opioids, nonetheless reports of its efficacy for chronic pain are still inconclusive (Wang *et al.*, 2008). There is substantial evidence for its benefits in the first stages of labour (Smith *et al.*, 2003, Nesheim and Kinge, 2006) and other pain modalities (Grasmuller and Irnich, 2007), but the research is still developing. Acupuncture became more readily acceptable in the Western world in 1997 when the National Institute for Health consensus accepted it as a legitimate form of analgesia and the World Health Organisation accepted its use for 43 different diseases (Zhao, 2008). The Western medical practice of acupuncture utilises high-threshold mechanoreceptors activated by low-frequency, high-intensity stimulation that may affect descending inhibitory pathways of the spinal cord (Grady, 2002b). More recently, a systematic review by Lewith *et al.* (2005) have suggested that acupuncture for pain produces a far less specific effect on the pain pathway and that there is an overlap between placebo and expectancy in the brain areas involved in pain. In 2009, the National Institute of Clinical Excellence (NICE) approved acupuncture for the treatment of low back pain (National Institute for Health and Clinical Excellence, 2009).

Mind, body therapies

When hypnosis was used in the management of pain Jensen and Patterson (2006) found a reduction in pain of between 2 and 57%. Such large individual variations in pain responses are also a factor in some people's responses to conventional medicines. Hypnosis is thought to operate through psychological processes that alter the patients mental perception of pain providing them with a form of mental focusing that enables them to manage their pain experience more successfully (Jensen and Patterson, 2006, Pyati and Gan, 2007, Jensen, 2008). A study by Casiglia *et al.* (2007) demonstrated that hypnotic forced analgesia produced a significant effect on pain compared to waking basal conditions. The first medical clinic for hypnosis was opened at the Royal London Homeopathic Hospital and has direct referral from GPs. In 2007 NICE recommended the use of hypnotherapy for irritable bowel syndrome in primary care facilities (Foundation for Integrated Health, 2009).

There is conflicting evidence for the use of primary muscle relaxation techniques with some studies showing similar results to those of hypnosis in clinical trials (Poole, 2001, Freisner *et al.*, 2005, Mackereth, 2005). When Castel *et al.* (2007) compared relaxation against hypnosis with analgesia suggestion and hypnosis with relaxation suggestion, the outcome indicated that hypnosis followed by analgesia suggestion had a greater effect on the intensity of pain and the sensory dimension of pain. They also found that hypnosis followed by relaxation suggestion was no better than relaxation alone. Seers and Carroll (1998) carried out a systematic review and found only weak evidence for relaxation in acute pain, but supported this by saying many of the experiments had methodological flaws.

Physical Therapies

Wall (1999a) commented that treatments such as osteopathy, chiropractic and even physiotherapy all produce impressive temporary results, but they are only transient and have yet to prove any long term benefits. Formal exercise programmes that help to treat musculoskeletal problems have been used for many years and are considered some of the more conservative approaches to pain management (Strong *et al.*, 2002). In a study by Ferrell-Torry and Glick (1993) therapeutic massage was given to nine male hospitalised cancer patients for thirty minutes on two consecutive evenings. A significant reduction in pain perception (60%) and anxiety (24%) together with

increases in general relaxation (58%) was shown. Decreases in heart rate, blood pressure and respiratory rate were also reported in the study. A variety of massage techniques have been used in other pain studies (Grealish *et al.*, 2000, Kubsch *et al.*, 2001), but unfortunately many of them lacked sufficient power and/or control methods. The general relaxation effect afforded by these treatments however is itself beneficial, if only from a psychological perspective (Cowen *et al.*, 2006, Donoyama and Shibasaki, 2009). There is however increasing evidence for marked effects of stress on the neuro and endocrine systems (Rabin *et al.*, 1989, Khansari *et al.*, 1990, Chrousos and Gold, 1992), so that these modalities may in the long term prove more beneficial than any of the study results suggest.

Reflexology

There is limited research on reflexology in pain management but a few randomised controlled studies have demonstrated physiological effects, including a reduction in observed pain and salivary alpha amylase (Hodgson and Andersen, 2008). A significant reduction in systolic blood pressure and pulse rate together with a reduction in state anxiety levels was established by McVicar *et al.* (2007). McNeill *et al.* (2006) demonstrated a significant reduction in the use of Entonox (gas and air) following reflexology, although there was no standardization in the treatment regime. In a much larger study by Poole (2001) 243 patients were randomised to receive reflexology, relaxation or usual care. The study found no significant difference in pain reduction across the groups although there was a trend toward greater pain reduction in the reflexology group. Some studies have supported the use of reflexology in pain management (Siev-Ner *et al.*, 2003, Stephenson *et al.*, 2003, Stephenson *et al.*, 2007) and the general consensus on its mode of action appears to be *via* the 'gating' mechanism, although to date this is still an unproven theory. A recent fMRI study (Nakamaru *et al.*, 2008) examined the relationship between cortical activity and the reflex areas associated with reflexology. Results indicated that stimulation of the foot reflex areas, corresponding to the eye, shoulder and small intestine, stimulated both the somatosensory areas relating to the foot, and the somatosensory areas of the eye, shoulder and small intestine. This is an important validation for reflexology and supports and develops previous work carried out by Tang and colleagues (Tang *et al.*, 2005a, b, Tang *et al.*, 2006).

1.12 PLACEBO ANALGESIA

Placebo analgesia is often described as a mock medicine with no therapeutic action (Strong *et al.*, 2002) and yet the power of the placebo has been an important therapeutic phenomenon since as early as the 18th century (Beecher, 1955). Placebos are often used to add psychological aspects to treatments, as an inert treatment modality in clinical trials and for the benefit of physiological improvement. Placebos were often used as a pacifier in patients who were neurotic about their illness and spent a lot of time with an overstretched doctor who could do little to ameliorate their anxieties (Beecher, 1955). The placebo in clinical trials was considered to be inert but in 1968 Beecher demonstrated that this was not the case. He carried out a clinical trial comparing the effects of morphine against a placebo of saline. Beecher found that patients who were given morphine at their first visit learned it was a powerful analgesic. On their second visit they were given saline, but led to believe it was morphine, they responded to both treatments in the same manner. The expectation of the patients was so high for the analgesic response, that they responded accordingly, thus demonstrating that expectancy and conditioning are a powerful tool in placebo medication (Wall, 1999b).

The percentage of responders to a placebo treatment has been suggested at anywhere between 33% and 50% (Beecher, 1955, Wall, 1999b, Diederich and Goetz, 2008) and the level of responders is reported as being greater in clinical pain than in experimental pain trials (Wall, 1999b, Charron *et al.*, 2006, Faria *et al.*, 2008). One group of clinical psychologists carrying out research into placebo responder 'types' reached an agreement that those who respond to placebo seemed to be more open, trusting and uninhibited, but there is no scientific evidence to support this statement (Brody, 2000). Richardson (1994) indicated that high anxiety types were good responders to the placebo, but again there appears to be no agreement amongst researchers on this matter. There are those who advise that placebo is based on expectations (Wager *et al.*, 2004, Kong *et al.*, 2006, Scott *et al.*, 2007) and conditioning, particularly when there is a conscious perception of the treatment involved (Benedetti *et al.*, 2003). Nonetheless despite this disparity it is clear that placebo is an extremely powerful phenomenon.

The effects of many CAM therapies have been attributed to another type of placebo, termed latroplacebogenic; the effect is based on the interpersonal relationship between the therapist and patient or the environment (Strong *et al.*, 2002). The charisma and the enthusiasm of the therapist are thought to strongly motivate the patient and thus produce positive results (Richardson, 1994, Pollo *et al.*, 2001, Pollo *et al.*, 2003). The term used for a negative placebo effect is nocebo and is bought about because negative connotations have been placed on the treatment outcome, either that it has no benefit, or that one can expect to incur various side-effects to their treatment, including, but not limited to, nausea, dizziness and increased pain (Staats *et al.*, 1998, Strong *et al.*, 2002, Klosterhalfen *et al.*, 2009).

Placebo analgesia has a place in medicine in its own right, and is most powerful in the area of pain management (Evans, 1974, Hrobjartsson and Gotzsche, 2001). There are numerous papers available that have established through functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) scans, that placebo analgesia initiates the same brain areas as inhibitory pain pathways (Petrovic *et al.*, 2002, Wager *et al.*, 2004, Bingel *et al.*, 2006, Scott *et al.*, 2007). Bingel *et al.* (2006) demonstrated that the rostral anterior cingulate cortex (rACC) is highly involved in placebo analgesia, a view that is supported by others (Kong *et al.*, 2006, Diederich and Goetz, 2008). The rACC region of the brain is an important centre of reward and cognition and contains many dopaminergic projections. Scott *et al.* (2007) have shown that nucleus accumbens (NAc), an area rich in dopaminergic neurons, plays a pivotal role that underlies expectation and reward in the placebo effect. fMRI studies have demonstrated that placebo analgesia exhibits interactions with other sub-cortical areas involved in the descending inhibitory mechanism, including the PAG and amygdala which release endogenous opioids into the circulation. Benedetti *et al.* (2003) indicated that verbally induced expectation is crucial for placebo analgesia even after pharmacological pre-conditioning whilst Petrovic *et al.* (2002) proposed that high placebo responders have a more opioid efficient system. Placebo analgesia is real and its mechanism of action is consistently linked to the same brain regions as those associated with descending inhibitory pathways, making it challenging, if not impossible, for a placebo group in clinical trials to be totally inert.

1.13 REFLEXOLOGY AS A TREATMENT IN THE ATTENUATION OF PAIN

The growth and development of CAM therapies in pain has seen a greater number of clinical trials appear in a variety of media systems all of which seek to establish effectiveness or efficacy above and beyond the placebo effect (Pomeranz, 1996, Poole, 2001, Hsieh *et al.*, 2006, Lewis and Johnson, 2006, Stephenson *et al.*, 2007). Many CAM therapies have been written off by orthodox medicine as quackery or placebo; nonetheless it would seem prudent to at least be open-minded about such treatments until scientific discovery either confirms or refutes their usefulness in pain management. There is much anecdotal evidence for the benefits of reflexology in pain management (Booth, 1997, Khan *et al.*, 2006) and several pilot studies have shown successful outcomes to treatment including a reduction in pain scores (Brown and Lido, 2008, Hughes *et al.*, 2008). By its very nature pain is a complex and subjective experience and one that the medical community still struggles to treat successfully. Pain ranks highest in the group of physical concerns for cancer sufferers and low back pain is the most costly medical condition in the UK (Maniadakis and Gray, 2000). It is estimated that 19% of the adult population within the European community suffer from chronic pain and that 40% report inadequate management (Phillips, 2009). In a 2004 audit in the UK it was established that 1 in 7 people suffered from musculoskeletal conditions and over ½ million suffered from neuropathic pain (Archard and Collett, 2004). The cost to the UK economy for loss of work days due to back pain alone was estimated, in a 1998 audit, to be between £5 and £10.7 billion (Phillips, 2009). Primary care management for chronic pain was estimated to be 4.6 million medical appointments per annum with a total cost of £69 million because of ineffective treatments.

Pain is generally treated conservatively with a variety of medications and/or physical therapies including mobilisations and manipulation. Relief of pain is an ongoing problem for the medical community (Bertolini *et al.*, 2001, Bates *et al.*, 2004, Taylor and Stanbury, 2009) and research into the effects of reflexology in pain management has shown some interesting developments (Poole, 2001, Stephenson *et al.*, 2003, Stephenson *et al.*, 2007, Quinn *et al.*, 2007). There is however no available literature assessing the efficacy of reflexology on acute pain in an experimental setting using

healthy human subjects. This research fills a gap in the literature and may provide scientific evidence of the efficacy of reflexology in this regard.

1.14 AIMS

Over the past 25 years there has been an increase in the popularity of reflexology which may be largely due to an increased awareness of CAM in mainstream medical practices. In particular CAM has predominantly been useful amongst palliative care patients. There is currently a paucity of good scientific evidence available to demonstrate the therapeutic benefits of reflexology. Although there are both anecdotal and clinical claims for the benefits of reflexology in chronic pain the evidence for the efficacy of reflexology in acute experimental pain is non-existent at the present time.

This research seeks to conduct controlled experiments on healthy human subjects under laboratory conditions. A variety of experimental conditions will be used in which the principal objective is to test the hypothesis that reflexology is beneficial in the treatment and management of acute pain. Ice pain will be used to provide a noxious stimulus and measurements will be recorded to evaluate the effects of reflexology on pain threshold and tolerance levels.

Ice pain has previously been used in experimental pain conditions for both acupuncture and hypnosis providing a valid reference in clinical pain. Cold interrupts blood circulation and the delivery of oxygen and nutrients to the neuronal processes impairing their ability to conduct impulses. In addition it induces stress in the individual and changes cardiac output making it an ideal choice for use as a noxious stimulus. It is widely used in cardiac medicine to establish vascular regulation and because of its unpleasantness mimics autonomic reactions normally associated with chronic pain.

To achieve these aims and objectives the following experiments were carried out:

1) *The effects of reflexology on basal heart rate, blood pressure and core body temperature* - healthy human subjects will be recruited to evaluate changes in basal heart rate, blood pressure and core body temperature following 30

minutes of standard reflexology treatment and this will be compared to a 30 minute control treatment of sham TENS.

2) *The effects of standard reflexology on pain threshold and tolerance in an ice-pain experiment in healthy human subjects* – this experiment will compare the effects of a 45-minute standard reflexology treatment with a 45-minute sham TENS (control) treatment in attenuating acute pain induced by plunging the non-dominant hand into crushed ice. Measurements for pain threshold and tolerance will be gathered, together with subjective evidence on levels of arousal, anxiety and discomfort.
3) *The effects of standard and light reflexology in an ice pain experiment* - two different levels of reflexology will be evaluated to replicate and extend the work of the previous experiment. Light and standard reflexology will be measured against a no treatment control and measurements for pain threshold and tolerance will be recorded alongside subjective ratings for levels of arousal, anxiety and discomfort. A modified version of the Eysenck Personality Questionnaire will be used to evaluate extroversion/introversion in relation to pain threshold and tolerance.
4) *Mechanical Reflexology vs Sham Tens (Control*) - As reflexology is a touch-based therapy that may alter the physiological responses of the subjects through tactile sensation, a non-tactile reflexology-like stimulus using a mechanical device will be used in an ice-pain experiment. Sham TENS will be used as a control method and the acute effects on treatment on pain threshold and tolerance will be recorded together with subjective evidence on levels of arousal, anxiety and discomfort during ice immersion.
5) *Habituation to ice pain* – in this short experiment, healthy human subjects will endure repeated ice pain exposure to assess whether a) repeated exposures affect basal physiological responses such as heart rate and core body temperature and b) subjects adapt to the ice over four days of repeated exposure.
6) *Effects of repeated reflexology exposure using ice pain in healthy human subjects* – in this cross-over experiment the effects of repeated exposure to standard reflexology will be evaluated against a sham TENS (control). The experiment seeks to evaluate whether a) the effects of standard reflexology treatments observed in previous experiments are repeatable and sustainable, b)

there is a conditioned response and, c) there are any cumulative effects on blood pressure (systolic, diastolic and pulse pressure) and heart rate.

7) *Applied pressure and reflexology stimulation* – the applied pressures of reflexology stimulation have not previously been measured. This experiment will evaluate pressure stimulation in relation to various foot types and discuss its relevance in terms of reflexology.

CHAPTER 2

2.1 MATERIALS AND EQUIPMENT

This research is divided into two experimental sections. The first section includes Chapters 3 – 7 and an account of the materials and methods used in these experimental procedures is documented below. The chapter to be found in the Appendix marked Miscellaneous Chapter is a stand-alone Chapter and experimental materials and methods for that chapter are documented therein.

A list of the equipment utilised during the experiments included:

- Multi-position folding Lafuma chair, shown in Figure 2.1, purchased from www.taobook.com, used for the purpose of performing the reflexology treatments on subjects. The chair has a tubular steel frame, 20mm in diameter on which there is a suspended canvas and an adjustable and removable ergonomic headrest.

Figure 2.1: The Lafuma chair. Used in the experimental procedures, shown in the reclined position. This position was adopted for easy access to the foot sole during reflexology stimulation and was also adopted for the control groups as specified in the relevant chapters.

- The medium used during the application of foot reflexology was ART®™ Foot Reflex Balm; (www.artreflex.com) ingredients shown in the Appendix.
- Un-perfumed wipes were used to cleanse the feet and K Y Jelly was used for improving contact on the heart rate monitor.
- A digital room thermometer was used to record ambient room temperature and was supplied by a medical representative for Detrusitol®XL.

- Polar® A1 heart rate monitor purchased from Bodycare at www.bodycare.co.uk
- Digital blood pressure monitor, model UA-767, purchased from PhysiQue Management Co. at www.physique.co.uk.
- Omron Gentletemp 510 digital ear thermometer, purchased from Boots.
- Stopwatch (W.G. Pye & Co.), provided by laboratory technician.
- Digital timer 8816, Malden Electronics Ltd, shown in Figure 2.2 was supplied by a technician. The equipment was set up with crocodile clips radiating from false leads attached to two 40 x 40 mm square (Shire Design Electronics Ltd) reusable self-adhesive Transcutaneous Electrical Nerve Stimulation (TENS) rubber pads.

Figure 2.2: Malden Electronics Ltd Digital timer 8816. Used for the Sham TENS (control) procedure. The non-pad ends of the TENS leads were attached to the back of the equipment by crocodile clips to give the impression of functioning equipment.

- TENS leads were taken from a portable TENS machine – Shire Design Electronics Ltd.
- Crushed ice was obtained from Scotsman AF10 ice maker and stored in a polystyrene insulating container with lid.
- A lidded polystyrene insulating container measuring approximately 150 x 110 mm was used to store the ice slurry. The container was provided by the laboratory technician.

- A Brannan minimum/maximum thermometer was used to record the temperature of the crushed ice slurry whilst in the polystyrene insulating container. The thermometer was provided by the laboratory technician.
- Scholl Ionic Rejuvenator Foot massager (Model number: DR3121UK1) purchased from Argos, shown in Figure 2.3.

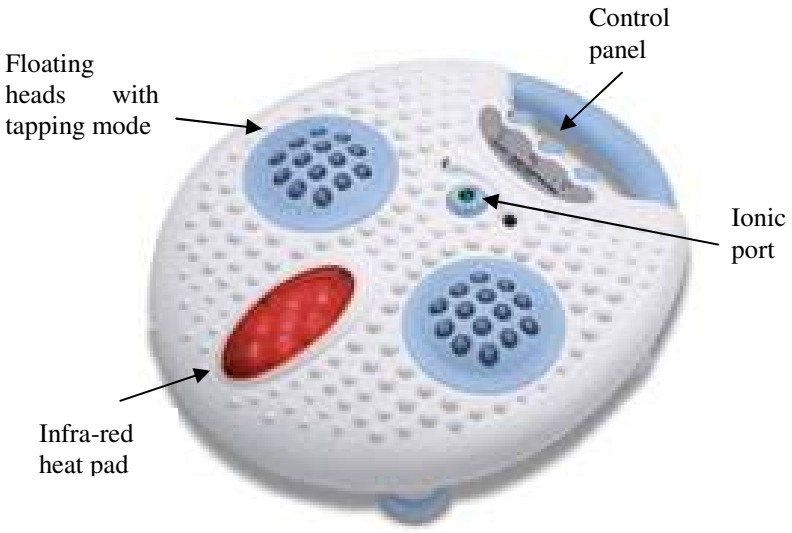


Figure 2.3: The Scholl Ionic Foot Rejuvenator Massager. Used in the Mechanical reflexology experiment discussed in Chapter 6.

2.1.1 Reflexology Foot Charts

For graphical clarity the Figures 2.4 - 2.7 show the placement of the anatomical locations on the feet as they are represented to the reflexologist. They are given here for each of the organs discussed in the reflexology procedure under 2.3.7

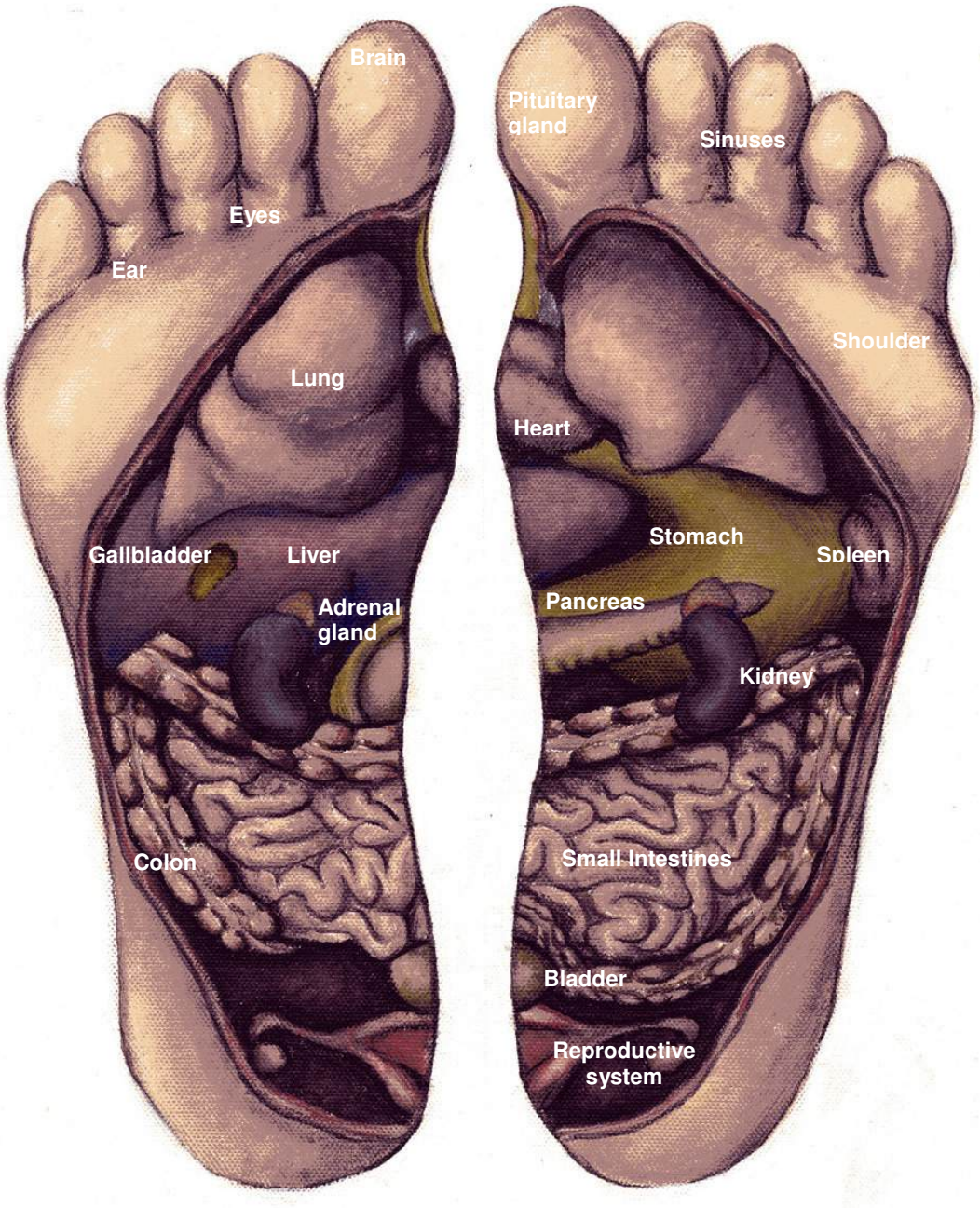


Figure 2.4: Diagrammatic representation of reflex points on the foot sole. The plantar aspect of the foot is shown indicating some of the anatomical representations for reflexology stimulation. Where organ location is bilateral in the human form, they are represented bilaterally on the feet. The image shows the female reproductive system only. Artist: Tina Signorelli ©Carol Samuel 2007

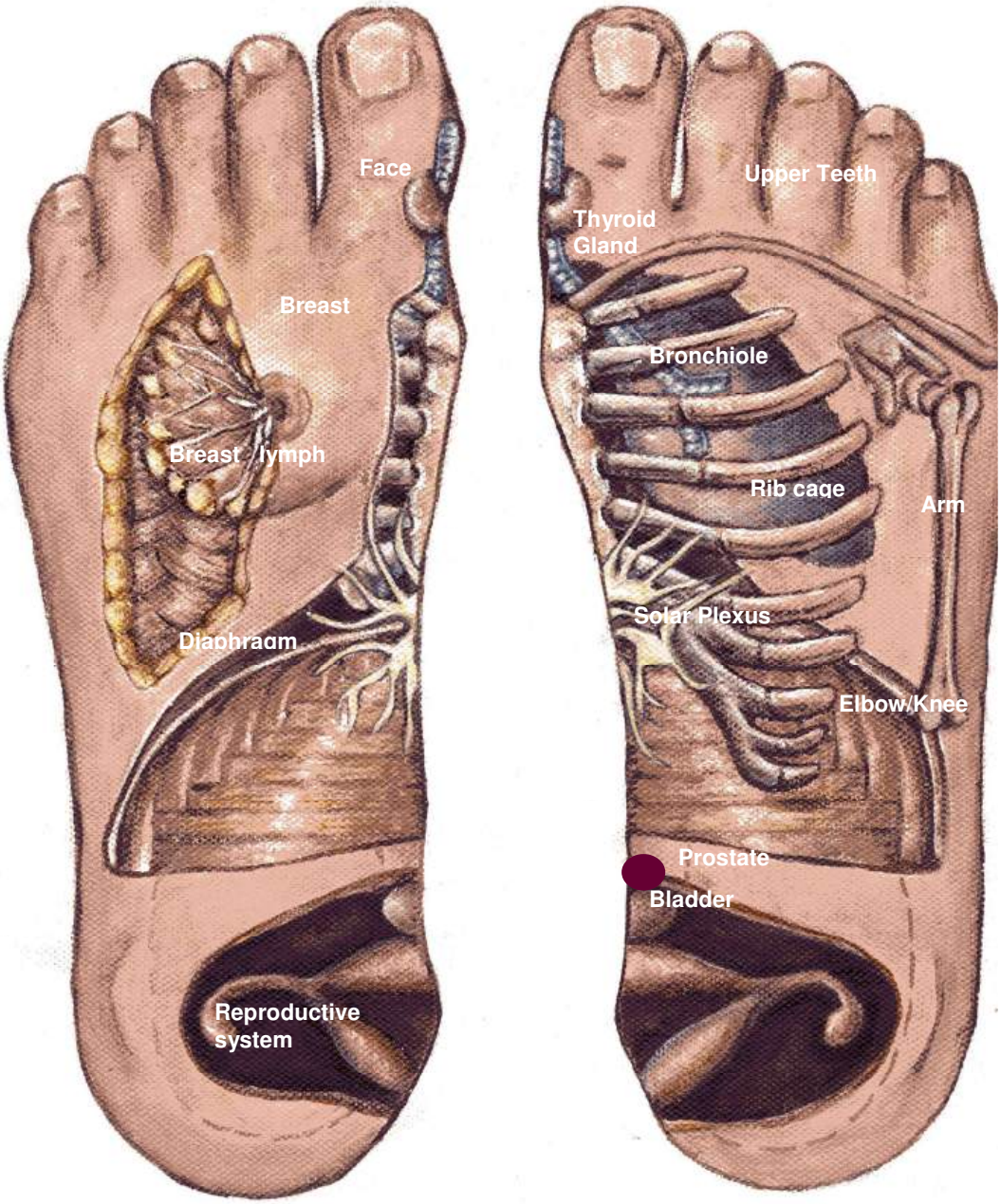


Figure 2.5: Diagrammatic representation of reflex points on the foot dorsum. The dorsal aspect of the foot shows some of the anatomical points used during reflexology stimulation. The graphic shows the female reproductive system. The prostate gland is found beneath the bladder reflex in males, whilst the testes and penis are placed on the medial line toward the heel. The dotted line shows the cut-away section of the leg for visual clarity. Artist: Tina Signorelli ©Carol Samuel 2007

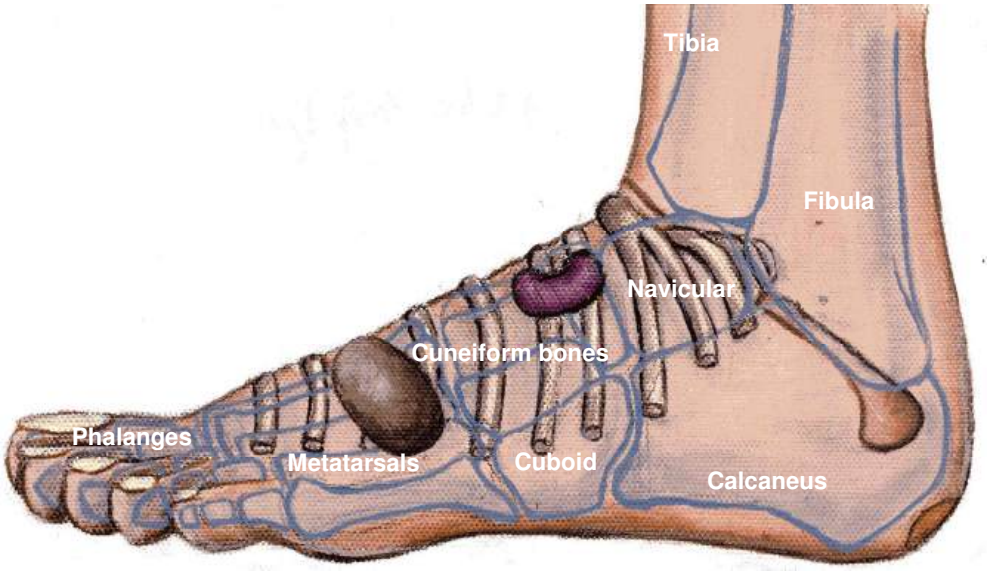


Figure 2.6: Diagrammatic representation of the lateral border of the foot. The diagram illustrates the representative anatomical placement of organs in relation to the foot skeleton. Artist: Tina Signorelli ©Carol Samuel 2007

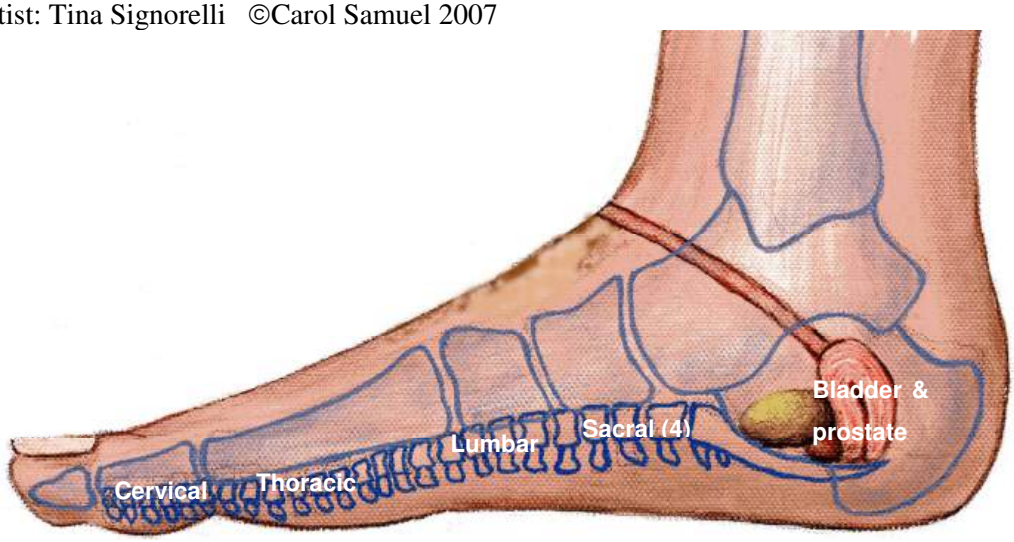


Figure 2.7: Diagrammatic representation of the medial border of the foot. The diagram illustrates the spinal reflexes in relation to the bones of the foot together with the bladder/prostate reflex of the male. Artist: Tina Signorelli ©Carol Samuel 2007

The charts show how organs are seen by the reflexologist on the various aspects of the foot and where the organs are normally bilaterally located within normal anatomy, so they are also depicted this way on the foot. The muscular and skeletal aspects of reflexology points are overlaid in the same manner as they are seen in normal anatomical charts.

2.2 GENERAL METHODS

2.2.1 Subject recruitment

Pain free subjects were recruited mainly from the University of Portsmouth community through posted advertisements, email systems and face to face communication. However members of the general public were also recruited *via* friends of the investigator.

2.2.2 Inclusion/Exclusion criteria

The general criteria for inclusion into the study were: -

- free from any ongoing pain condition
- no previous experience of either reflexology or Transcutaneous Electrical Nerve Stimulation (TENS)
- aged between 18 – 60 years

Subjects were excluded if they: -

- had an ongoing pain problem, and/or were being treated for this condition by their own GP/consultant,
- were taking prescribed or over-the-counter medication for ongoing pain,
- had previous experience of reflexology or TENS,
- had an interest in the outcomes of the experiments,
- had severe psychiatric or somatic illness,
- had established pregnancy at project start,
- had or currently have a thrombosis,
- had Raynauds Syndrome or other neurological disorders, or
- suffer from clinical hypertension for which they received regular medication.

Note:

It is possible that a subject who had volunteered to participate in these experiments was not aware that he/she was suffering from clinical hypertension and this may have become apparent during the experimental procedure. The criterion for exclusion was that the subject's blood pressure (systolic/diastolic) did not normally exceed 20% of those published for the subject's age.

2.2.3 Ethical Approval

Ethical approval for the study was sought and approved by the University of Portsmouth ethics committee prior to commencement of the experimental procedures.

2.2.4 Experimental Design

Unless otherwise stated the experiments set out in this research used a two period crossover design, see Table 2.1. Subjects acted as their own control providing less likelihood of between-subject variability (Grimm, 2002). In addition by utilising this method fewer subjects were required in this difficult to recruit research (Senn, 1993, Blackwood and Lavery, 1998, Carriere and Huang, 2000). Cross-over studies where one group of subjects are used provide a higher degree of internal validity so that results can only be due to the experimental treatment. There are a number of concerns in using a crossover design, but in this research programme each of these was controlled or eliminated. One such concern was the carry-over effect, where the treatment effect in period one, impacts on the treatment effect on period two. Treatment in these experiments was delivered at least one week apart and to date, there has been no evidence to suggest that reflexology has anything other than a transient effect on treatment (Mackereth, 2005), thus for the purpose of this research it was assumed there was no carry-over effect.

2.2.5 Randomisation Procedure

Due to the difficulties of recruitment two methods of randomisation were adopted for this experimental protocol. Randomisation one – this was used where no subject list had formed, *i.e*. subjects were recruited on an ongoing basis. Two labels (reflexology/control) were placed in an envelope and a person unrelated to the experimental procedures removed one label and thus set the treatment sequence. For example if reflexology was drawn, the person who joined the experiment first, received reflexology. The second person then received the control treatment and any further randomisation was by alternating the two treatments until all subjects had

been recruited. Subjects were subsequently crossed over to the opposite group on their second visit see Table 2.1.

Table 2.1: Cross over design randomisation sequence. Subjects were recruited on their first visit to either sequence 1 or sequence 2 and then crossed over to the opposite group for their second visit.

Sequence	Visit One	Visit Two
1	A	B
2	B	A

A = REFLEXOLOGY, B = SHAM TENS

The second randomisation procedure was adopted where there was already a waiting subject list. In this instance multiple labels were placed in an envelope with the words reflexology or control. A person unrelated to the experimental procedures removed a label for each one of the subjects listed, which set the order in which they received their treatment. The order did not necessarily follow a pattern of A then B and B then A. On the contrary the sequence was much more randomised.

The final randomisation procedure followed a Latin-square design to include a three way sequence as shown in Table 2.2 below. Subjects were recruited to this experiment on an ongoing basis and received the treatment as set below for each visit. For example if the sequence for subject one was ABC, the sequence for subject 2 was BCA and for subject 3, CBA before returning to ABC for subject 4.

Table 2.2: Latin square randomisation procedure. This sequence of randomisation was adopted in Chapter 5.

Subject No.	Visit One	Visit Two	Visit Three
1	A	B	C
2	B	C	A
3	C	B	A
4	A	B	C

A = STANDARD REFLEXOLOGY, B = NO TREATMENT (CONTROL),

C = LIGHT REFLEXOLOGY

2.2.6 Calculation of the sample size

There is currently a paucity of data in reflexology research and no data available on the efficacy of reflexology for acute pain in healthy human subjects. The sample size for the initial ice pain experiment (Chapter 4) was therefore estimated.

2.3 GENERAL PROCEDURES

Experimental sessions were carried out between 8a.m. and 8p.m. Monday – Friday and after agreeing to the terms of the experiments, subjects were vetted for any of the exclusion criteria. Prior to attending their first session subjects were asked to avoid consuming beverages containing caffeine, to avoid smoking, alcohol and non-prescription medication such as analgesics, aspirin-like drugs, cough mixtures or nasal inhalers within the two hours prior to participating in each experiment. Subjects were further advised that they would be unable to drink, save for periodic sips of water, eat or go to the toilet during the experimental session.

Unless otherwise stated the general experimental protocol was discussed on the first visit and subjects were issued a copy of the 'Subject Information Sheet' which further explained the requirements. Except for the mechanical reflexology experiment (Chapter 6) all subjects were invited to sit in the Lafuma chair, shown in Figure 2.1, in an upright position. After obtaining informed consent subjects were fitted with all necessary monitoring equipment. KY jelly was used on the heart transmitter chest belt to assist in signal transmission. A short consultation was carried out and subjects were screened for relevant contraindications such as ongoing pain, raynauds syndrome, diabetes, thrombosis etc. Baseline readings were obtained for heart rate, blood pressure, core temperature, pain threshold and pain tolerance where indicated, following which subjects were introduced to the appropriate subjective rating questionnaire for that experiment. Pain threshold is defined as the moment the subject experiences physical pain after ice immersion and pain tolerance as the moment the subject is no longer able to tolerate such physical pain (Ashton *et al.*, 1984). Blood pressure is defined by the systolic pressure, *i.e.* the maximum pressure of blood in the arteries, diastolic pressure as the minimum pressure of blood flowing in the arteries *i.e.* resting heart, and pulse pressure, the difference between

systolic and diastolic pressure. During the experiments subjects were advised that they should remain seated in the Lafuma chair and were given light reading materials or were permitted to converse with the therapist. They were not permitted to discuss the treatment, their health concerns or the research programme. However, it should be noted that the discussion periods during experimental procedures were not timed and some subjects were more talkative than others in both the experimental condition and the control condition. Data were recorded on the appropriate data collection sheets relating to each experimental procedure. The ambient room temperature across all experiments was maintained at 22°C ± 1°C. The same female investigator was used across the experiments and provided all treatments and recorded all data.

2.3.1 Subjective Rating Questionnaire

Subjective rating questionnaires based on a Likert-scale were used for qualitative information pertaining to levels of arousal, anxiety and discomfort during experimental ice immersion procedures (Bolognese *et al.*, 2003). Forms were completed prior to and following the first ice plunge to achieve pre baseline and baseline data. They were later completed subsequent to either reflexology or control and thereafter each ice plunge post treatment. Furthermore in the final question, subjects were required to evaluate whether or not they felt the treatment had an effect on their pain threshold and tolerance levels throughout the experiment.

In the physiological experiment (Chapter 3) the subjective rating questionnaires were used to evaluate anxiety and general health measurements. Evaluation was based on the total of scores marked. The range of scores for the anxiety related points on the subjective ratings questionnaire was between 0 – 25. A low score suggested the subject was extremely nervous, very tense and anxious, was easily upset and felt under heavy pressure. A high score suggested the subject was not affected by nervous tension, was not anxious, and felt relaxed and with little or no stress or strain in their life. The general health questionnaire was also evaluated on the total of scores marked. The total range of scores for the general health related aspects of the questionnaires was between 0 – 15. A low score suggested the subject was often affected by ill-health or bodily disorders; needed help in caring for themselves and was worried or fearful about their health. A high score suggested that subjects was

rarely, if ever affected by ill-health; were easily able to carry out normal tasks and were not fearful or worried about their health.

2.3.2 Feedback Questionnaires

Feedback questionnaires were presented to each subject at the end of each experimental attendance. The questionnaire was used to obtain data relating to the 24 hour period post treatment. It suggested typical known side-effects to treatment and required the subjects to become aware of such events. All forms were returned to the investigator either prior to, or at, later visits. Sleep deprivation is a common problem for chronic pain sufferers and side-effects to drugs is one of the reasons members of the public seek out CAM therapies. This questionnaire provided valuable data that were useful to the qualitative aspects and highlighted the perceived benefits of the research.

2.3.3 Eysenck Personality Questionnaires

In Chapter 5 subjects were invited to complete an adapted version of the Eysenck Personality Questionnaire to see if personality traits, such as extroversion /introversion, correlate with experimental results. Eysencks theory stipulates that the terms extroversion/introversion (E) relate to the level of arousal in the reticular formation and cortical areas of the brain, proposing that introverts are typically more aroused than extroverts. The level of arousal in pain subjects is an important marker for the cognitive/affective processes involved in the pain experience (Matthews and Gilliland, 1999).

2.3.4 Ice-Pain Procedure

Crushed ice slurry (0°C ± 4°C) was placed in an insulating box in which subjects were invited to plunge their non-dominant hand. The hand was immersed flat with the fingers slightly splayed, up to the first wrist crease, see Figure 2.10. A stopwatch was initiated as soon as the hand was immersed up to the first wrist crease and the two measurements (in seconds) were taken as (i) pain threshold (the time it took for the subject to find the experience painful and shout ‘now’) and (ii) pain tolerance (the time it took until the subject could no longer keep his/her hand in the crushed ice

and shout ‘out’). Subjects were advised that no other communication would be permitted during the ice immersions. Subjects were not informed that there was a 5-minute time restriction to the ice immersion.

Figure 2.8: Photograph of the immersed hand of a subject in the crushed ice. The box was covered in between ice immersion with a polystyrene lid.

2.3.5 Procedure for sham TENS

Two 40 x 40 mm square rubber pads were connected to TENS leads attached to the digital timer equipment used as a sham TENS machine. Figure 2.11 shows the placement of the two pads, one of which was placed at 25 mm above the first wrist crease, whilst the other was placed 25 mm below the elbow crease on the ventral surface of the dominant forearm. The digital timer was used to show a running meter and to encourage the perception of an active treatment, but had no other electrical output.

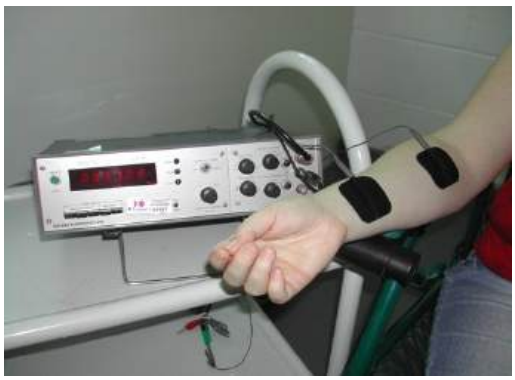


Figure 2.9: Applied TENS pads attached to the ventral forearm and the digital timer. The photograph illustrates the position of the TENS pads when used for the sham TENS (control) procedure.

Subjects were instructed to sit upright in the Lafuma chair at the start of the sham TENS (control) procedure so that the head was resting on the head restraint and the legs were resting on the lower section of the chair over a support. They were then

tipped backward by the investigator to a semi-recumbent position, shown in Figure 2.12 where they remained throughout the treatment period. Prior to the experiment subjects were informed that some forms of TENS were imperceptible and therefore they may or may not feel any stimulating sensation. In addition they were told that this particular type of TENS affected only the d-delta two nerve fibres, which were not as sensitive to the stimulus as some of the other nerve fibres. These nerve fibres do not exist but the script was used to further support an active treatment. Subjects were asked at regular intervals if they were experiencing any kind of tingling sensation and the dials on the box were tweaked to uphold the idea of an active treatment.

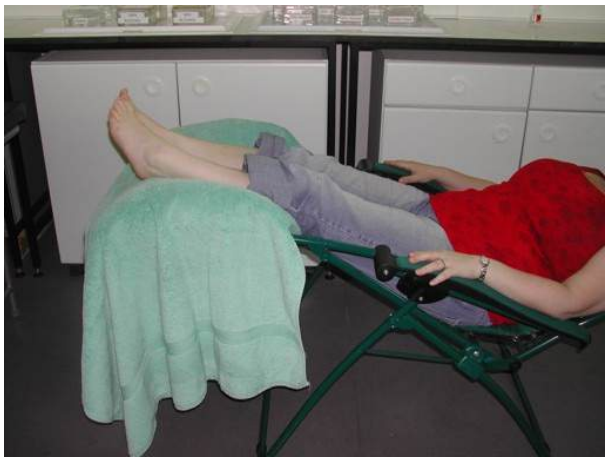


Figure 2.10: Subject tilted to a semi-recumbent position in the Lafuma chair. Feet were raised above waist level and were supported by pillows.

2.3.6 Procedure for Reflexology

The reflexology treatment adopted the same positional features as discussed above for the sham TENS treatment. The experimenter was positioned at the foot of the Lafuma chair and the subject's feet were presented at waist height for ease of working, as shown in Figure 2.12. Once the subject was secured in this position the feet were cleansed using un-perfumed wipes in order to provide a clean, lint free surface for treatment. Both feet were lightly wiped with a small amount of the ART®™ Foot Reflex Balm. Each foot was then stimulated using appropriate reflexology techniques. The reflex points of the head and brain received the initial stimulus, followed by the spinal column, the respiratory system, digestive system, urinary system, reproductive system, the limbs, muscular and lymphatic systems.

In the ice pain experiments (Chapters 4, 5 and 7) the treatment period for both the experimental condition (reflexology) and the control condition (sham TENS or no treatment) was 45 minutes, however, during the physiological experiment (Chapter 3) the treatment period was reduced to 30 minutes. The shorter treatment period was deemed necessary in order to try and reduce the effect of relaxation which is known to lower autonomic activity (Kaushik *et al.*, 2006).

2.3.7 Reflexology treatment sequence

A variety of movements make up the procedure of reflexology and these include holding, pressing, sliding, gliding, walking, stretching and rotations. The most often used technique is known as caterpillar walking in which the medial aspect of the thumb creeps slowly along in an intermittent on/off pressure. It is usual for the feet to be stimulated in systems, working both feet simultaneously. Figures 2.11 – 2.29 illustrate some of the reflex points used in the treatment procedure.

The first point of contact was the pituitary gland, seen as a raised point in the centre of the plantar surface of the big toe, Figure 2.11a. This point was stimulated with the medial edge of the thumb in an on/off movement. The top of the big toe, Figure 2.11b is the representative area for the brain, whilst the base of the big toe represents the neck region, Figure 2.11c.

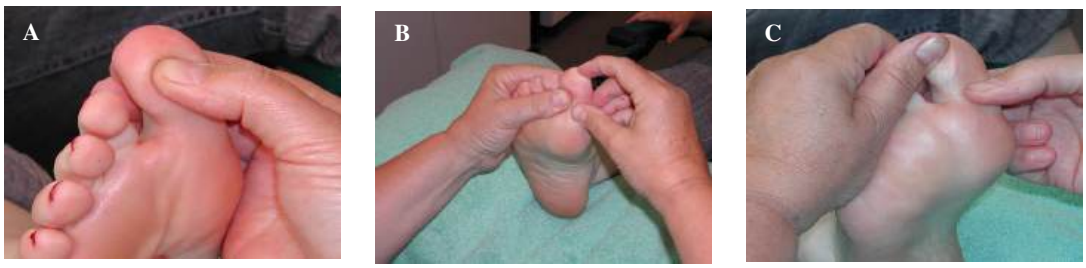


Figure 2.11: Reflexes points for a) Pituitary gland, b) brain/top of head and c) neck.

The next sequence followed the pathway for the spinal reflexes starting at the first interphalangeal joint, Figure 2.12a, representing the cervical spine. From the head of metatarsal one, Figure 2.12b to the distal edge of the cuneiform bone represents the thoracic spine the cuneiform, navicular and talus represent the lumbar-sacral region, Figure 2.12c and finally the lower medial edge of the calcaneus provides the placement for the coccyx.

Figure 2.12: Reflexes for a) cervical spine, b) thoracic spine and c) lumbar/sacral spine.

The shoulder reflex is shown in Figure 2.13a on the lateral aspect of the foot around the area of the 5th metatarsal head. The sinuses are located on the plantar aspect of the toes shown in Figure 2.13b and the dorsal aspect of the toes shown in Figure 2.13c represents the reflexes for the teeth.

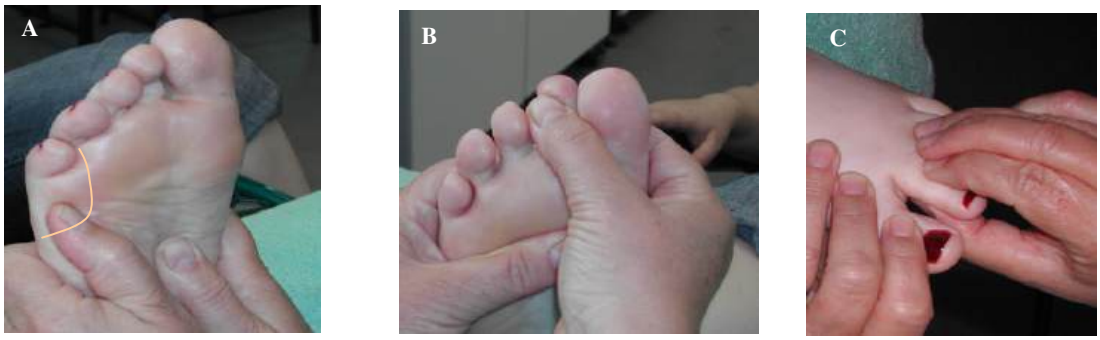


Figure 2.13: Reflex points for a) shoulder, b) sinuses and c) teeth.

The features of the face, thyroid gland, larynx, and tonsils are projected on the dorsal surface of the big toes, Figure 2.14a. In Figure 2.14b the distal edge of the metatarsal heads are indicated as the reflexes for the eustachian tube, the ears in general and the eye reflexes. The lungs are located on the ball of the foot; Figure 2.14c, covering the region of the metatarsal space from head to base. Stimulation of these reflex points is by a caterpillar on/off palpation technique.

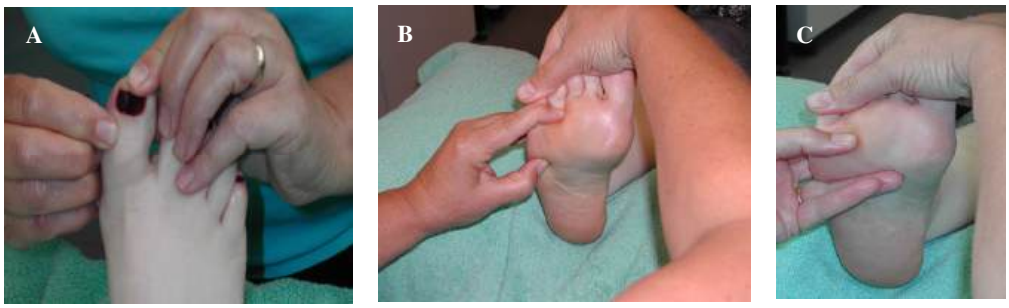


Figure 2.14: Reflex points for the a) face, b) ears and c) lungs

The foot arch is the placement for the digestive system, shown in Figures 2.15a-c. The treatment sequence follows the a) small intestine, b) illeo-caecal valve, located on the right foot, just beneath the fifth metatarsal tuberosity and finally c) the colon in the direction of natural flow, ascending, transverse, descending, sigmoid colon and finally the rectum.

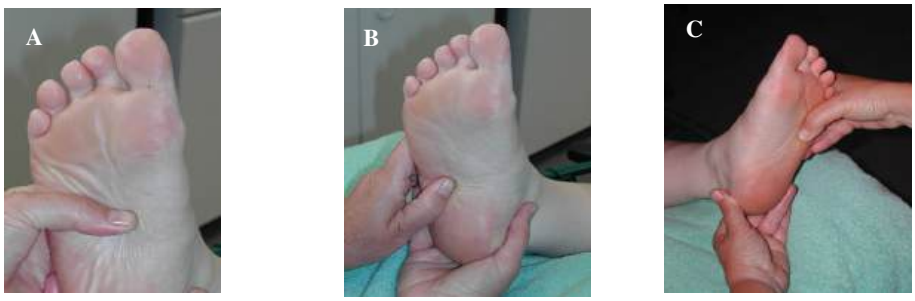


Figure 2.15: Reflex points for a) small intestine b) illeocaecal valve and c) the descending colon

The kidney and adrenal glands are located in line with the second toe, Figure 2.16a in the foot arch. A gliding movement with the thumb moving toward the bladder reflex is used to flush out the urinary tract. The reflexes for the ovaries and testes are located on the outer aspect of the foot just beneath the lateral malleolus, shown in Figure 2.16b. The stimulation uses a rotation movement of the static thumb. The uterus and prostate, located just beneath the medial malleoulus, Figure 2.16c were stimulated in a similar manner. The fallopian tubes and vas deferens are located across the dorsal surface from the lateral to medial aspect of the foot around the area of the malleoli.

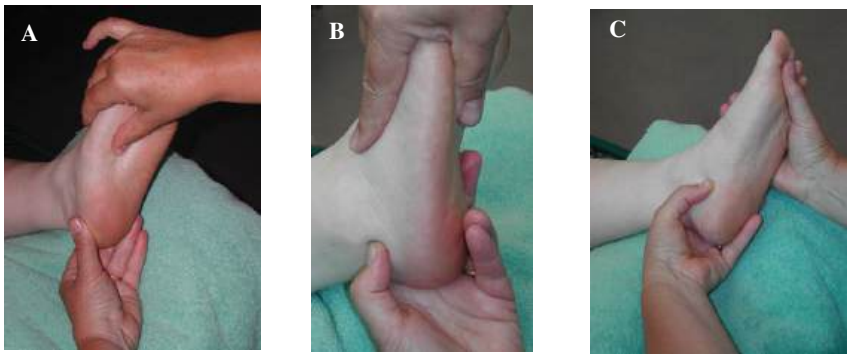


Figure 2.16: Reflex points for a) kidney, b) ovaries/testes and c) uterus/prostate

The lymphatic system was drained using a sliding, gliding and milking technique and was stimulated to encourage lymphatic flow throughout the entire lymphatic system. The milking technique incorporates an on/off sequence combined with

sliding the thumb and forefinger simultaneously. The spleen found on the left foot was also stimulated during this process, together with the thymus gland. The ribs and intercostal muscles together with the diaphragm form part of the respiratory system and were stimulated using the caterpillar on/off walking either by single forefinger, or all four fingers together. In a clinical setting the therapist must palpate each reflex point and be aware of the responses associated with that reflex point. In these laboratory based experiments however, the investigator stimulated each reflex point in turn in the order discussed above without recording or verbalising any disordered reflexes to the subject. No questions were asked during the treatment session and subjects were not provided with any information pertaining to the treatment.

2.3.8 Procedure for Mechanical Reflexology

Subjects were seated in a standard upright chair free of armrests or neck support. Feet were cleansed using un-performed wipes and then rested over the floating heads of the Scholl Ionic Rejuvenator Foot Massager, illustrated in Figure 2.17. The machinery was placed on an even floor surface and the setting switched to a relaxing massage for 20 minutes; the maximum time permitted with this machinery. The main feature of the massage is vibratory. Following the 20 minutes of stimulus the machine was switched off and subjects were asked to remain still until heart rate readings were recorded.

Figure 2.17: The feet shown over the floating heads on the Scholl Ionic Rejuvenator Foot Massager. The equipment was set for 20 minutes on a low massage setting.

2.4 STATISTICAL METHODS

Unless otherwise indicated data were analysed using a two-way analysis of variance (ANOVA) with repeated measures, with one between-subjects factor (i.e. treatment), and one within-subjects factor (i.e. time) with respect to time on the raw data. In Chapter 7 a 3-way ANOVA with one between-subjects factor (i.e. treatment) and three within-subjects factors (i.e. time, group and period) was used. They were subsequently analysed using ANOVA for change from pre-treatment baseline scores (Twisk and Proper, 2004). This method of analysing the data is in line with the statistical processing carried out by others for small group repeated measures trials (Ashton *et al.*, 1984, Vickers, 2001, van Breukelen, 2006, Winkens *et al.*, 2007). In addition, in Chapter 6 the data were calculated as a percentage change from a normalised baseline because significantly different baselines were observed for pain tolerance (Vickers, 2001). Test-retest and reliability statistics for baselines were calculated using the Pearsons product-moment correlation coefficient statistic (Salkind, 2004).

A bespoke programme for the two and three way ANOVA was designed for use in Microsoft Excel 5.0 by Dr I S Ebenezer of the University of Portsmouth. Graphical representations were prepared using GraphPad Prism 5.

The subjective rating questionnaires were analysed using the Wilcoxon sign rank test for non-parametric statistics of matched pairs using SPSS 15.0. The subjective rating analysis for Chapter 5a used the Friedman test in Graphpad Prism 5 (Winer, 1971, Siegel and Castellan, 1988).

In Chapters 5a, 6 and 7 the Pitman permutation test was used. This type of test is sometimes used when testing for equal variances in paired data (Pitman, 1939, Bland, 2000). It was introduced in these chapters as the raw data showed significant inter-individual variations. Such tests are known to control for errors in cross-over design trials providing exact distribution-free significance levels (Gresty *et al.*, 2003, Good and Xie, 2008, Howell, 2010). Where small group data are presented and group differences in effect size are compared the Pitman calculation (Figure 2.18) is expected to provide superior statistical power whilst preserving the relational properties of a time-series such as those used in these experiments (Goulden *et al.*, 2010).

$$t = \frac{(f-1)*\sqrt{n-2}}{2*\sqrt{f*(1-r^2)}}$$

Figure 2.18: Statistical equation for the Pitman permutation test

Chapter 5b introduces a method of analysis using the minimum and maximum criteria set out by Ashton *et al.* (1980) and accounts for inter-individual variations between subject's.

2.4.1 Inclusion/Exclusion criteria for statistical analysis

A review of the literature for pain threshold values indicated that an average range of pain threshold level in experimental pain studies was 15.0 ± 7.0 SD – 22.0 ± 19.6 SD (Ashton *et al.*, 1984, Johnson and Din, 1997, Smith *et al.*, 2008) whilst Kowalczk *et al.* (2006) concluded that normal menstruating women showed higher pain thresholds during the menstrual cycle phase with an average between 40 – 50 seconds. To account for menstrual cycle phase in this mostly female group of subjects, the cut-off for pain threshold was set at 40 seconds. Subjects demonstrating pain threshold levels greater than 40 seconds in the control groups were removed entirely from the analysis.

All forms used in the experimental procedures are shown in Appendix B.

CHAPTER 3

THE EFFECTS OF REFLEXOLOGY ON BASAL HEART RATE, BLOOD PRESSURE AND CORE BODY TEMPERATURE

3.1 INTRODUCTION

A number of studies have claimed that there may be physiological and psychological benefits from the effects of standard reflexology treatment, including improvements in blood circulation (Sudmeier *et al.*, 1999, Mur *et al.*, 2001), increases in sinus arrhythmia (Frankel, 1997), improved pain perception and intensity (Siev-Ner *et al.*, 2003, Stephenson *et al.*, 2007, Brown and Lido, 2008) and reductions in stress and anxiety levels (Gambles *et al.*, 2000, Stephenson *et al.*, 2000, Quattrin *et al.*, 2006, Mackereth *et al.*, 2008). However, data on basic physiological parameters such as heart rate, blood pressure and temperature is scant, and whilst many believe that reflexology can lower these parameters only one study has measured them independently of any other pathological characteristics. McVicar *et al.* (2007) in a pilot study of thirty normal healthy subjects showed no significant between group differences in either systolic, diastolic blood pressure or pulse rate when compared to no treatment.

Many side-effects of pain medications such as morphine and NSAID's are known to induce suppressive effects on autonomic function (Jordan *et al.*, 2000, Bertolini *et al.*, 2001, Jamison *et al.*, 2003, Bates *et al.*, 2004, Berger, 2005) On the other hand stress-induced analgesia is well recognised as a mechanism for pain suppression and its ability to change basic physiological functions by increasing heart rate, blood pressure and core body temperature (Marazatti *et al.*, 1992, Henry, 1992, Khansari *et al.*, 1990, Al Absi and Petersen, 2003, Martenson *et al.*, 2009, Vierck *et al.*, 2009). Investigations on the effects of standard reflexology on autonomic function have suggested that the treatment has beneficial effects on the stress response (Hodgson and Andersen, 2008) and anxiety related ailments (McVicar *et al.*, 2007, Mackereth *et al.*, 2008). Changes in heart rate, blood pressure and core temperature are affected by psychological and physical stress which may add to pain perception (Marazatti *et al.*, 1992, Al Absi and Petersen, 2003, Chapman *et al.*, 2008). This study is an

important preliminary investigation for future ice pain experiments because it seeks to establish whether changes in basal physiological function are affected by standard reflexology and whether or not standard reflexology induces stress.

3.2 AIMS

The aim of this experiment was to evaluate the effect of a single 30-minute reflexology session on acute autonomic changes compared to a single sham TENS (control) treatment of 30 minutes. Objective measurements for heart rate, blood pressure (systolic, diastolic and pulse pressure) and core temperature together with subjective measurements for general health and anxiety were reviewed.

3.3 METHOD

3.3.1 Design

This was a randomized cross-over design experiment in which subjects took part in both standard reflexology and sham TENS (control) given one week apart, see Chapter 2, (sub-section 2.2.4).

3.3.2 Demographics

Sixteen volunteer subjects were recruited to the study from across the University of Portsmouth and general community; two female subjects left the study prior to commencement. A total of 14 subjects completed the experimental procedure consisting of 13 females and 1 male subject with a mean age of 32.6 ± 2.69 (range 19-56). One of the subjects was of Asian origin, the remaining thirteen were Caucasians. All subjects were found to be normotensive. Five of the subjects were taking the oral contraceptive pill. Five were in the follicular phase (days 8 - 14) of their menstrual cycle and one was in the luteal phase (days 15 – 21) of her menstrual cycle during their first attendance. Of the remaining eight subjects, one of whom was male, six were in the first week post menstruation and one was post menopausal. These data were based on the subject's own record of their menstrual cycles and not on ovulation testing (Greenspan *et al.*, 2007).

3.3.3 Procedure

Prior to attending subjects were informed on the protocol and advised to refrain from consuming any beverages containing caffeine, to avoid smoking, alcohol and non-prescription medication such as analgesics, aspirin-like drugs, cough mixtures or nasal inhalers, within two hours of each experimental attendance. Subjects were further advised that they would be unable to drink, eat or go to the toilet during the experimental session.

Informed consent was obtained and subjects were fitted with monitoring equipment including a heart rate monitor chest belt (T31 transmitter). The output device (Polar® A1 heart rate monitor) was hung from a neck cord placed over the subjects' head. A blood pressure cuff (Model UA-767) was positioned on the upper left arm superior to the brachial artery. The digitised monitor was placed on a trolley directly alongside the subject. Temperature was recorded using the Omron Gentletemp 510. Subjects were settled in the Lafuma chair and allowed a 5-minute rest period to acclimatise to the environment and a general medical consultation was completed. Baseline measurements for heart rate, blood pressure and core temperature were observed while subjects remained fully upright. Following the initial baseline readings subjects completed the subjective rating form. When a period of 10 minutes had elapsed from the baseline readings, a further set of readings were taken for heart rate and core temperature. Readings were recorded on the data collection sheet in the following pattern throughout the duration of the trial. Heart rate and core temperature were recorded every 10-minutes, and blood pressure was recorded every 20-minutes. Except for the measurement taken during the treatment period, when the blood pressure was recorded in the semi-reclined position, subjects were asked to ensure their feet were firmly on the ground and uncrossed. Prior to treatment, three baseline measurements were obtained for heart rate and core temperature, whilst two baseline measurements were obtained for blood pressure. Immediately following the second baseline blood pressure reading the treatment commenced. Three heart rate and core temperature recordings and one blood pressure recording were obtained during the treatment. A further six heart rate and core temperature recordings and three blood pressure recordings were taken following the treatment. The timeline is shown in Table 3.1.

Table 3.1: The experimental timeline in minutes. Total experimental time 120 minutes
KEY: BP = systolic and diastolic blood pressure, HR = heart rate, Tc = core body temperature.

TIME ↳	Baseline 30 minutes			Treatment 30 minutes			Post treatment 60 minutes					
0 – 9 minutes	10	20	30	40	50	60	70	80	90	100	110	120
Consultation/ forms/monitors etc	BP		BP		BP		BP		BP		BP	
	HR Tc	HR Tc	HR Tc	HR Tc	HR Tc	HR Tc	HR Tc	HR Tc	HR Tc	HR Tc	HR Tc	HR Tc

During the experiments subjects were advised that they should remain seated in the Lafuma chair, they were given light reading materials or were permitted to converse with the therapist. They were not permitted to discuss the treatment, their health concerns or the research programme. The procedure for both reflexology and sham TENS (control) is described earlier in Chapter 2 (Sections 2.2.6/7). Following the final recordings of the physiological parameters subjects were given an aftercare advice leaflet together with a feedback questionnaire. Ambient room temperature was maintained at 22°C ± 1°C. Subjects were tested individually at the same time of day on both attendance days, one week apart.

3.3.4 Subjective rating questionnaire

Two subjective rating questionnaires were given to subjects to ascertain their level of general health and anxiety. The first questionnaire was based on the month prior to their first visit. The second questionnaire was based on their general health and anxiety levels for the week prior to attending their second visit. There were a total of eight questions and each question gave a choice of six answers. The answers were rated and scored according to the responses given by the subjects.

3.3.5 Feedback questionnaire

Feedback questionnaires were issued at the end of each visit. The questionnaire was used to obtain data pertaining to the 24 hour period post treatment in which subjects may experience side-effects to treatment. The form suggests typical known side-effects to treatment and required the subjects to become aware of such events. Questionnaires were issued following both standard reflexology and sham TENS (control).

3.3.6 Statistical analysis

Data were analysed using a two-way analysis of variance (ANOVA) with repeated measures on the raw data with respect to time and also as a change from pre-treatment baselines, with one between-subjects factor (i.e. treatment), and one within-subjects factor (i.e. time). Test-retest reliability statistics for baselines were calculated using the Pearsons product-moment correlation coefficient statistic (Salkind, 2004). Subjective rating questionnaires were analysed to show the median, 1st and 3rd quartiles.

3.4 RESULTS

3.4.1 The effects of reflexology on blood pressure

The results shown in the Tables 3.2, 3.3 and 3.4 represent the mean ± SEM of the raw data for diastolic blood pressure (mmHg), systolic blood pressure (mmHg) and pulse pressure (mmHg) respectively.

Table 3.2: Mean ± SEM for diastolic BP (mmHg), by treatment and by time showing 2 pre-treatment, 1 during treatment and 3 successive post treatment observations each at 20 minute intervals. *n=14.* There were no significant main effects of treatment ($F_{(1,13)}$=0.4031,n.s.) no significant effect of time ($F_{(3,39)}$=0.9910,n.s.) and there was no treatment x time interaction ($F_{(3,39)}$=2.4211,n.s.).

Time ⇨	10 min	30 min	50 min	70 min	90 min	110 min
Treatment	*Pre-treatment Baselines x 2*		*During treatment*	*Post treatment x 3*		
Control	66.3 ± 2.7	69.0 ± 2.7	67.9 ± 3.3	69.8 ± 3.1	68.1 ± 2.5	69.2 ± 2.4
S. Reflex	71.2 ± 4.4	68.9 ± 2.8	69.1 ± 2.5	67.7 ± 2.6	72.4 ± 2.5	71.1 ± 2.2

Table 3.3: Mean ± SEM for systolic BP (mmHg), by treatment and by time showing 2 pre-treatment, 1 during treatment and 3 successive post treatment observations each at 20 minute intervals. *n=14.* There were no significant main effects of treatment ($F_{(1,13)}$=0.0073,n.s.) no significant effect of time ($F_{(3,39)}$=0.2992,n.s.) and there was no treatment x time interaction ($F_{(3,39)}$=1.0591,n.s.)

Time ⇨	10 min	30 min	50 min	70 min	90 min	110 min
Treatment	*Pre-treatment Baselines x 2*		*During treatment*	*Post treatment x 3*		
Control	114.1±2.7	108.9±3.0	108.9±3.0	110.9±2.9	110.2±2.3	110.1±3.2
S. Reflex	115.7±4.9	109.6±2.5	110.9±2.5	108.4±2.9	111.0±3.2	109.0±2.9

Table 3.4: Mean ± SEM for pulse pressure BP (mmHg), (the difference between diastolic and systolic pressures) by treatment and by time showing 2 pre-treatment, 1 during treatment and 3 successive post treatment observations each at 20 minute intervals. *n=14.* There were no significant main effects of treatment ($F_{(1,13)}$=1.1748,n.s.) no significant effect of time ($F_{(3,39)}$=0.7005,n.s.) and there was no treatment x time interaction ($F_{(3,39)}$=0.9587,n.s.).

Time ⇨	10 min	30 min	50 min	70 min	90 min	110 min
Treatment	*Pre-treatment Baselines x 2*		*During treatment*	*Post treatment x 3*		
Control	-47.9 ± 2.5	-39.9 ± 1.9	-41.0 ± 2.0	-41.1 ± 2.0	-42.1 ± 1.2	-42.1 ± 2.4
S. Reflex	-44.5 ± 3.0	-40.7 ± 1.7	-41.8 ± 1.9	-40.6 ± 2.2	-38.6 ± 1.8	-37.9 ± 2.0

Test-retest reliability of the baselines was carried out using the Pearsons product-moment correlation coefficient statistic and the results showed that the measurements for the systolic blood pressure were significantly correlated (r = +0.66, df = 14, $p<0.05$) at 10 min and (r = +0.78, df = 14, $p<0.01$) at 30 min. The baseline measurement for diastolic blood pressure at 10 min showed no correlation (r = -0.09, df = 14, n.s) but at 30 min the baselines were significantly correlated (r = +0.57, df = 14, $p<0.05$). In general the data showed good test-retest reliability for systolic blood pressure but for diastolic blood pressure there was some variance in the 10 min baseline data. However a paired t-test showed no significant differences between baseline scores in either systolic (p=0.66,n.s and p=0.72,n.s for 10 and 30 min respectively) or diastolic pressure (p=0.36,n.s and p=0.95,n.s for 10 and 30 min respectively).

3.4.2 Change from pre-treatment baselines

There is much evidence in the literature that analyses of data for small groups with repeated measures is best served by a change from pre-treatment baseline calculation and in line with the statistical analyses carried out by others (Ashton *et al.*, 1984, Vickers, 2001, van Breukelen, 2006, Winkens *et al.*, 2007) this method has been adopted here.

Figures 3.1 – 3.3 shows the (change from the pre-treatment baselines) mean ± SEM values for diastolic, systolic and pulse pressure (mmHg) respectively. In order to obtain an accurate baseline recording from which to calculate the change, the two measured baselines taken at 10 and 30 min (see Tables 3.2-3.4) were averaged and the change during and after treatment were calculated using this average.

Diastolic blood pressure

The ANOVA showed that there were no significant main effects of treatment in the diastolic measurement ($F_{(1,13)}$=0.2350,n.s.). When compared to the sham TENS (control) there was an initial reduction in diastolic pressure during the standard reflexology treatment period, Figure 3.1. This effect was maintained for a further 20 min but was followed by an increase in diastolic pressure at 40 min post treatment and did not quite return to the averaged baseline. There were no significant effects of time ($F_{(3,39)}$=0.9910,n.s.) but the ANOVA did show a significant treatment x time interaction ($F_{(3,39)}$=3.2010,$p<0.05$).

Systolic blood pressure

Whilst the systolic pressure remains lower than the averaged baseline figure throughout the entire treatment period, Figure 3.2, there were no significant differences for either treatment ($F_{(1,13)}$=0.2664,n.s.), time ($F_{(3,39)}$=0.2992,n.s.) or treatment x time interaction ($F_{(3,39)}$=1.0591,n.s.) when compared to the sham TENS (control).

Pulse pressure

In addition the difference between diastolic and systolic pressure recorded as pulse pressure, Figure 3.3 also showed that there were no significant differences for effect of treatment ($F_{(1,13)}$=0.0118,n.s.), time ($F_{(3,39)}$=0.7006,n.s.) nor were there any treatment x time interactions ($F_{(3,39)}$=0.9587,n.s.).

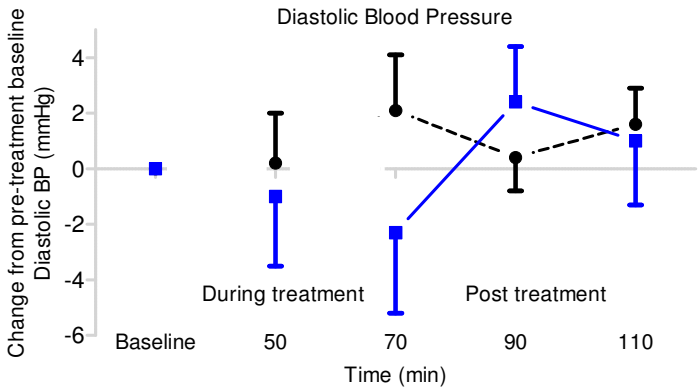


Figure 3.1: Mean ± SEM diastolic blood pressure (mmHg) shown as a change from the pre-treatment baseline, *n=14*. Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Reflexology

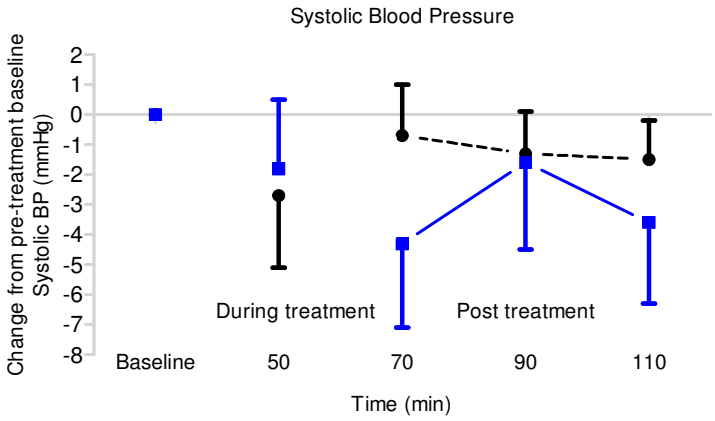


Figure 3.2: Mean ± SEM systolic blood pressure (mmHg) shown as a change from the pre-treatment baseline, *n=14*. Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Reflexology

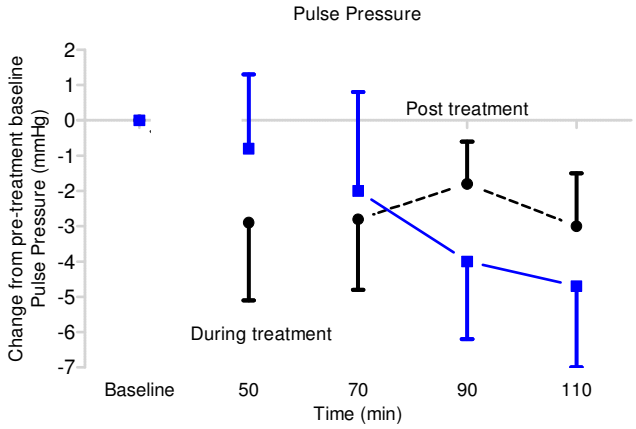


Figure 3.3: Mean ± SEM change from pre-treatment baseline in pulse pressure (mmHg), *n=14*. Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Reflexology

3.4.3 The effects of reflexology on heart rate

Table 3.5 shows the effect of reflexology on heart rate. Pearson's product-moment correlation for test-retest reliability of baseline data were carried out at 10 min, 20 min and 30 min and showed that the data were not significantly correlated (r = +0.28, df = 14, n.s) at 10 min (r = +0.36, df = 14, n.s) at 20 min or (r = +0.12, df = 14, n.s) at 30 min. A paired t-test on the data however revealed no significant differences at baseline p=0.26,n.s, p=0.13,n.s, and p=0.24,n.s at 10, 20 and 30 min respectively.

Table 3.5: Mean ± SEM for heart rate (bpm), by treatment and by time showing 3 pre-treatment, 3 during treatment and 6 successive post treatment observations each at 10 minute intervals. *n=14.* There were no significant main effects of treatment ($F_{(1,13)}$=0.9537,n.s.) there were significant effects of time ($F_{(8,104)}$=4.5139,p<0.01) and there was also a treatment x time interaction ($F_{8,104)}$=2.1681,p<0.05) following reflexology treatment.

Time ⇨	10 min	20 min	30 min
Treatment	*Pre-treatment baselines x3*		
Control	73.2±3.4	70.8±2.6	69.9±2.7
S Reflex	76.5±3.4	74.6±3.4	72.1±3.1

Time ⇨	40 min	50 min	60 min
Treatment	*During treatment x 3*		
Control	66.4±2.7	65.1±2.9	64.9±2.4
S Reflex	63.1±2.3	61.0±2.1	60.2±2.1

Time ⇨	70 min	80 min	90 min	100 min	110 min	120 min
Treatment	*Post treatment x 6*					
Control	66.5±2.5	67.1±2.3	66.4±2.8	66.9±2.6	67.1±2.6	65.6±2.3
S Reflex	67.1±2.7	66.4±2.5	66.3±3.1	67.6±2.9	66.2±3.0	67.1±3.0

In line with the analysis carried out for blood pressure above, the three baseline observations were averaged and a two way analysis of variance with repeated measures on treatment and time was performed on the change in heart rate from pre-treatment baselines. The results are illustrated in Figure 3.4 and revealed significant main effects of treatment ($F_{(1,13)}$=10.2677,p<0.01.), time ($F_{(8,104)}$=4.5139,p<0.01) and treatment x time interactions ($F_{(8,104)}$=2.1681,p<0.05). The average baseline heart rate for the two treatments was in the range 70.4 ± 2.6 - 73.4 ± 3.2 bpm (control and reflexology). Whilst there was a fall off during the 30 minute treatment under control conditions of -3.9, -5.3 and -5.4 bpm (t=40, 50 and 60 min) the reflexology treatment was found to be significantly lower during treatment with a decrease of -10.3, -12.4 and -13.2 bpm (t=40, 50 and 60 min) when compared to the pre-treatment

baselines. Following both sham TENS (control) and reflexology treatments the heart rate levelled out but for the reflexology treatment there were significant differences post treatment. Neither the heart rate values for the sham TENS (control) nor the reflexology treatment returned to the average pre-treatment baselines but the difference between baseline averages and the final post-treatment score at 120 minutes showed a fall in the number of heart beats per minute of -4.7 ± 1.8 SEM for the sham TENS (control) and -6.3 ± 1.8 SEM for standard reflexology. It remains to be seen whether this effect would prove to be clinically significant in individuals in the long term.

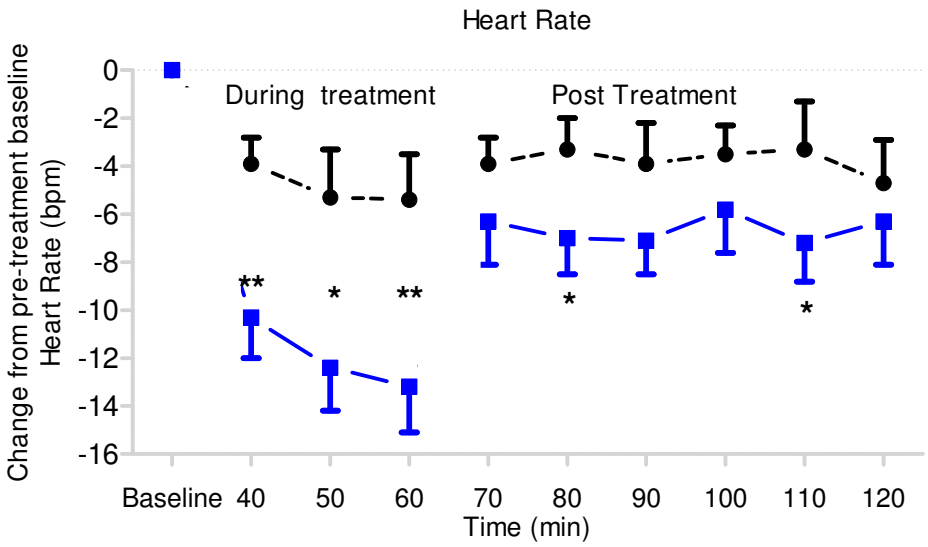


Figure 3.4: Mean ± SEM heart rate (bpm) shown as change from pre-treatment baseline, *n=14*. **p<0.01 and *p<0.05 for standard reflexology treatment. Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Standard reflexology

3.4.4 The effects of reflexology on core temperature

The effects of sham TENS (control) and reflexology on core temperature are shown in Table 3.6. Figure 3.5 illustrates the two-way ANOVA with repeated measures for treatment and time on change from pre-treatment baselines after the three baseline observations were averaged. There were no significant differences between treatments in terms of their effect on core body temperature. There were no significant main effects of treatment ($F_{(1,13)}$=0.0099,n.s.) or time ($F_{(8,104)}$=0.9386,n.s.) and there were no treatment x time interactions ($F_{8,104)}$=0.8782,n.s). Figure 3.5 shows that there were no significant differences between the treatments.

Table 3.6: Mean ± SEM for core body temperature (°C), by treatment and by time showing 3 pre-treatment, 3 during treatment and 6 successive post treatment observations each at 10 minute intervals. *n=14.* There were no significant main effects of treatment ($F_{(1,13)}$=1.0900,n.s.) there were no significant effects of time ($F_{(8,104)}$=0.9386,n.s.) and there were no treatment x time interactions ($F_{8,104)}$=0.8782,n.s).

Time ⇨	10 min	20 min	30 min
Treatment	*Pre-treatment baselines x3*		
Control	36.21±0.13	36.23±0.10	36.26±0.10
S Reflex	36.15±0.11	36.27±0.09	36.31±0.08

Time ⇨	40 min	50 min	60 min
Treatment	*During treatment x 3*		
Control	36.23±0.10	36.26±0.09	36.19±0.10
S Reflex	36.30±0.10	36.29±0.09	36.26±0.11

Time ⇨	70 min	80 min	90 min	100 min	110 min	120 min
Treatment	*Post treatment x 6*					
Control	36.17±0.10	36.23±0.09	36.17±0.10	36.16±0.11	36.11±0.09	36.19±0.12
S Reflex	36.22±0.09	36.20±0.12	36.19±0.09	36.18±0.07	36.27±0.09	36.23±0.13

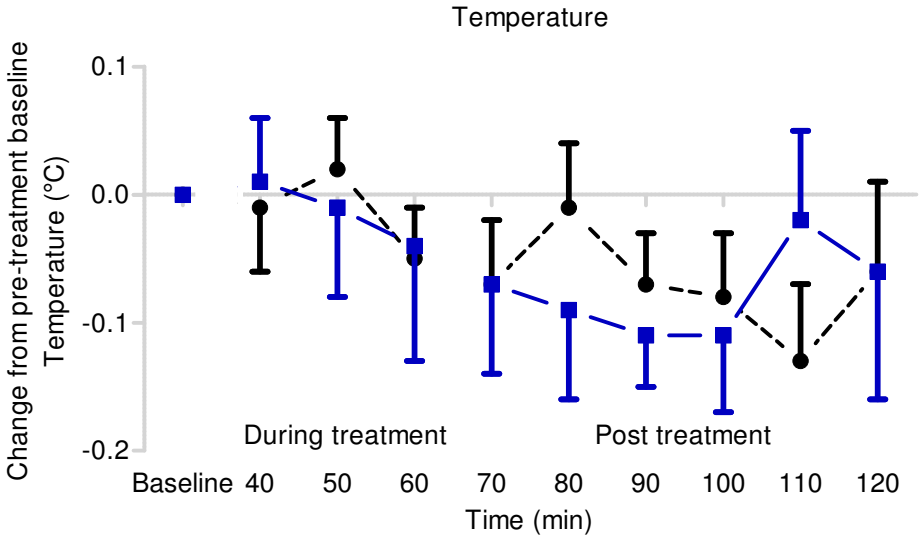


Figure 3.5: Mean ±SEM core temperature (°C) shown as a change from the pre-treatment averaged baseline, *n=14*. Vertical lines show +/- SEM. ●=Sham TENS (control) ■=Reflexology

3.4.5 Subjective rating analyses

The analysis of the subjective rating questionnaires for levels of anxiety and general health indicated that 71% of the subjects who participated in this experiment were from a population who were free from anxiety and were in good general health.

Table 3.7 illustrates the result of the scores for each subject across the two treatment periods and represents the median, 1st and 3rd quartiles. All scores were in the higher range which meant the subjects were not anxious and rarely suffered from ill-health and this is reflected in the low heart rate during treatment.

Table 3.7: Subjective rating analysis. Table shows the levels of anxiety and general health of subjects in a) the month preceding their first treatment and, b) the week following their first treatment, *n=14.*. The range of scores for anxiety were 0-25 and for general health 0 - 15.

	Past Month A	**Past Week B**	**Past Month A**	**Past Week B**
Subject No.	*Anxiety*	*Anxiety*	*General Health*	*General Health*
1	20	20	14	15
2	11	18	10	12
3	19	24	12	14
4	12	16	11	13
5	16	19	10	13
6	10	16	14	14
7	16	19	8	14
8	22	25	15	15
9	11	18	11	10
10	17	21	15	14
11	21	22	15	14
12	19	22	13	12
13	23	22	10	13
14	20	19	19	11
MEDIAN	18	19.5	12.5	13.5
1st Quartile	13	18.25	10.25	12.25
3rd Quartile	20	22	14.75	14

Feedback questionnaire

Following each experimental session subjects were given a feedback questionnaire on which to record any reactions either positive or negative, to their treatment. The forms were completed within 24 hours following the experimental procedure and were returned to the investigator for analysis. Results are shown in Figures 3.6 and 3.7. A greater number of subjects reported side-effects following standard reflexology than following the sham TENS (control) treatment. Most of the side-effects listed for standard reflexology included increased bowel movements, improved energy levels, improved sleep, increased nasal and vaginal secretions, increased urination, headaches at the forehead and muscular aches and pains not usual for them. Whilst the numbers affected were similar in the sham TENS (control) treatment, there was no indication of improved sleep.

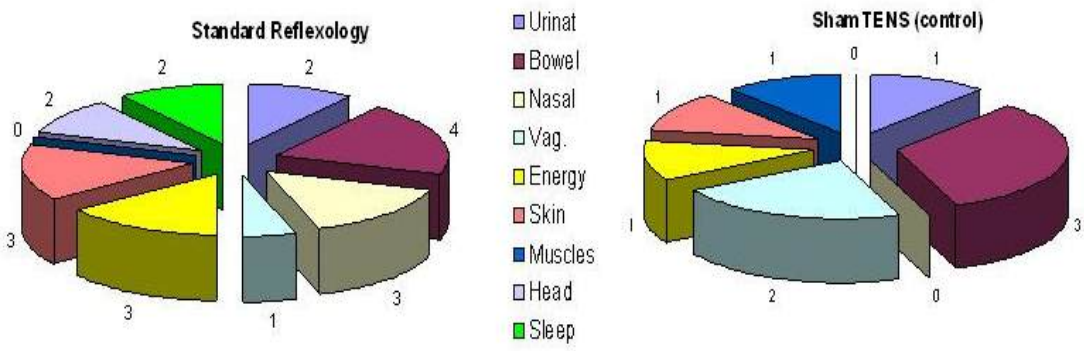


Figure 3.6: Illustration of the results of the feedback questionnaires, *n=14*. They show the number of subjects who experienced side-effects.

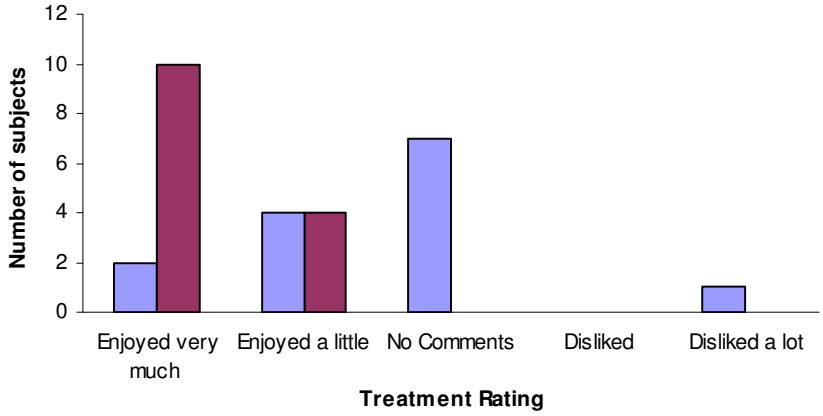


Figure 3.7: The result of the overall treatment ratings, *n=14*. ■ = sham TENS (control) and ■ = standard reflexology.

3.5 DISCUSSION

Sham TENS as a control for reflexology studies

Finding an appropriate control method in CAM therapies is fraught with problems and presented a challenge to this experimental procedure. A review of the literature showed that foot massage had been used as a control method, but results from the experiments were inconclusive because of the similarities in treatment. Whilst Wang and Keck (2004) showed statistically significant decreases in sympathetic responses to pain, including reductions in heart rate and respiratory rate but not blood pressure, others have indicated that foot massage does not produce alterations in any of the physiological functions (Hattan *et al.*, 2002). Frankel (1997) showed that both foot massage and reflexology may alter Baroreceptor reflex sensitivity, thus maintaining the balance of blood pressure and so this method of control was also ruled out. Other studies have used reflex points unrelated to the area under examination, for example Mur *et al.* (2001) used reflex points reported to be of the gastro-intestinal tract and compared it with reflex points reported to be from the eyes, ears, neck, spine and lungs, in order to evaluate the effects of reflexology on blood flow. This method of control assumes that organs have been scientifically identified on the foot sole and there is, as yet, no evidence for this.

Sham TENS has been used as a moderator for the relief of pain and also in experimental pain trials for many years (Carroll *et al.*, 1996, Chesterton *et al.*, 2003, Reeves *et al.*, 2004). Sham TENS does not require the practitioner to touch the subject nor does it interfere with reflex points in the feet (Hodgson, 2000). In addition there is evidence that equipment perceived to be of medical origin may have a greater influence on placebo responses (Kaptchuk *et al.*, 2000). Subjects recruited into this experiment were TENS naïve and were told that TENS stimulated the d-delta 2 nerve fibres, producing an extremely low frequency stimulus which may be barely perceptible in some people. However these nerve fibres do not exist and this verbal instruction was added to induce a level of expectancy from the treatment. In addition the dials on the equipment (Chapter 2, Section 2.1, Figure 2.2) were tweaked periodically to enhance the affect of active treatment.

This experiment was a preliminary study for the ice pain experiments which will be discussed in Chapters 4 – 7. The aim here was to establish whether a standard reflexology treatment could affect the autonomic nervous system physiology and to observe such changes without the stress of ice pain. Primary muscle relaxation, mental relaxation, slow breathing and hypnosis have previously been used as forms of control in CAM experiments (Kaushik *et al.*, 2006, Castel *et al.*, 2007, Poole *et al.*, 2007, Mackereth *et al.*, 2008). Hypnosis was found to reduce the perception of chronic pain such as that seen in irritable bowel syndrome by as much as 70% (Foundation for Integrated Health, 2009), whilst mental relaxation and slow breathing resulted in decreased systolic and diastolic blood pressure, heart rate and respiratory rates (Kaushik et al., 2006). Sham TENS was a simple non-invasive means of utilising a control without deliberately creating a state of relaxation.

Blood pressure response to reflexology

The autonomic changes in heart rate, blood pressure and core temperature were measured in response to standard reflexology and a sham TENS (control) procedure. In this group of normotensive mainly female subjects, there were no significant effects of standard reflexology on either systolic, diastolic or blood pressures. When Mackereth (2005) compared the effects of primary muscle relaxation and reflexology in multiple sclerosis patients he found no significant pre and post treatment effects on systolic or diastolic blood pressure. McVicar *et al.* (2007) achieved the same result when systolic and diastolic blood pressures were recorded pre and post reflexology in healthy individuals compared to a no treatment (control). However, when McVicar *et al.* (2007) compared within group values they found significant reductions in systolic blood pressure which have not been observed in this experiment. Further experiments where there is repeated exposure to reflexology treatment in hypertensive patients may however show more clinical relevance for this data.

Heart rate response to reflexology

The results of the ANOVA on change from pre-treatment baseline showed there were significant effects of reflexology treatment ($p<0.01$), time ($p<0.01$) and treatment x time interactions ($p<0.05$). The effect showed decreases in heart rate values during the entire treatment phase of standard reflexology and at t=20 and t=50

minutes post treatment. Decreases in heart rate values have previously been achieved for massage based therapies and have largely been attributed to the relaxation response suggesting the possibility that subjects become more relaxed as a direct result of treatment (Ferrell-Torry and Glick, 1993, Grealish *et al.*, 2000, Wang and Keck, 2004, Cowen *et al.*, 2006). Rajendra *et al.* (2005) demonstrated that heart rate changes occur according to the position of the body, and that heart rate variability decreases in the lying position after sitting. All subjects, regardless of their treatment regime, were placed in the semi-recumbent position during the treatment period for the duration of 30 minutes. This had followed a 30 minute period of sitting upright in the Lafuma chair. One would therefore expect to observe a natural decrease in heart rate. It was clear from the analysis of the data however that the decrease in heart rate following reflexology stimulation was significantly greater than the decrease following sham TENS (control) and one might conclude therefore that this was a direct result of treatment. However, other causal mechanisms such as general skin stimulation and/or personal interaction with the subjects may have contributed to the effect. Drescher *et al.* (1980) demonstrated lower heart rates in subjects who were touched by an experimenter and in a larger study Fishman *et al.* (1994) indicated that physical contact produced small, but significant changes in heart rate and blood pressure. Thorlby and Panton (2002) have suggested that reflexology can unite two people in a therapeutic relationship through a process of interaction, and that part of the interaction includes the element of touch. Whilst it is possible that the effects seen in this experiment may be the result of the physical contact rather than sympathetic stimulation, they are consistent with the literature for both reflexology (Wilkinson *et al.*, 2006) and acupuncture (Haker *et al.*, 2000, Backer *et al.*, 2002). Wilkinson *et al.* (2006) showed significant differences in heart rate values pre to post reflexology treatment in 20 patients suffering from chronic obstructive pulmonary disease when compared with a no treatment control, but attributed the effects to 50 minutes in an almost supine position. Uschida *et al.* (2008) demonstrated a similar effect as a result of acupuncture in anaesthetised rats and when acupuncture-like stimulation was administered to the hind limb a decrease in heart rate was observed, during treatment. This is supported in previous work of Sakai *et al.* (2007) in which acupuncture significantly reduced heart rate and increased systolic blood pressure during acupuncture manipulation, whilst there was no post acupuncture effect. A standard reflexology treatment appears to take this one

step further in that the decrease in heart rate was not only present to a significant level throughout the treatment period, but was also present for a prolonged period post treatment.

Temperature response to reflexology

The normal human range for temperature varies depending on the individual's metabolic rate, the time of day and the area of the body in which it is taken, but is generally standardised to 37ºC, fluctuating by approximately 1ºC in 24 hours, usually in the early hours of the morning and late afternoon (van Marken Lichtenbelt *et al.*, 2001, Westerterp-Plantenga *et al.*, 2001, Pocock and Richards, 2006) In addition fluctuations can be observed in women during the luteal phase following ovulation when temperature may increase by approximately 0.5ºC until the beginning of the next menstrual cycle (Kurz, 2008). Proponents of reflexology suggest that it has a calming effect on the stress response, suggesting that one might observe a lowering of body temperature; however there is no evidence in the literature that core temperature has been measured as part of the physiological responses to treatment. This experiment found that there were no significant main effects of treatment on core temperature. Core temperature dropped by 0.1ºC during the post treatment phase following both sham TENS (control) and reflexology. The temperature remained lower following reflexology stimulation for a further 30 minutes post treatment when in both groups there was a change of ± 0.1ºC. Temperature decreased following standard reflexology and increased following sham TENS control but neither treatment showed a return to pre-treatment baseline values. Although this is not thought to be clinically relevant it may explain why subjects undergoing reflexology treatments often feel temporarily chilled post treatment, despite their being no change in the ambient room temperature (personal observation). These changes in temperature do not appear to correlate with any of the other autonomic changes and the small but insignificant differences seen in the results could be attributed to either the menstrual cycle phase or to the effects of taking the oral contraceptive pill (Badia *et al.*, 1997).

Subjective rating questionnaires

A transitory emotional state is associated with a consciously perceived feeling of tension and apprehension and is accompanied by increased sympathetic nervous

system activity (Vickland *et al.*, 2009). In this experiment the results of the subjective ratings showed high scores, indicating that subjects were in sound health and were not anxious. There was no relationship between subjective anxiety and any of the outcome measures.

Feedback Questionnaires

The feedback questionnaire showed typical side-effects expected following standard reflexology treatment. One would not expect subjects to have ticked any of the side-effects listed following the sham TENS (control) treatment which suggests that subjects were responding on a psychological level. This type of responding could indicate the possibility of a placebo response (Benedetti, 2006a). It is possible that the list of side-effects may have provided an expectation in the subjects and they ticked the boxes because they thought a response was expected of them. Of interest though is the perceived improvement in energy levels and sleep patterns following standard reflexology. It will be interesting to observe these patterns throughout further experiments to see if it is possible to identify the non-specific effects of treatment, or to establish if this is merely expectancy of effect.

Conclusion

This experiment showed that standard reflexology significantly produced decreases in heart rate during treatment compared with sham TENS (control) and furthermore the heart rate was significantly lower than control for up to 40 minutes following treatment. There was a small but insignificant decrease in blood pressure and core body temperature following reflexology and in review of the aims of this experiment it has confirmed that standard reflexology does have an effect on some aspects of autonomic activity.

CHAPTER 4

THE EFFECTS OF REFLEXOLOGY ON PAIN THRESHOLD AND TOLERANCE IN AN ICE-PAIN EXPERIMENT IN HEALTHY HUMAN SUBJECTS

4.1 INTRODUCTION

There is a paucity of data for properly controlled studies on the effects of standard reflexology in acute and chronic pain conditions and there are no scientific studies that have looked at pain *per se*. There is however a lot of anecdotal evidence and uncontrolled reports (Wilson, 1995, Tiran, 1996, Booth, 1997, Launso *et al.*, 1999, Khan *et al.*, 2006) and there is some clinical evidence for the effectiveness of reflexology in low back pain and cancer (Stephenson *et al.*, 2000, Poole, 2001, Stephenson *et al.*, 2003, Stephenson *et al.*, 2007, Brown and Lido, 2008). Unfortunately because of the nature of pain many of these studies were superimposed on drugs that subjects were already taking for pain.

This is the first experiment to investigate the effects of standard reflexology in acute pain and uses ice pain in healthy human subjects. In the main, ice pain experiments (cold-pressor tests) have been utilised for monitoring cardiovascular responses (Peckerman *et al.*, 1994, Lafleche *et al.*, 1998, de Marchi *et al.*, 2001). However there is a large body of evidence for the use of ice pain for experimental pain paradigms (Ashton *et al.*, 1984, Fasano *et al.*, 1996, Johnson and Din, 1997, Hirsch and Liebert, 1998, Kim *et al.*, 2004, Roelofs *et al.*, 2004, Siegrist *et al.*, 2006, Casiglia *et al.*, 2007, Stening *et al.*, 2007). The model adopted for this experiment is based on that of Ashton *et al.* (1984) in which ice pain was used to evaluate the effects of transcutaneous electrical nerve stimulation (TENS) and acupuncture. In that experiment acupuncture was found to raise pain thresholds to significant levels. As acupuncture is deemed by many to produce similar responses to those observed in standard reflexology stimulation, this method of inducing pain seems an appropriate model for these experiments.

4.2 AIMS

This experiment was carried out to fully evaluate the efficacy of standard reflexology in acute pain induced in healthy human subjects using the principles of the cold-pressor test for ice pain. Quantitative measurements were acquired for a) pain threshold, (the time taken for subjects to experience the first pain sensation) and b) pain tolerance, (the time when the subject is unable to tolerate any further pain). These were measured under two conditions, i) standard reflexology and ii) a control of sham Transcutaneous Electrical Nerve Stimulation (TENS). Qualitative measurements for the subjective elements of pain such as level of arousal, anxiety and discomfort were employed and feedback questionnaires were utilised for observation of side-effects to treatments.

4.3 METHOD

4.3.1 Design

The experiment used a single blind, two-period crossover design in which subjects received standard reflexology and sham TENS (control) each for 45 minutes over alternate weeks. The randomisation procedure is described in Chapter 2, (Section 2.2.5). Subjects were informed that two attendances were required, each one requiring 3½ hours of their time, given one week apart. Subjects were subsequently transferred to the alternate treatment on the second attendance. The study received ethical approval from the University of Portsmouth Ethics Committee.

4.3.2 Demographics

Subjects were recruited to the study from a variety of places including the general public, the undergraduate, post-graduate and staff members at the University of Portsmouth. Nineteen subjects entered the study but three of the subjects failed to complete the experimental procedures. The 16 subjects' who did complete the experiment consisted of 12 female and 4 male with a mean ± SEM age of 37.4 ± 2.56 yrs (range 22–54). All subjects were Caucasian. All subjects recruited to the experiment were TENS and reflexology naïve.

4.3.3 Procedure

Subjects were apprised of the experimental protocol prior to recruitment into the study. On arrival they were fitted with the heart rate monitoring equipment described in Chapter 2, (Section 2.1). They were issued with an information sheet and informed consent was obtained. A brief consultation was taken to confirm the subjects' suitability for entry into the experiments and ruling out any contra-indications to treatment. Subjects were then introduced to the subjective rating questionnaire and asked to record their current level of arousal and anxiety. The subjective rating questionnaire was completed following each ice plunge subsequent to either reflexology or sham TENS (control) and thereafter each ice plunge at 30 minute intervals. New age background music was played throughout the experimental procedures. Ambient room temperature was maintained at 22ºC ± 1ºC. After a 15-minute rest period in which subjects were seated upright in the Lafuma chair, baseline measurements were recorded for heart rate pre and post ice plunge and for ice pain threshold and pain tolerance. Immediately following which subjects were then reclined to a semi-recumbent position for the 45 minute treatment period. Subjects remained in the semi-recumbent position for a further 30 minutes after the treatment period. At 30 minutes post treatment they were assisted to the upright position and asked to plunge their non-dominant hand into the ice. Measurements were obtained for pre plunge heart rate, pain threshold, pain tolerance and post plunge heart rate. Subjects completed the second set of questions on the subjective rating questionnaire observing their level of arousal, anxiety and discomfort. Subjects remained in the upright position for the remainder of the experiment. Subsequent pain threshold and tolerance levels, together with pre/post plunge heart rate readings were recorded at 30 minute intervals until 120 minutes post treatment, (see Table 4.1). Subjects completed one ice immersion cycle prior to treatment of either reflexology or sham TENS (control) and four cycles post treatment. In order to keep the inter-interval constant within each subject, each cycle post treatment lasted 30 minutes from the time the subject removed their hand from the ice. During the intervening period subjects remained seated in the Lafuma chair and were given either light reading material or were permitted to converse with the therapist. They were not permitted to discuss the treatment, their health concerns or the research programme.

Table 4.1: Experimental timeline – total time of experiment 180 minutes. KEY: HR = heart rate, PThr = pain threshold, PTol = Pain tolerance. SReflex = Standard reflexology, Control = Sham TENS.

Pre treatment 0 - 15 minutes		Subjective rating Questionnaire	Treatment 15 - 60 minutes	Post treatment period 60 – 180 min							
0 -14	15 min		45 min	30 min post Ice plunge		60 min post Ice plunge		90 min post Ice plunge		120 min post Ice plunge	
Rest period, consultation etc	B/line HR pre/post ice PThr PTol		Treatment SReflex Control	HR pre/post ice PThr PTol	Subjective rating	HR pre/post Ice PThr PTol	Subjective rating	HR pre/post ice PThr PTol	Subjective rating	HR pre/post ice PThr PTol	Subjective rating

4.3.4 Statistical Analysis

Data for each set of measurements were analysed using a two-way analysis of variance (ANOVA) with repeated measures on raw data with respect to time and on change from pre-treatment baseline scores (Twisk and Proper, 2004). This method of analysing the data is in line with the statistical processing carried out by others for small group repeated measures trials (Ashton *et al.*, 1984, Vickers, 2001, van Breukelen, 2006, Winkens *et al.*, 2007) Inter-session reliability of the baseline statistics were calculated using the Pearsons product moment correlation coefficient statistic (Salkind, 2004). Subjective rating questionnaires were analysed using the Wilcoxon sign rank test for non-parametric statistics of matched pairs.

4.4 RESULTS

The criteria for including subjects in the analysis were discussed in Chapter 2, (Section 2.4.1). Of the sixteen subjects who completed the experimental procedures, one subject (7) demonstrated pain threshold levels higher than 40 seconds (s) in the control treatment and was thus, removed from further analysis. The results therefore represent fifteen subjects, 11 female and 4 male with a mean ± SEM age of 37.7 ± 2.6 yrs.

4.4.1 Effects of standard reflexology on pain threshold

The effects of reflexology on pain threshold (s) are illustrated in Table 4.2. The reliability of the pre-treatment baselines between sham TENS (control) and reflexology was measured using the Pearson product moment correlation coefficient which showed that the data were significantly correlated (r = +0.60, df = 15, $p<0.05$), demonstrating good inter-session reliability for baseline data. This was confirmed by the paired t-test where observations showed no significant differences between baseline scores (p=0.50, n.s.).

Table 4.2: Mean ± SEM for pain threshold (s) by group and by time showing 1 pre treatment and 4 successive post treatment observations at 30 minute intervals. *n=15.* Treatment ($F_{(1,14)}$=0.6644,n.s.), time ($F_{(3,42)}$=4.2629, $p<0.01$), treatment x time interaction ($F_{(3,42)}$ = 0.3481,n.s.).

Group	*Pre-treatment baselines*	*Post treatment (+30 min)*	*Post treatment (+60 min)*	*Post treatment (+90 min)*	*Post treatment (+120 min)*
Control	8.4 ± 0.8	9.6 ± 0.8	10.1 ± 1.5	10.9 ± 1.8	12.9 ± 2.5
Reflexology	9.1 ± 1.2	10.0 ± 0.8	14.1 ± 1.6	14.7 ± 2.6	17.0 ± 3.7

Change from baseline was calculated as the difference between the pre-treatment score and the post-treatment scores and the results are illustrated in Figure 4.1. Pain threshold prior to reflexology and sham TENS (control) was similar. Statistical analysis of the results following treatment showed significant main effects of reflexology treatment ($F_{(1,14)}$=4.5958, $p<0.05$), with a significant effect over time ($F_{(3,42)}$=3.9736, $p<0.05$) when compared to the sham TENS (control).

Whilst both treatments increased pain thresholds over time, post-hoc tests showed that at trial 2 (t=60min) subjects pain thresholds were significantly increased following the reflexology treatment and remained higher, albeit non-significantly for trials 3 (t=90min) and 4 (t=120min). The data did not reveal any treatment x time interactions ($F_{(3,42)}$=0.7482, ns).

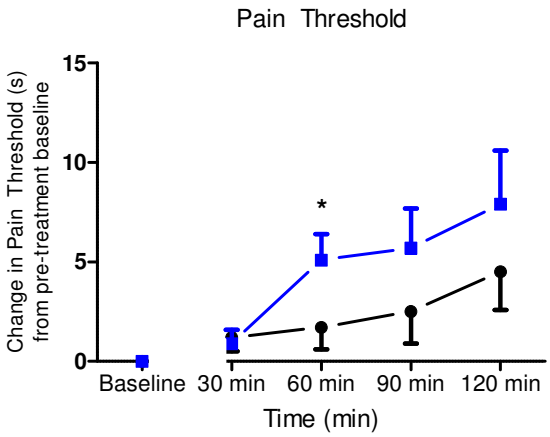


Figure 4.1: The effect of change in pain threshold from pre-treatment baselines, *n=16*. Mean ± SEM pain threshold scores (s), p<0.05 for standard reflexology. Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Reflexology

4.4.2 Effects of standard reflexology on pain tolerance

The effects of reflexology on pain tolerance (s) are illustrated in Table 4.3. The inter-session reliability statistics for pre-treatment mean baselines between sham TENS (control) and reflexology were significantly correlated (r =+0.70, df = 15, p<0.01) demonstrating good reliability for baseline data between the two treatment sessions. Observations made by a paired t-test confirmed that there were no significant differences between the baseline scores (p=3.55, n.s.).

Table 4.3: Mean ± SEM for pain tolerance (s) by group and by time showing 1 pre treatment and 4 successive post treatment observations at 30 minute intervals. *n=15.* ANOVA revealed a significant treatment effect ($F_{(1,14)}$=7.7563,p<0.05) a significant effect of time ($F_{(3,42)}$=3.2885,p<0.05) but no treatment x time interaction ($F_{(3,42)}$=1.6198,n.s.).

Group	*Pre-treatment baselines*	*Post treatment (+30 min)*	*Post treatment (+60 min)*	*Post treatment (+90 min)*	*Post treatment (+120 min)*
Control	133.7 ± 31.0	98.3 ± 24.6	95.0 ± 26.8	111.9 ± 29.0	102.7 ± 26.6
Reflexology	112.7 ± 27.9	111.3 ± 30.2	145.3 ± 33.2	162.9 ± 36.7	136.5 ± 34.6

Figure 4.2 shows the result of the statistical analysis for change from pre-treatment baseline on pain tolerance with a significant main effect of reflexology treatment ($F_{(1,14)}$=5.1095, p<0.05) and a significant effect of time ($F_{(3,42)}$=3.2505, p<0.05) when compared to the sham TENS (control) but there was no treatment x time interaction ($F_{(3,42)}$=1.6098, ns). Post-hoc tests revealed that reflexology significantly increased pain tolerance during trials 2 (t=60min) 3 (t=90min) and 4 (t=120min) whilst there was no tolerance at all following the sham TENS (control) treatment and one might

speculate that by comparison the effect of sham TENS (control) is one of nociception, i.e. it is increasing pain.

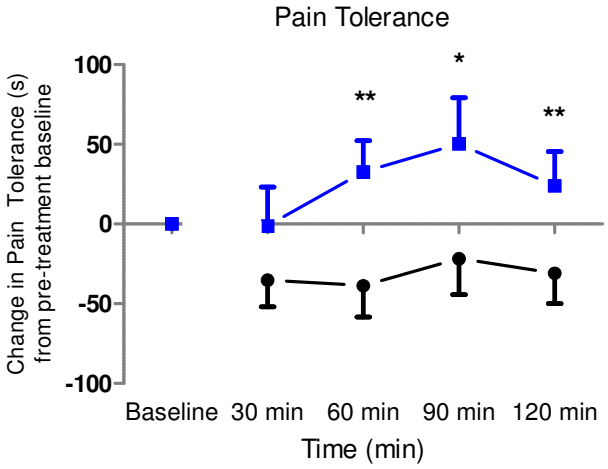


Figure 4.2: The effect of change in ice pain tolerance (s) from pre-treatment baselines, *n=16*. p<0.01 at 60 and 120 min, p<0.05 at 90 min (students *t*-test). Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Reflexology

4.4.3 Heart rate pre plunge

Table 4.4 shows the mean ± SEM values for the effect of standard reflexology and sham TENS (control) on pre plunge heart rate (bpm). A Pearson correlation on the inter-session reliability statistics for baselines between sham TENS (control) and reflexology revealed the data were significantly correlated (r =+0.87, df = 15, p<0.01). This was confirmed with a paired t-test which revealed no significant differences between baseline scores (p=0.17, n.s.), thus the baseline data showed good inter-session reliability.

Table 4.4: Mean ± SEM for pre plunge heart rate (bpm) by group and by time showing 1 pre treatment and 4 successive post treatment observations at 30 minute intervals. *n=15.* There were no significant effects of treatment ($F_{(1,14)}$=1.5749,n.s.), time ($F_{(3,42)}$=1.2608,n.s), or any treatment x time interactions ($F_{(3,42)}$ =1.4877,n.s)

Group	*Pre-treatment baselines*	*Post treatment (+30 min)*	*Post treatment (+60 min)*	*Post treatment (+90 min)*	*Post treatment (+120 min)*
Control	78.5 ± 3.8	73.9 ± 3.4	74.2 ± 3.7	71.9 ± 3.7	72.9 ± 3.6
Reflexology	81.2 ± 3.7	68.1 ± 4.2	69.4 ± 4.0	69.5 ± 4.2	71.8 ± 3.8

Figure 4.3 shows the change from the pre-treatment baselines for heart rate prior to the ice plunge. Statistical analysis of the results showed a significant main effect of treatment ($F_{(1,14)}$=7.8404,p<0.05) and post-hoc tests revealed that reflexology

treatment significantly lowered heart rate for the first 60 min post treatment ($p<0.01$) when compared to the sham (TENS) control and remained lower throughout the duration of the experiment. There were no significant differences observed for the effect of time ($F_{(3,42)}$=1.1325,n.s), and there were no treatment x time interactions ($F_{(3,42)}$ =1.4748,n.s.)

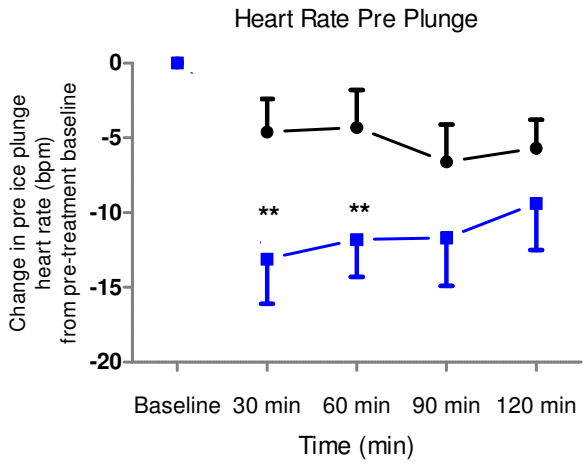


Figure 4.3: The effect of treatment on mean ± SEM pre plunge heart rate (bpm) as a change from pre-treatment baselines, *n=16*. $p<0.01$ for reflexology. Vertical lines illustrate +/- SEM. ●=Sham TENS (control) ■=Reflexology

4.4.4 Heart rate post plunge

The results for the mean ± SEM for post plunge heart rate (bpm) are shown in Table 4.5. The inter-session reliability statistics on the baseline data between sham TENS (control) and reflexology showed that the data were highly correlated (r = +0.83, df =15, $p<0.01$) but a paired t-test showed no significant differences (p= 0.64, n.s.) and thus inter-session baselines were shown to be reliable.

Table 4.5: Mean ± SEM for post plunge heart rate (bpm) by group and by time showing 1 pre treatment and 4 successive post treatment observations at 30 minute intervals. *n=15*. There were no significant treatment effects ($F_{(1,14)}$=0.8691,n.s.), no significant effects of time ($F_{(3,42)}$=2.6185,n.s.) and no treatment x time interactions ($F_{(3,42)}$=0.6826,n.s.).

Group	*Pre-treatment baselines*	*Post treatment (+30 min)*	*Post treatment (+60 min)*	*Post treatment (+90 min)*	*Post treatment (+120 min)*
Control	78.7 ± 3.9	73.3 ± 3.4	72.5 ± 3.3	72.5 ± 3.3	74.3 ± 3.7
Reflexology	79.7 ± 3.4	69.9 ± 3.6	70.7 ± 3.3	72.8± 2.8	73.1± 3.6

Figure 4.4 illustrates the change from pre-treatment baseline data. The ANOVA on the change from pre-treatment baselines showed that there were no significant effects of treatment ($F_{(1,14)}$=1.7574, n.s). A paired t-test however, showed a significant

decrease in heart rate at trial 1 (t=30min) post treatment ($p<0.05$) indicating an effect of reflexology treatment which was maintained for a further 30 min, albeit non-significantly at these time and the heart rates remained lower than controls throughout the experiment. There were no significant differences observed for time ($F_{(3,42)}$=2.1308,n.s) and there were no treatment x time interactions ($F_{(3,42)}$ =1.2107,n.s.)

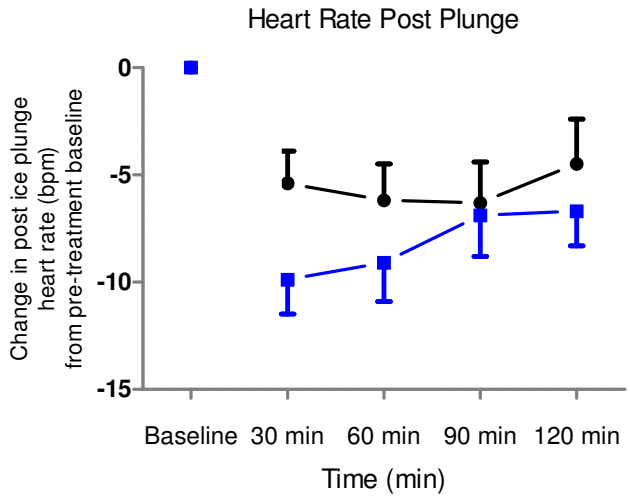


Figure 4.4: The effect of treatment on mean ± SEM post plunge heart rate (bpm) as a change from the pre-treatment baselines, *n=16*. Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Reflexology

4.4.5 Subjective rating analyses

Results of the subjective rating questionnaires were computed in SPSS v15.0 using the Wilcoxon sign rank test for non-parametric statistics of matched pairs. Results were compared for each of the subjective elements of anxiety, arousal and discomfort during the experimental procedures. Results revealed that there were no significant differences between either of the two treatments of standard reflexology or sham TENS (control) for level of arousal and level of anxiety. There was however a significant difference at 90 minutes post treatment in the level of discomfort between the two treatments $p<0.05$. The sham TENS (control) treatment produced a significantly higher level of discomfort in subjects during ice immersion than the standard reflexology treatment at the same time point. The results for the median, 1st and 3rd quartiles are shown in Table 4.6 and the Wilcoxon sign rank test scores are shown in Table 4.7.

Table 4.6: Subjective rating analysis. The data show the median with 1st and 3rd quartiles shown in brackets. The ratings were categorised thus: 4 = very high, 3 = high, 2 = normal, 1 = below normal for each of the three categories, arousal, anxiety and discomfort. KEY: Control = Sham TENS, S.Reflex = Standard Reflexology

	30	60	90	120
AROUSAL				
Control	2 (2,2)	2 (2,2)	2 (2,2)	2 (2,2)
S.Reflex	2 (1,2)	2 (1.5,2)	2 (1.5,2)	2 (2,2)
ANXIETY				
Control	1 (1,1.5)	1 (1,2)	1 (1, 1.5)	1 (1, 1.5)
S.Reflex	1 (1,1)	1 (1,1)	1 (1,1)	1 (1,1)
DISCOMFORT				
Control	3 (3.0,3.5)	3 (3,3.5)	3 (2.5,4)	3 (2.5,4)
S.Reflex	3 (2,3)	3 (2,3)	3 (2,3)	3 (2.5,3)

Table 4.7: The Wilcoxon signed rank test scores. Exact significance (2-tailed)

Post treatment time →	**30**	**60**	**90**	**120**
AROUSAL	0.109	0.125	0.125	0.625
ANXIETY	0.250	0.125	0.500	1.000
DISCOMFORT	0.344	0.078	**0.039**	0.313

The final question on the subjective rating questionnaire asked the subject if they felt the treatment had any effect on the two measurements of pain threshold and tolerance which were taken across the experimental procedure. Results indicated that 62% for sham TENS (control) and 81% for standard reflexology felt that the treatment had improved their pain threshold and tolerance levels.

Feedback questionnaire

All 16 subjects returned their feedback questionnaires following the sham TENS (control) treatment, whilst only 14 subjects returned their questionnaires following the standard reflexology treatment. Differences between the two groups are shown in Figure 4.5 and account for the responses of all eligible subjects. Both treatments showed benefits for improved sleep, and an increase in energy levels. The results indicated that following standard reflexology a greater number of side-effects were experienced compared to the sham TENS (control). When receiving standard reflexology 86% of subjects reported they had enjoyed the treatment a lot whilst the remaining 14% had either enjoyed the treatment a little or made no comment. For

sham TENS (control), 25% had enjoyed the treatment a little and the remaining 75% made no comment.

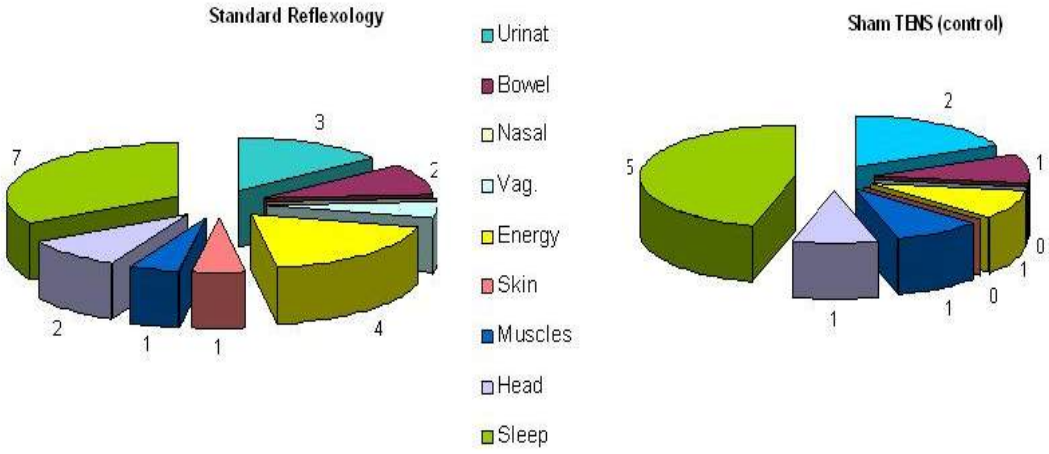


Figure 4.5: Illustration of the results of the feedback questionnaire analysis. Each section of the pie chart indicates the number of subjects experiencing side-effects of treatment. Each colour is represents a different side-effect as shown, *n=16*.

4.5 DISCUSSION

The aim of this chapter was to evaluate the effects of standard reflexology on healthy human subjects in an ice pain experiment by comparing the effect of treatment with a sham TENS (control).

Rationale for Sham TENS

One of the concerns in experiments using CAM treatments is the effectiveness of the control procedure. It is rarely possible to introduce a valid control treatment in interventions that are non-drug related (Carroll *et al.*, 1996, Dincer and Linde, 2003) and in CAM the difficulty lies with the person-to-person contact. It is almost impossible to blind the therapist to the treatment they are administering as they are an integral part of the intervention (Richardson, 2000). In Chapter 3 the use of Sham TENS as a control method showed it was an effective method for use alongside reflexology. Melzack (1975b) was an early user of sham TENS and promoted its benefits as a placebo control treatment when he examined the effects of brief, intense TENS at trigger points. Chesterton *et al.* (2003) used TENS equipment with a dead battery in a double-blind study to assess the effectiveness of TENS at different frequencies and thus, this method has formed the model for using sham TENS in

these experiments. Other types of control treatment were considered, for example a general foot massage and simply holding the feet. However, foot massage has been used in numerous reflexology experiments and was found to be a poor control because of its similarity to reflexology (Holt *et al.*, 2008, Hodgson, 2000, Mur *et al.*, 2001, Quinn *et al.*, 2007). Holding the feet without any form of stimulation was ruled out because it was felt that subjects would readily detect an inactive treatment. Hand reflexology was ruled out as the hand was being used to perform the ice immersions and there may have been a lack of sensation. One might query why a specific foot region was not stimulated for the immersed hand, especially since Nakamura (2008) has shown some correlation between the brain regions and foot reflexes. In part, this is because the hand is not identified on the foot reflexology charts so does not have a specific reflex and secondly because these experiments are about the general effect of reflexology on pain threshold and tolerance rather than any specific pain condition. Sham TENS was shown to be an effective means of introducing a believable control treatment (Chapter 3) that produces a placebo effect and was found to be preferable to foot massage or treatments in which 'non-related' reflex areas were stimulated.

Pain threshold and tolerance

Statistical analysis for pain threshold and tolerance having been calculated using the change from baseline method (Twisk and Proper, 2004) have shown that reflexology significantly increased pain threshold and tolerance when compared to sham TENS (control) in an acute ice pain experiment of healthy human subjects. The main effect of treatment occurred between 60 and 120 min post reflexology for both pain threshold and pain tolerance. The effectiveness of the increase in pain threshold appears over time and is comparable to a study carried out by Poole (2001) in which there was a trend for higher pain threshold values, albeit non-significant, when reflexology was compared to a control of primary muscle relaxation. Such an outcome only adds to the evidence that it produces significant benefits other than those of simple relaxation. The difference in change from pre-treatment baselines for pain tolerance at these time points was 71.3 s at 60 min, 72.1 s at 90 min and 54.9 s at 120 min, above those found for the control treatment indicating that subjects receiving reflexology were also able to tolerate their pain for longer, whereas one

might speculate a more nociceptive effect following the control treatment, Figure 4.2.

Since only one baseline measurement was taken during the experiments it was not possible to carry out test-retest reliability statistics on baseline scores within each session. However, to test the reliability of the baselines between sessions a Pearson product-moment correlation coefficient was carried out. The results demonstrated there were no differences in baseline scores between reflexology and sham TENS (control).

The results obtained in this experiment are consistent with the literature; for example Ashton *et al.* (1984) showed similar effects when measuring the differences in 46 healthy subjects, between acupuncture, 8 and 100Hz TENS and a lactose placebo capsule. They identified a significant increase in pain threshold for the 8Hz TENS and acupuncture treatments when compared to the placebo but they found no differences in the 100Hz TENS. At 5 min post treatment the differences in pain tolerance between the acupuncture and placebo group was 45.7 s and at 50 min it was 29.2 s higher than the placebo. By comparison the standard reflexology treatment appears to increase the effect on pain tolerance over time, whilst the acupuncture treatment of the Ashton *et al.* (1984) study showed a decrease in effect over time. The overall effect of acupuncture on pain threshold and tolerance was similar to the effects seen following standard reflexology, except that the effects of reflexology appear to last longer and were slower to tail off. The duration of the effect was about 90 – 100 min, compared to 35 min in the acupuncture treatment. Whether these effects would have continued is not known since asking subjects to freely give up more than 3½ hours of their time was problematic.

Whilst the range for the mean ± SD of pain thresholds has been recorded at between 15.0 ± 7.0 – 22.0 ± 19.0s (Ashton *et al.*, 1984, Johnson and Din, 1997) pain tolerance is known to vary greatly between individuals by as much as 50 - >180 seconds (Mogil and Adhikari, 1999). Similarly, differences in pain threshold and tolerance scores were observed in individuals across this experiment. Their individual graphs showed a large variation in response patterns for both pain threshold and tolerance levels (Appendix C). However, the results revealed that subjects take longer

following reflexology before reaching their pain threshold when compared to a sham TENS (control) treatment and are subsequently able to tolerate that pain for longer. Pain threshold and tolerance significantly increased following reflexology treatment when compared to the sham TENS (control) however, the mechanism on which the effect is elicited is not known and maybe the affect of pressure on the nerve endings within the foot, simple tactile stimulation or interaction between therapist and subject.

Heart rate

In Chapter 3 there was a significant decrease in heart rate *during* standard reflexology stimulation and it remained lower than the sham TENS (control) throughout the entire experimental procedures. The effect on heart rate has been replicated in this ice pain experiment and showed that the pre-treatment, pre ice plunge heart rate values were significantly higher than at post-treatment following standard reflexology. They remained significantly lower than the Sham TENS (control) for a further 60 min post treatment and until the experimental session was concluded. In the post ice plunge analysis there was a significant effect of reflexology treatment for at least 30 min post reflexology treatment and heart rate values remained lower than the control treatment throughout the experimental procedure albeit non-significantly. One might suggest that this effect can be attributed to relaxation, especially since subjects were placed in a semi-recumbent position and remained in that position for 75 minutes. The affect demonstrated shows that subjects had recovered from the stress-related effects of the ice plunge, when one would expect to see an increase in heart rate, yet it was lower than in the control treatment which indicates that reflexology is having a decreasing effect on the sympathetic activity. In the short-term it would seem that reflexology is producing a significant decrease in heart rate which may be worthy of further investigation.

Nonetheless there is evidence that changes in heart rate are unrelated to increased analgesia (Martinez-Gomez *et al.*, 1988) or to ice immersion (Peckerman *et al.*, 1994, Stancak *et al.*, 1996, Mizushima *et al.*, 2003) which suggests that the increases observed in pain threshold and tolerance shown in this experiment may not be related to any changes in heart rate.

Subjective Analysis

Results for the subjective elements of the ice plunge showed there were no significant differences in anxiety or arousal levels between the two treatments. Both increased levels of arousal and increased anxiety have been connected with acute stress and pain (Gedney and Logan, 2004, Ribeiro *et al.*, 2005, Bossart *et al.*, 2007) and these results demonstrate that this subject group was not affected by the stress of the ice plunge or the pain associated with it. However, the results did reveal a significant difference between subjects' level of discomfort during the ice plunge which may suggest some form of analgesic event occurred following standard reflexology. It is not clear from this data whether the side-effects listed by subjects following treatment were real or the effect of expectation. Whilst there were a greater number of reported side-effects following standard reflexology it was interesting to see that following the sham TENS (control), 31% of subjects reported improved sleep compared to 50% following standard reflexology. The subjects were led to believe that the sham TENS (control) was an active treatment and during the experimental procedure the dials on the equipment were periodically adjusted so enhance this perception. The data support the idea that subjects may have had a certain level of expectancy from their treatment (Scott *et al.*, 2007, Wager *et al.*, 2004, Kong *et al.*, 2006).

Conclusion

Results showed that the ice pain tests for standard reflexology produce acute increases in both pain threshold and tolerance compared to sham TENS (control). One might speculate from this result that such an effect may enable one to withstand their pain experience for much longer. If this is so, then perhaps reflexology may be of benefit in reducing the number of drugs taken by pain sufferers and perhaps maybe useful clinically in the treatment of pain.

CHAPTER 5a

THE EFFECTS OF STANDARD AND LIGHT REFLEXOLOGY IN AN ICE PAIN EXPERIMENT

5.1A INTRODUCTION

The results obtained in Chapter 4 indicate that standard reflexology produces significant increases in pain threshold and tolerance in human volunteers in an acute ice-pain experiment. The pressure applied to the feet for standard reflexology depends on many factors, but is mainly dependent on the sensitivity of the feet of a particular subject. A reflexologist learns through practice, experience and feed-back from clients the amount of pressure that should be applied for standard reflexology. This, in turn will tend to vary at different locations on the foot. Attempts to measure and characterise the pressure applied to different foot-types for standard reflexology are presented in the Appendix under Miscellaneous Chapter. Reflexology practitioners can sometimes use different modes of pressure. For example, light touch reflexology is a procedure adopted by practitioners trained in the Morrell reflexology technique (Evans *et al.*, 1998, Poole *et al.*, 2007). It utilises a much lighter pressure stimulus than standard reflexology. In general there is approximately a 40 – 50% difference in the pressure used for light reflexology compared with that of standard reflexology.

Pharmacological studies have shown that drugs, such as morphine, codeine and pethidine display dose-related analgesic effects (MacPherson, 2000, Enggaard *et al.*, 2001, Lorimer *et al.*, 2002, Vonsy *et al.*, 2009). Similarly, altering the intensity or frequency of stimulation in CAM therapies, such as TENS or electro-acupuncture can also influence the analgesia provided by these therapies (Ashton *et al.*, 1984, Chesterton *et al.*, 2003, Chen *et al.*, 2008, Claydon *et al.*, 2008, Itoh *et al.*, 2009). It was therefore of interest to determine whether there is a difference in the effects of light and standard reflexology on pain threshold and tolerance. Thus, the experiments described in the present Chapter were designed to confirm and extend the observations made in Chapter 4. This was done by evaluating the effects of both

light and standard reflexology on pain threshold and tolerance in an acute ice-pain experiment in human subjects.

5.2A METHOD

5.2.1a Design

Subjects were randomised to receive either 45 min of standard reflexology, light reflexology or no treatment (control) alternately in a Latin-square design, given at weekly intervals. The randomisation method is described earlier in Chapter 2 (Section 2.2.5). All treatments were performed at 7-day intervals and 80% during the same section of the day, either a.m. or p.m.

5.2.2a Demographics

Thirty two subjects were recruited to this experimental procedure, two male subjects dropped out leaving thirty subjects in the experimental group. The groups consisted of three males and twenty seven females with a mean ± SEM age of 36.3 ± 2.09 years (range 19 – 56). Twenty seven of the subjects were Caucasian, two Chinese and one Moroccan. Of the twenty seven females in the experiment, five were taking the oral contraceptive pill and one had the contraceptive injection. Subjects were excluded from the experiment if their pain threshold exceeded a level greater than 40 seconds in the no treatment (control). The rationale for this is discussed in Chapter 2, (Section 2.4.1). Subjects were further excluded if their pain tolerance levels were high for the control.

5.2.3a Procedure

The protocol for the experimental procedures was discussed with the subjects via a telephone conversation or electronic media prior to recruitment into the study. Subjects were fitted with a heart rate monitor on entering the laboratory environment as described in Chapter 2, (Section 2.3). An information sheet detailing the experimental outline was provided and informed consent was obtained. A general consultation was carried out and subjects were asked to complete the first round of questions on the subjective rating questionnaire. Following each ice immersion subjects were asked to complete a further section of the subjective rating

questionnaire. Following the final ice immersion they were also asked whether they felt the treatment had any effect on their pain threshold and tolerance levels throughout the experiment.

Subjects were seated upright in the Lafuma chair for 10-minutes rest after entering the laboratory room in order that they could acclimatise to the environment and complete the various forms specified above. After which the first ice plunge was performed and baseline readings for pain threshold, pre plunge heart rate, pain tolerance and post plunge heart rate were recorded. There followed a further 5-minute rest during which the subjects removed their footwear and were assisted into the reclined position in the Lafuma chair where they remained for 45 minutes, Figure 2.12. During this period they were given either standard reflexology, light reflexology or allowed to simply relax in the semi-recumbent position without treatment. The subjects were permitted to converse with the therapist about menial everyday events or were provided with light reading material. They were not permitted to discuss the treatment, their general health concerns or the research programme. Immediately following treatment the subjects were brought to the upright position and a further heart rate reading was taken prior to immersion of the non-dominant hand into the ice. Pain threshold and tolerance readings were recorded, followed by a post ice plunge heart rate measurement taken immediately following removal of the hand from the ice. Subjects remained upright for the remainder of the experiment and were invited to replace their footwear. Pain threshold, pain tolerance and heart rate pre/post ice plunge were recorded at 30-minute intervals for the remainder of the experimental procedure. Altogether there was one pre-treatment reading and five post treatment readings, Table 5.1a. The data were recorded on the data collection sheet shown in the appendix. The inter-interval was held constant within each subject with each cycle post treatment timed at 30 minutes following removal of the hand from the ice. Subjective rating questionnaires were completed following each ice immersion. After each experimental procedure was completed subjects were provided with a feedback questionnaire and asked to complete and return the questionnaire to the investigator prior to, or at the start of their next visit. On the first visit only, subjects were asked to complete the modified version of the Eysenk Personality Questionnaire at 90 minutes post treatment.

Table 5.1a: Experimental timeline, total time of experiment 180min. PThr = pain threshold, PTol = pain tolerance, HR = heart rate.

Pre treatment baseline period			Treatment		Post treatment period									
					0		30		60		90		120	
0 – 9	10	15	15 – 60	61		90		120		150		180		
Documents completed, monitors attached	PThr , PTol, HR pre/post	Subjective Rating Questionnaire	Rest – 5min	S.Reflex, L.Reflex, No treat	Ice plunge - PThr, PTol HR pre/post	Subjective Rating Questionnaires	Ice plunge - PThr, PTol HR pre/post	Subjective Rating Questionnaire	Ice plunge - PThr, PTol HR pre/post	Subjective Rating	Ice plunge - PThr, PTol HR pre/post	Subjective Rating & EPQ	Ice plunge - PThr, PTol HR pre/post	Subjective Rating Questionnaire

5.2.4a Eysenck Personality Questionnaire

There is some evidence that extroversion and introversion correlate with pain threshold and tolerance levels (Pearce and Porter, 1983, Harkins *et al.*, 1989, Wade *et al.*, 1992). In order to compare the extroversion/introversion dimensions of the Eysenck Personality Questionnaire (EPQ) with pain threshold and tolerance scores, this experiment utilised a modified version of the (EPQ). The subjects were asked to complete 41 questions of the modified version, 20 of which related to the E-scores, see Appendix B.

5.2.5a Statistical Analysis

Analyses to calculate statistical significance on the quantitative data for pain threshold, pain tolerance and heart rate were made on the raw data following the methods adopted for Chapter 3 and 4, and for the change from pre-treatment baselines using a between-groups two-way analysis of variance with repeated measures on treatment and time (Winer, 1971). The Newman-Keuls multiple comparison tests were used and inter-session reliability statistics for baselines were calculated using the Pearsons product-moment correlation coefficient statistic (Salkind, 2004). The nature of the data in this experiment was such that there were large inter-individual variations and such variability required the use of the Pitman permutation test. This test was carried out to show equal variances in the paired data

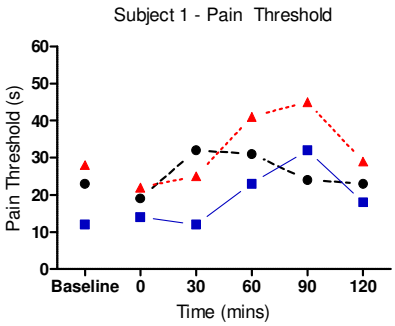
at the various time points across the experimental procedure (Pitman, 1939, Bland, 2000). The subjective rating questionnaires were analysed using the non-parametric Friedman test (Siegel and Castellan, 1988).

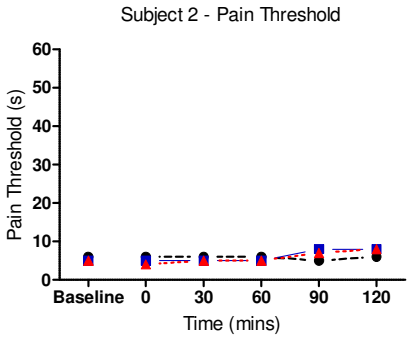
5.3 A RESULTS

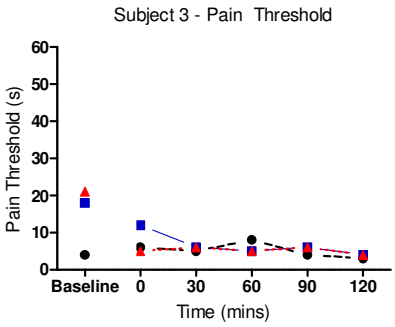
5.3.1a Pain Threshold and Tolerance

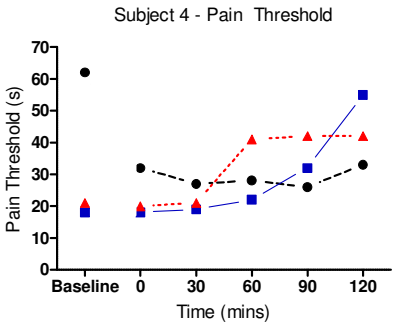
As reported in earlier chapters, see Chapter 2 (Section 2.4.1) and Chapter 4, (Section 4.7.1) a review of the literature indicated that the average pain threshold levels in experimental pain studies were in the mean ± SD range of 15.0 ± 7.0 – 22.0 ± 19.6s (Ashton *et al.*, 1984, Johnson and Din, 1997, Smith *et al.*, 2008). Subjects who demonstrated thresholds greater than 40s during the no treatment (control) period were removed from the analysis, this included subjects 17, 19, 23, 26 and 29. Individual graphs for these subjects are shown in Appendix D whilst the remaining results for the individual subjects are shown in Figures 5.1a for pain threshold and 5.2a for pain tolerance.

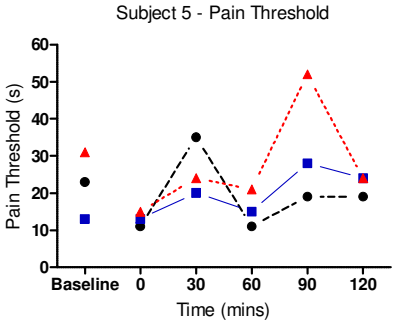
Pain Threshold

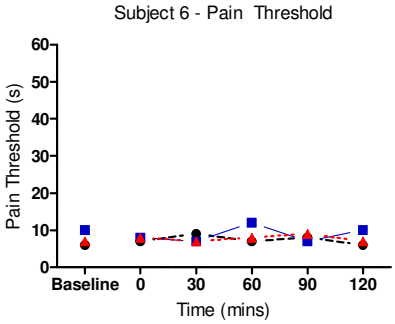


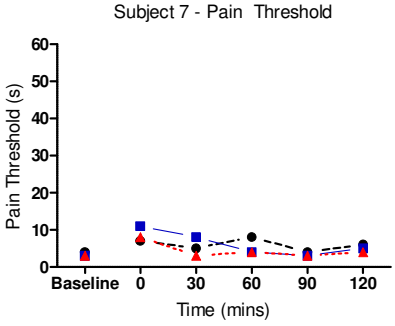


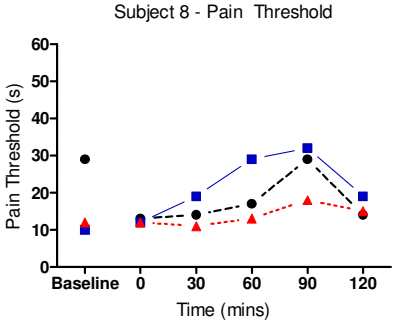




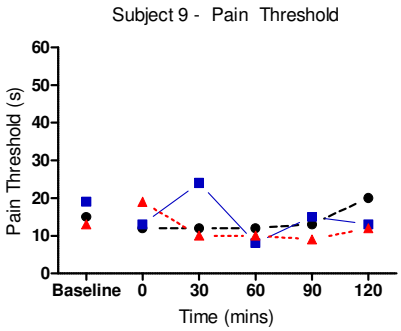


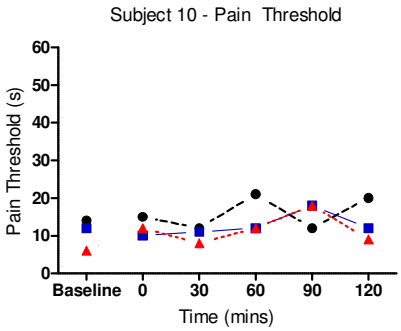


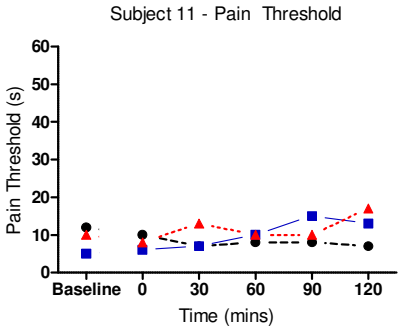


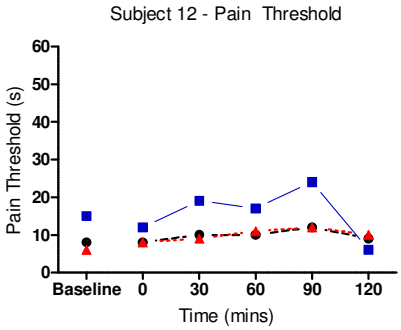


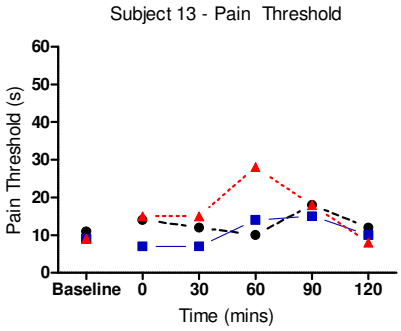
Pain Threshold

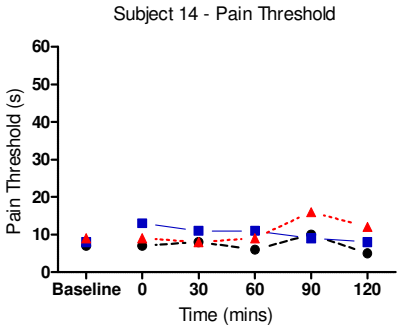


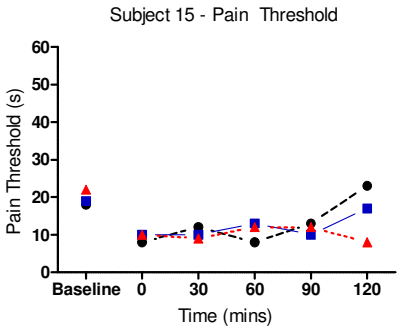


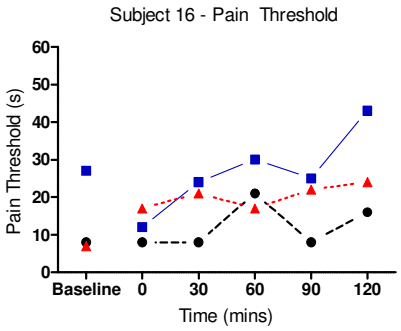




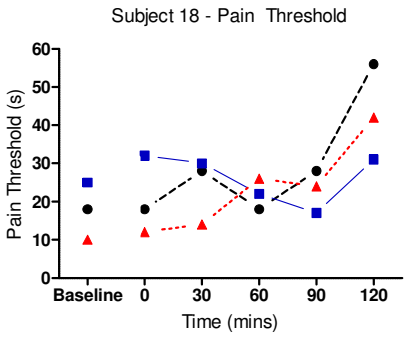


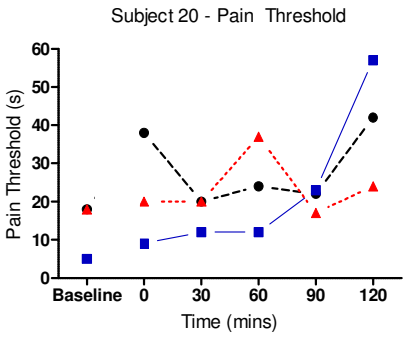


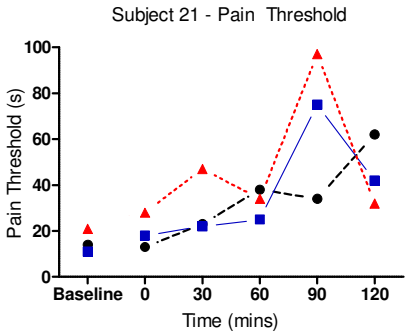


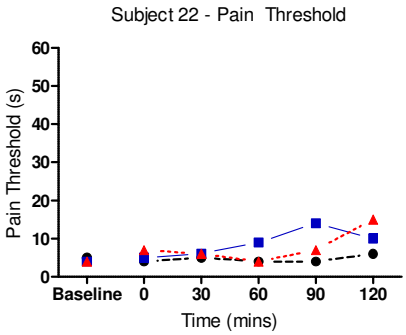


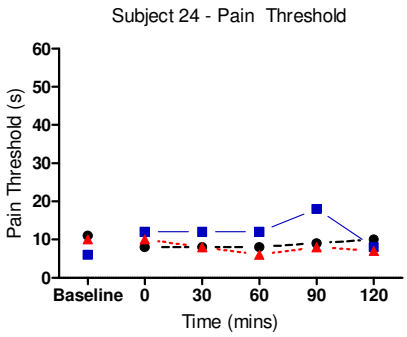
Pain Threshold

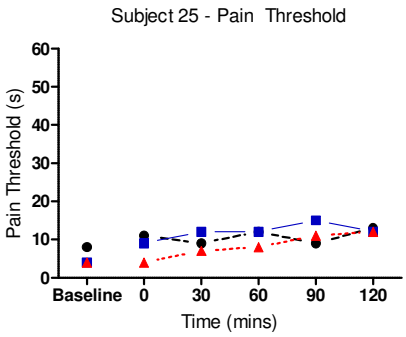


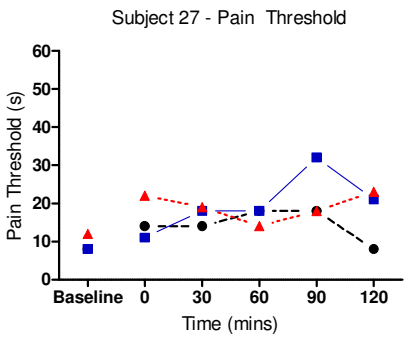


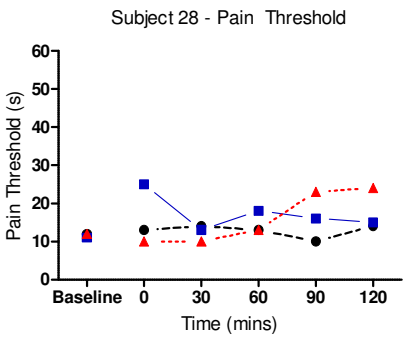












Pain Threshold

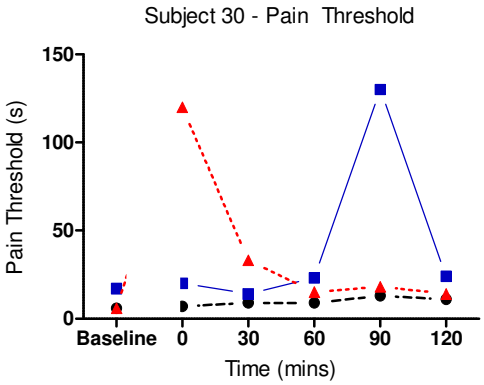
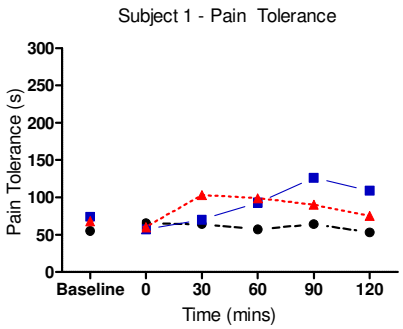
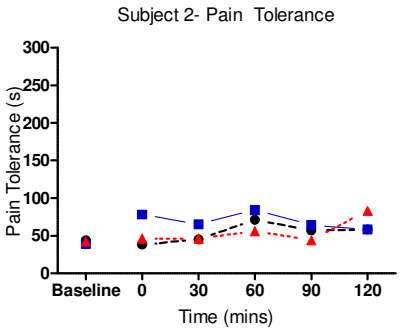
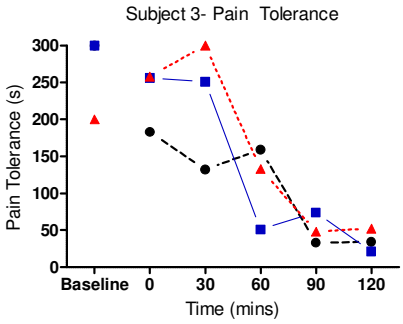


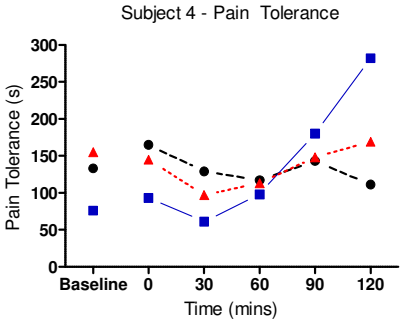
Figure 5.1a: The effect of standard and light reflexology on pain threshold (s) for the individual subjects, *n=25*. Note the extended Y-axis for subjects, 21 and 30. ● = No treatment (control), ■ = Standard Reflexology ▲ = Light reflexology.

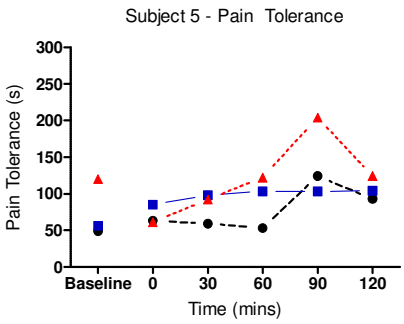
Pain Tolerance

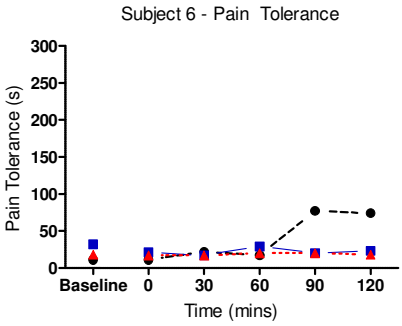


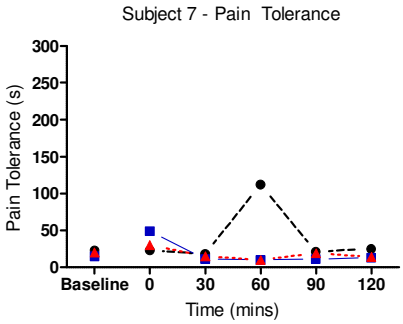


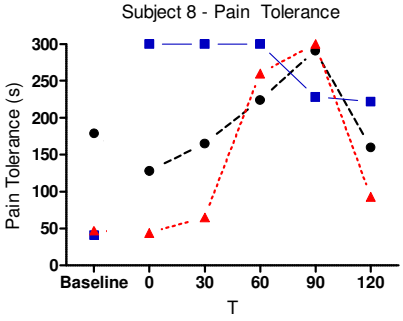




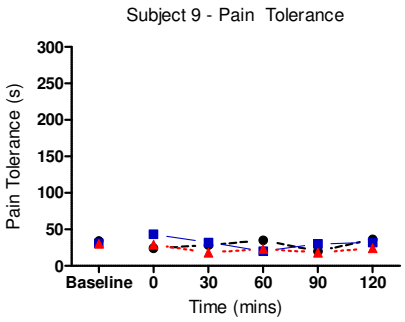


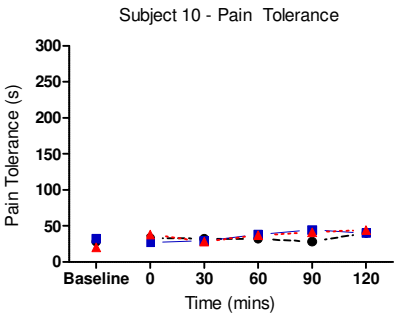


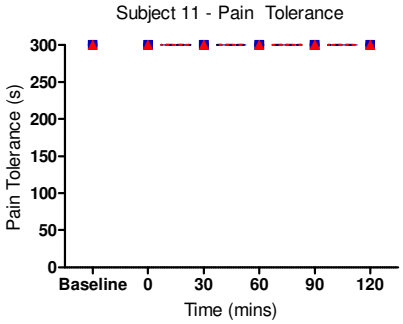


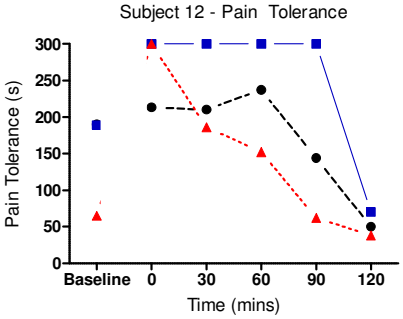


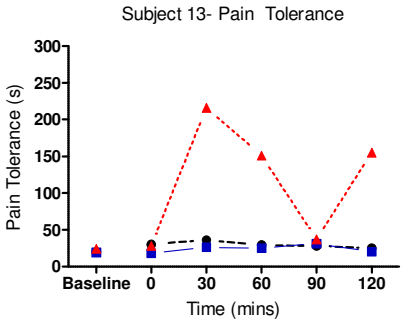
Pain Tolerance

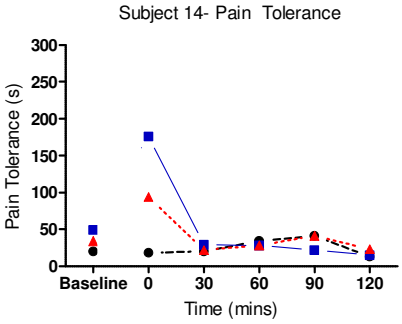


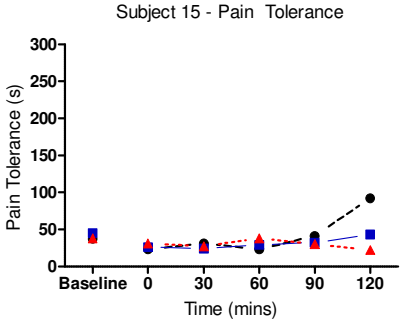


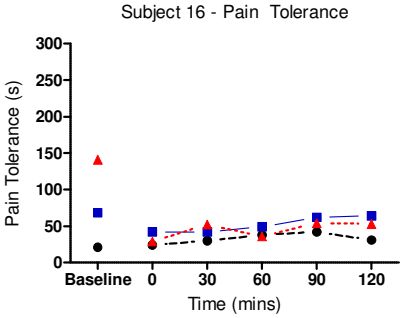




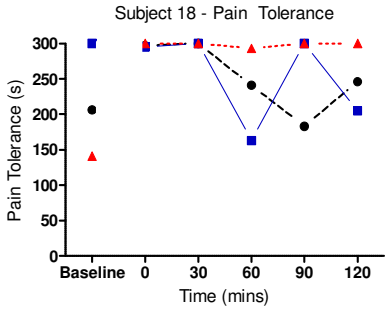


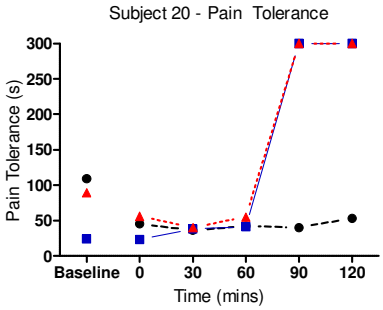


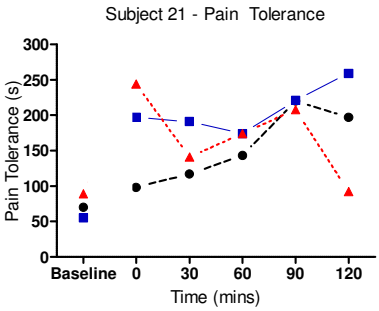


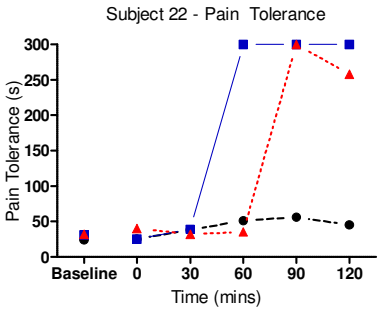


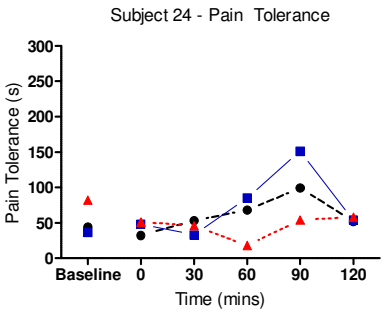
Pain Tolerance

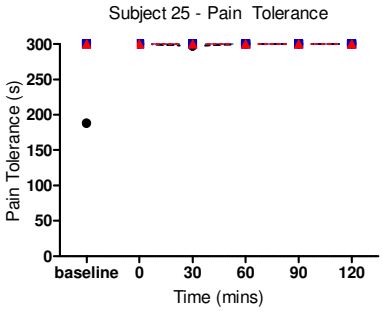


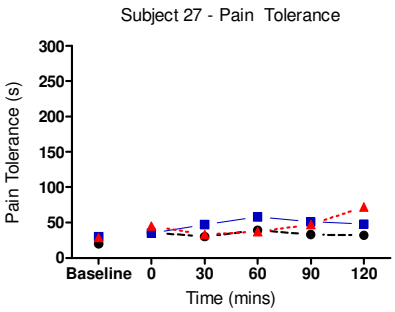


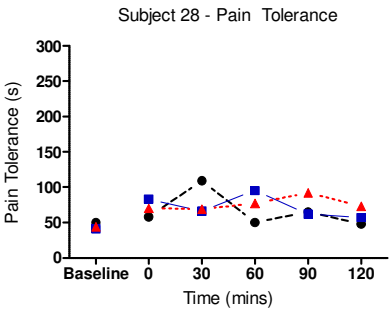












Pain Tolerance

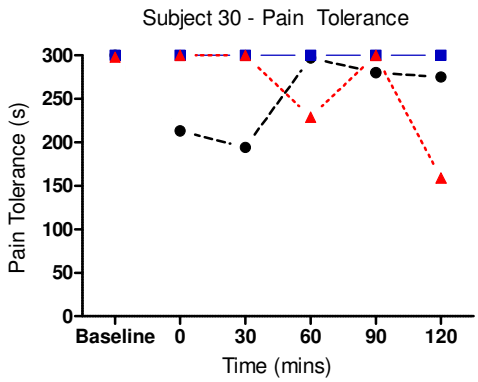


Figure 5.2b: The effect of standard and light reflexology on pain tolerance (s) for the individual subjects, *n=25*. See text for experimental details. ● = No treatment (control) ■ = Standard Reflexology ▲ = Light reflexology.

Tables 5.2a and 5.3a illustrate the raw data mean ± SEM in pain threshold (s) and tolerance scores (s) respectively for the eligible subjects after the different treatments.

Table 5.2a: Mean ± SEM for pain threshold (s) by treatment and by time showing the pre treatment baseline and the 5 successive post treatment observations, each at 30 minute intervals. *n=25.* There was no significant main effect of treatment ($F_{(2,48)}$=2.5487,n.s.) but there was a significant effect of time ($F_{(4,96)}$=4.2058,p<0.01). There was no treatment x time interaction ($F_{(8,192)}$=1.4705,n.s.).

Group	*Pre-treatment*	*Post treatment*				
	Baseline	*(+0 min)*	*(+30 min)*	*(+60 min)*	*(+90 min)*	*(+120 min)*
Control	14.0 ± 2.4	12.4 ± 1.6	13.8 ± 1.8	14.2 ± 1.8	14.4 ± 1.8	17.8 ± 3.2
S. Reflex	11.3 ± 1.3	12.7 ± 1.3	13.9 ± 1.4	15.2 ± 1.5	24.8 ± 5.3	19.4 ± 3.1
L. Reflex	11.7 ± 1.6	17.0 ± 4.6	14.4 ± 2.1	16.2 ± 2.4	20.9 ± 4.1	17.0 ± 2.2

Table 5.3a: Mean ± SEM for pain tolerance (s) by treatment and by time showing the pre treatment baseline and the 5 successive post treatment observations each at 30 minute intervals. *n=25.* There were significant main effects of treatment ($F_{(2,48)}$=5.2046,p<0.01) but no significant effect of time ($F_{(4,96)}$=0.7475,n.s.) and no treatment x time interactions ($F_{(8,192)}$=0.4432,n.s.).

Group	*Pre-treatment*	*Post treatment*				
	Baseline	*(+0 min)*	*(+30 min)*	*(+60 min)*	*(+90 min)*	*(+120 min)*
Control	98.2 ± 19.9	97.8± 19.9	99.8± 19.1	110.8± 19.9	109.2± 19.8	97.7 ± 18.8
S. Reflex	99.3 ± 22.0	127.1± 23.3	118.8± 23.8	122.9± 22.3	144.5± 23.4	129.6± 23.5
L. Reflex	101.9± 19.2	116.6± 22.7	113.8± 22.0	111.8± 19.8	134.3± 23.8	116.0± 20.3

As described earlier, and following the method adopted in Chapters 3 and 4, the data were then calculated as a change from baseline (Twisk and Proper, 2004).

Pain Threshold

The effects of reflexology on pain threshold are illustrated in Figure 5.3a which shows the change in pain threshold from the pre-treatment baseline. Baseline data calculations were carried out using the Pearson product-moment correlation. The no treatment (control) *vs* standard reflexology result showed that the data were below the level of significant correlation (r = +0.32, df = 25, n.s) but a paired t-test showed there was no significant difference in the data (p=0.26, n.s). However the analysis between the no treatment (control) and light reflexology revealed the data were

significantly correlated (r = +0.60, df = 25, p<0.01), but the paired t-test revealed they were not significantly different (p=0.23, n.s). Thus, there was little difference in the baselines between the treatment sessions.

A two-way analysis of variance showed a significant main effect of treatment ($F_{(2,48)}$=4.7152,p<0.05) with both standard and light reflexology treatments increasing pain thresholds at t=90min post treatment when compared to a no treatment (control). Post-hoc Newman-Keuls test showed p<0.01 for standard and p<0.05 for light reflexology at this time. Furthermore there was a significant effect of time ($F_{(4,96)}$=4.2059,p<0.01) in both standard and light reflexology but there was no treatment x time interaction ($F_{(8,192)}$=1.4702,n.s.). Following the no treatment (control) there was a decreased effect on pain threshold at t=0min and t=30min post treatment which only rose by 0.2 and 0.4 s respectively at t=60min and t=90min when compared to increases of 3.9 and 13.4 s for standard and 4.5 and 9.2 s for light reflexology at t=60 and 90 min.

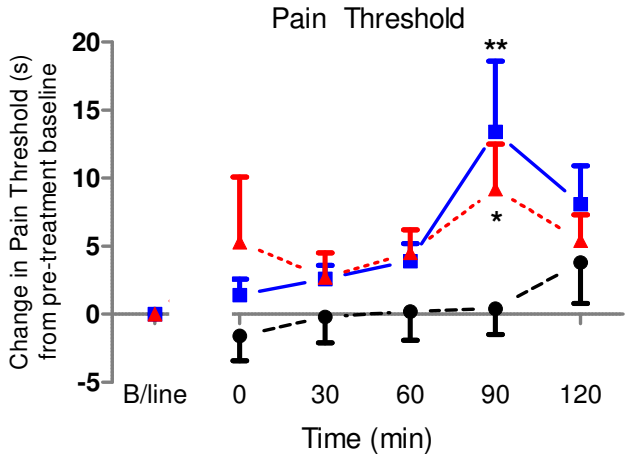


Figure 5.3a: Change in ice pain threshold (s) from pre-treatment baseline, *n=25*. p<0.01 for standard and p<0.05 for light reflexology compared to no treatment (control). Vertical lines show +/- SEM. ● = No treatment (control) ■ = Standard Reflexology ▲ = Light reflexology.

To control for errors in cross-over design trials, permutation tests such as the Pitman test, are considered to provide exact distribution-free significance levels, furthermore they test for equal variances of paired data (Gresty *et al.*, 2003, Good and Xie, 2008, Howell, 2010). The data for pain threshold and tolerance were therefore subjected to the Pitman test. The result for pain thresholds are shown in Table 5.4 a) standard and b) light reflexology. The results indicated significant differences at t=30, t=60 and t=90 min for standard reflexology and at t=0 min, t=90 and t=120 min for light

reflexology, thus highlighting significant effects of treatment not made obvious by the ANOVA and post-hoc tests.

Table 5.4a: Pitman permutation test for change from pre-treatment baseline in pain threshold for, A) standard and, B) light reflexology showing the post treatment effects when compared to a no treatment (control), *n=25*. Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

A

Standard Reflexology					
Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**	**120 min**
F-ratio	2.222	3.599	2.866	7.283	1.182
N =	25	25	25	25	25
Pearson	0.201	0.163	0.189	0.292	0.223
Pitman test	2.00	3.33	2.691	5.837	0.412
p-value	ns	**0.01**	**0.05**	**0.01**	ns

B

Light Reflexology					
Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**	**120 min**
F-ratio	7.126	1.1111	1.545	2.881	2.558
N =	25	25	25	25	25
Pearson	0.164	0.212	0.132	0.283	0.278
Pitman test	5.57	0.25	1.06	2.77	2.43
p-value	**0.01**	ns	ns	**0.05**	**0.05**

Pain Tolerance

Pearson product-moment correlation coefficients for pain tolerance baselines in the no treatment (control) *vs* standard reflexology were highly significant (r = +0.89, df = 25, p<0.01), as were the no treatment (control) *vs* light reflexology (r = +0.81, df = 25, p<0.01). A paired *t*-test showed no significant differences between the baselines with p=0.90, n.s. for standard and p=0.75, n.s. for light reflexology when compared to control. The correlations show good reliability in baseline responses between sessions. ANOVA for the change from pre-treatment pain tolerance baselines are represented by Figure 5.4a. There were no significant main effects of treatment ($F_{(2,48)}$=1.6732,n.s). Both the standard and light reflexology treatments revealed increased tolerance levels when compared to the no treatment (control) particularly at t=90min but there were no significant effects of time ($F_{(4,96)}$=0.7476,n.s.) and there was no treatment x time interactions ($F_{(8,192)}$=0.4432,n.s.). In the control treatment there was again a slight decrease in pain tolerance at t=0min, down 0.4 s from baseline and at t=120 when the pain tolerance score decreased by 0.5 s from baseline. However all data showed large SEM readings thus confirming great inter-individual variation amongst subjects.

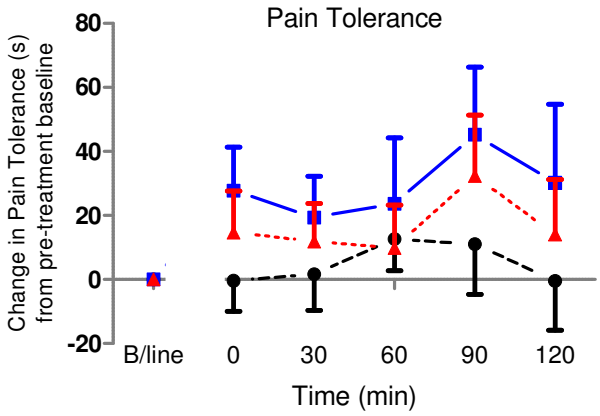


Figure 5.4a: Change in ice pain tolerance (s) from pre-treatment baseline, *n=25*. Vertical lines represent +/- SEM. ● = No treatment (control) ■ = Standard Reflexology ▲ = Light reflexology

The Pitman test showing the differences in variability on the paired data are shown in Table 5.5a: a) standard and b) light reflexology. The results showed significant differences at t=60 and t=120 min for standard reflexology but none for light reflexology.

Table 5.5a: Pitman permutation test for change from pre-treatment baseline in pain tolerance for, A) standard and, B) light reflexology showing the post treatment effects when compared to a no treatment (control), *n=25*. Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value= probability of significance.

A

Standard Reflexology					
Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**	**120 min**
F-ratio	2.020	1.324	4.449	1.829	2.583
N =	25	25	25	25	25
Pearson	-0.014	0.160	0.482	0.471	0.449
Pitman test	1.722	0.685	4.488	1.667	2.644
p-value	ns	ns	**0.01**	ns	**0.05**

B

Light Reflexology					
Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**	**120 min**
F-ratio	1.830	1.227	1.873	1.497	1.269
N =	25	25	25	25	25
Pearson	0.142	-0.003	0.353	0.408	0.247
Pitman test	1.497	0.277	1.636	1.067	0.592
p-value	ns	ns	ns	ns	ns

5.3.3a Results obtained for heart rate responses

Heart rate pre plunge

A between sessions Pearsons product-moment correlation on the pre-treatment baselines for no treatment (control) and standard reflexology pre plunge heart rate (r = +0.47, df = 25, p<0.05) and between the no treatment (control) and light reflexology (r = +0.52, df = 25, p<0.01) revealed the data were significantly correlated, thus demonstrating good inter-session reliability. Paired *t*-tests showed no significant differences for either standard p=0.80, n.s. or light reflexology p=0.06, n.s.

Raw data results for the pre ice plunge heart rate (bpm) are illustrated in Table 5.6a.

Table 5.6a: Mean ± SEM for pre plunge heart rate (bpm) by treatment and by time showing pre treatment baseline and 5 successive post treatment observations at 30 minute intervals. *n=25.* There were significant effects of treatment ($F_{(2,48)}$=3.5381,p<0.05), significant main effects of time ($F_{(4,96)}$=4.9684,p<0.01) and a treatment x time interaction ($F_{(8,192)}$=2.5773,p<0.05) for standard and light reflexology compared to control.

Group	*Pre-treatment baselines*	*Post treatment (+0 min)*	*Post treatment (+30 min)*	*Post treatment (+60 min)*	*Post treatment (+90 min)*	*Post treatment (+120 min)*
Control	76.3 ± 10.4	70.8± 11.4	70.4 ± 8.9	69.2 ± 9.5	69.3 ± 10.4	70.5 ± 11.1
S. Reflex	76.8 ± 11.3	66.0 ± 10.1	67.8 ± 10.3	70.7 ± 10.2	69.0 ± 10.4	71.2 ± 12.0
L.Reflex	81.3 ± 11.3	62.3 ± 9.3	67.0 ± 9.2	68.5 ± 9.1	67.8 ± 8.7	69.7 ± 8.2

ANOVA on pre-plunge change from pre-treatment baselines is shown in Figure 5.5a. There was a significant main effect of treatment ($F_{(2,48)}$=8.3197,p<0.01). The decreasing effect of light reflexology treatment on pre-plunge heart rates post treatment is maintained throughout the entire experimental cycle, whilst for the standard reflexology treatment the effect is only significantly different at t=0min, it does however, remain lower than control for a further 30 min correlating to the results seen in Chapters 3 and 4. The pre-plunge heart rate does not return to pre-treatment baselines under any condition which may be indicating an additional effect of relaxation in the subjects. There were significant main effects of time ($F_{(4,96)}$=4.9685,p<0.01) and a treatment x time interaction ($F_{(8,192)}$=2.5773,p<0.05) for standard and light reflexology compared to control.

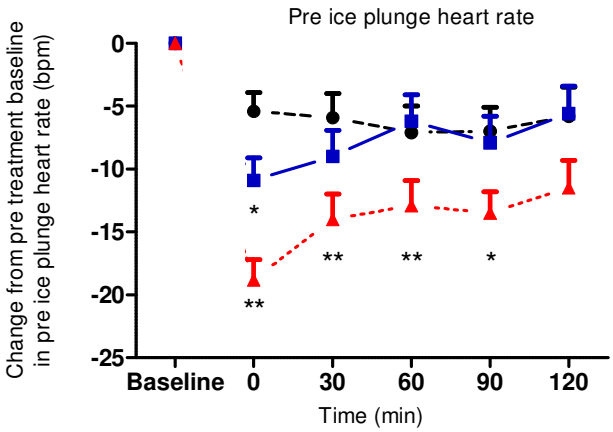


Figure 5.5a: The mean ± SEM change from pre-treatment baseline in pre plunge heart rate (bpm), *n=25*. **p<0.01 for light reflexology, **p<0.05 for standard and light reflexology compared to no treatment (control). Vertical lines represent +/- SEM. ● = No treatment (control) ■ = Standard Reflexology ▲ = Light reflexology

Of interest is the result of the Pitman permutation test on the change from baseline pre plunge heart rate as shown in Table 5.7a. It shows the data were not significantly different at any time point for either standard or light reflexology when compared to the no treatment (control), suggesting that the ANOVA may have produced a false positive result.

Table 5.7a: Pitman permutation test as a change from pre-treatment baseline in pre-plunge heart rate (bpm) for A) standard and B) light reflexology showing the 5 post treatment effect when compared to a no treatment (control), *n=25*. Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

A

Standard Reflexology					
Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**	**120 min**
F-ratio	1.137	1.277	1.005	1.169	1.043
N =	25	25	25	25	25
Pearson	0.258	0.201	0.206	0.272	0.108
Pitman	0.321	0.601	0.014	0.390	0.103
p-value	ns	ns	ns	ns	ns

B

Light Reflexology					
Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**	**120 min**
F-ratio	1.148	1.102	1.102	1.230	1.090
N =	25	25	25	25	25
Pearson	0.127	0.262	0.368	-0.176	-0.030
Pitman	0.336	0.243	0.251	0.505	0.208
p-value	ns	ns	ns	ns	ns

Heart rate post plunge

A Pearsons product-moment correlation on the post ice plunge heart rate (bpm) of the pre-treatment baselines for no treatment (control) and standard reflexology showed no significant corelation (r = +0.08, df = 25, n.s.) but a paired t-test showed there was no significant difference p=0.94, n.s. However, between the no treatment (control) and light reflexology there was a small but significant correlation in baselines (r = +0.42, df = 25, p<0.05) but the paired t-test showed no significant differences p=0.32, n.s. Therefore, there was good inter-reliability between sessions for control and standard reflexology and a moderate relationship between control and light reflexology baselines.

Raw data for the post ice plunge heart rate (bpm) are illustrated in Table 5.8a

Table 5.8a: Mean ± SEM for post plunge heart rate (bpm) by treatment and by time showing pre treatment baseline and 5 successive post treatment observations at 30 minute intervals. *n=25.* There were no significant effects of treatment ($F_{(2,48)}$=1.9934,n.s), no significant main effects of time ($F_{(4,96)}$=0.7252,n.s) and there were no treatment x time interactions ($F_{(8,192)}$=0.6056,n.s) for standard and light reflexology compared to control.

Group	*Pre-treatment baselines*	*Post treatment (+0 min)*	*Post treatment (+30 min)*	*Post treatment (+60 min)*	*Post treatment (+90 min)*	*Post treatment (+120 min)*
Control	76.3 ± 10.4	70.8± 11.4	70.4 ± 8.9	69.2 ± 9.5	69.3 ± 10.4	70.5 ± 11.1
S. Reflex	76.8 ± 11.3	66.0 ± 10.1	67.8 ± 10.3	70.7 ± 10.2	69.0 ± 10.4	71.2 ± 12.0
L.Reflex	81.3 ± 11.3	62.3 ± 9.3	67.0 ± 9.2	68.5 ± 9.1	67.8 ± 8.7	69.7 ± 8.2

Post ice plunge heart rate values as a change from the pre-treatment baselines is shown in Figure 5.6a. Whilst there were no significant effects of treatment ($F_{(2,48)}$=2.7666,n.s) for either standard or light reflexology when compared to the 'no treatment' control, there was a greater decrease in heart rates following light reflexology. Rather interestingly the effect of standard reflexology on post plunge heart rate is higher than the control which has not been seen in earlier experiments (Chapters 3 and 4) and may be because subjects found the light reflexology treatment more relaxing. There were no significant effects of time ($F_{(4,96)}$=0.7253,n.s) nor any treatment x time interactions ($F_{(8,192)}$=0.6056,n.s).

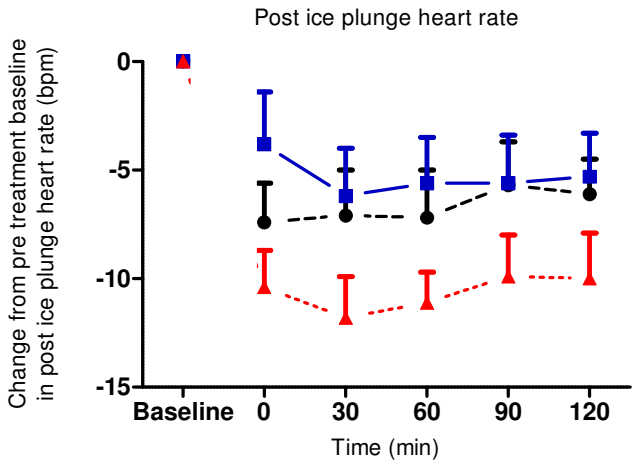


Figure 5.6a: The mean ± SEM change from pre-treatment baseline in post plunge heart rate (bpm), *n=25*. Vertical lines represent +/- SEM. ● = No treatment (control) ■ = Standard Reflexology ▲ = Light reflexology.

The Pitman test on the post plunge heart rate is shown in Table 5.9a. The test did not significantly alter the results but did reveal an effect of light reflexology on post plunge heart rates at t=60min which was not apparent from the ANOVA.

Table 5.9a: Pitman permutation test as a change from pre-treatment baseline in post-plunge heart rate (bpm) for A) standard and B) light reflexology showing the 5 post treatment effects when compared to a no treatment (control), *n=25*. Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

A

Standard Reflexology					
Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**	**120 min**
F-ratio	1.589	1.180	1.173	1.294	1.700
N =	25	25	25	25	25
Pearson	-0.377	-0.260	-0.113	-0.009	-0.034
Pitman	1.211	0.413	0.386	0.621	1.288
p-value	ns	ns	ns	ns	ns

B

Light Reflexology					
Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**	**120 min**
F-ratio	1.175	1.200	2.538	1.017	1.831
N =	25	25	25	25	25
Pearson	0.123	0.193	0.338	0.406	0.420
Pitman	0.390	0.447	2.461	0.046	1.623
p-value	ns	ns	**0.05**	ns	ns

5.3.4a Results of the Subjective Analyses

Analysis of the subjective rating questionnaires was carried out using the Friedmann non-parametric statistic with repeated measures and a post-hoc Dunnett's t-test. The median and 1st and 3rd quartiles are shown in Table 5.10a. Results showed there were no significant differences between the treatments with respect to levels of arousal, anxiety or discomfort. The final question on the subjective rating questionnaire asked the subjects to rate whether or not they felt the treatment had any effect on their outcomes for pain threshold or tolerance. The questionnaires revealed that 76% of the standard reflexology and 84% for light reflexology felt the treatment had a positive effect.

Table 5.10a: Analysis of subjective rating questionnaires. The table shows the median and 1st and 3rd quartiles are shown in brackets, *n=25*. Key = 4 = very high, 3 = high, 2 = normal, 1 = below normal.

AROUSAL	**0 mins**	**30 mins**	**60 mins**	**90 mins**	**120 mins**
No treatment	2 (2,3)	2 (2,2)	2 (2,2)	2 (2, 2)	2 (2,2)
Standard Reflexology	2 (1,2)	2 (2,2)	2 (2,2)	2 (2,2)	2 (2,2)
Light Reflexology	2 (2,2)	2 (2,2)	2 (2,2)	2 (2,2)	2 (2,2)
ANXIETY					
No treatment	1 (1,2)	1 (1,2)	1 (1,2)	1 (1, 2)	1 (1,2)
Standard Reflexology	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)
Light Reflexology	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)
DISCOMFORT					
No treatment	3 (2,3)	3 (3,3)	3 (2,3)	3 (2,3)	3 (2,3)
Standard Reflexology	3 (2,3)	3 (2,3)	2 (2, 3)	3 (2,3)	3 (2,3)
Light Reflexology	3 (2,3)	2 (2,3)	3 (2, 3)	3 (2,3)	3 (2, 3)

Feedback Questionnaires

The feedback questionnaires review the side-effects that may be normal responses in subjects receiving reflexology in a clinical environment. They are identified thus:

- Dark colour/strong odour to urination
- Increase in bowel movements and/or flatulence
- Increase in nasal secretions and/or coughing
- Increase in vaginal discharge
- Extra or depleted energy levels
- Spots and/or minor skin blemishes (not usual for you)

- Muscular/skeletal aches and pains (not usual for you)
- Headaches at the front of the forehead
- Improved sleep

As the control was 'no treatment', forms were not issued following this session. When asked their overall opinion of the treatment experience, 61% for standard reflexology and 72% for light reflexology said they enjoyed the treatment very much. Of the remaining responses, 35% for standard reflexology and 28% for light reflexology said they enjoyed the treatment a little.

The pie chart shown in Figures 5.7a shows the analysis of reported side-effects following both standard and light reflexology treatment whether real effects or simply placebo. It is probable however, that in providing a list to subjects they felt obliged to tick the boxes regardless as to whether the reactions were real effects or not.

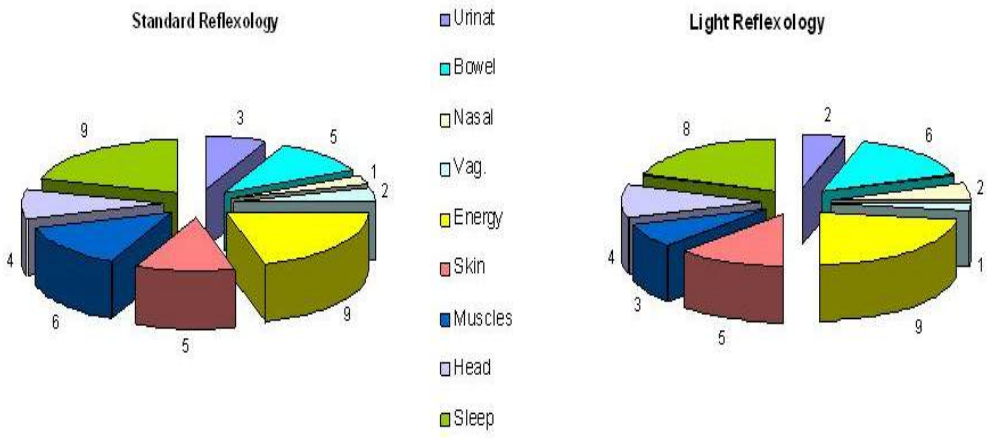


Figure 5.7a: Illustration of the results for the number of subjects who experienced side-effects to standard and light reflexology, *n=25*.

Subjects were given the opportunity to reflect on their treatment and subsequently provided the following general comments relating to treatment: -

<u>Standard reflexology</u>

- *I felt absolutely great!*
- *I usually feel sleepy around 5 – 7p.m. but today I didn't feel sleepy at all.*
- *Something wrong with my neck.*
- *Stomach cramps.*

- *Asthma was good again.*
- *Cramp in the arch of my foot during the night (only the night after treatment).*

Light reflexology

- *Some of the above questions are difficult to answer, as I was off sick the two days after the treatment with a cold.*
- *Need to urinate more frequently.*
- *Asthma has been controlled, better than usual.*
- *Felt more relaxed after reflexology.*

Eysenck Personality Questionnaires

Analysis of the Eysenck personality questionnaires showed that the mean ± SEM E-scores for the 25 eligible subjects who participated in the experiments was 13.25 ± 1.04. There was no correlation between E-scores and pain threshold or tolerance scores.

5.4A DISCUSSION

The principal aim of the study described in this chapter was to investigate the effects of standard and light reflexology in an ice pain experiment. The results obtained in Chapter 4 showed that standard reflexology significantly increased both pain threshold and pain tolerance. However, compared to the experiment carried out in Chapter 4 the present study was fraught with a number of problems and the analysis of the data obtained, raised a number of issues which will be discussed below.

1. A survey of the literature has revealed that pain threshold scores in ice pain experiments are normally associated with a mean ± SD in the range of 15.0 ± 7.0 – 22.0 ± 19s under controlled conditions (Ashton *et al.*, 1984, Johnson and Din, 1997, Smith *et al.*, 2008). Therefore, the criterion used in the experiments within this thesis was that subjects with pain threshold >40s recorded under controlled conditions, should be eliminated from further consideration. Subsequently the data obtained for five subjects in this experiment were removed from further consideration. It is quite plausible that some of the subjects may

have misinterpreted the instructions on how to immerse their hands in the ice container and therefore displayed prolonged thresholds.

2. Of the original 30 volunteers recruited to the experiment, 27 were female and 3 were males. The subjects were recruited from within the University of Portsmouth undergraduate, post-graduate and staff population, and also subjects from the general public with a mean ± SEM age group 36.3 ± 2.0 years. They received no monetary or other form of payment for volunteering. An attempt was made to recruit more male subjects but this met with some resistance and the male subjects who did volunteer found excuses not to participate in the experiment. Although users of complementary therapies are predominantly female (Thomas *et al.*, 2001, Ernst and White, 2000), there is a large bias toward females in this study group which may have compromised the outcomes.
3. A major problem was encountered when analysing the data and in particular one of the concerns was that in trials where there are a small number of subjects a simple analysis of variance may introduce errors. To overcome this, the data were analysed as a change from the pre-treatment baseline (Twisk and Proper, 2004, Vickers, 2001, van Breukelen, 2006, Winkens *et al.*, 2007). To further avoid the risk of errors additional analysis was carried out in the form of the Pitman permutation test which tests for differences in equal variances of paired data (Gresty *et al.*, 2003, Pitman, 1939, Bland, 2000, Good and Xie, 2008). Pitman tests are thought to provide superior statistical power and do not require that the data are normally distributed (Goulden *et al.*, 2010).
4. Test-retest reliability statistics could not be carried out on this data because only one pre-treatment baseline was used. In retrospect it may have been a good idea to have two baseline values as this would have shown the intra-session reliability. However because of the already long duration of the experiment and the difficulty in recruiting subjects, this was not tenable. Therefore, as shown in Chapter 4 the Pearsons product-moment correlation statistic was used to compare the pre-treatment baselines. The result for the effect of the no treatment (control) *vs* standard reflexology on pain threshold was very close and a *t*-test comparison showed there was no significant difference in the baselines p=0.26, n.s. It is proposed that this may be due to the inter-individual variations amongst subjects. In pain tolerance however there was good correlation between the no treatment (control) and both standard and light reflexology.

5. In Chapter 4 sham TENS was used as a control and an argument for its use was discussed (Section 4.6.1). A 'no-treatment' control was used in the present study to establish if there was an effect of reflexology over and above that of the placebo used in Chapter 4. In an ideal situation, the experimental design should have included four 'treatments', (i) a no treatment control (ii) sham TENS control (iii) light reflexology and (iv) standard reflexology. Unfortunately this design was considered untenable because of the reluctance of volunteers to attend four sessions. Subsequently the design used in this study did not have a sham TENS control. However the experimental design used in Chapter 4 was very similar to the design used in this study making it possible to measure the effects of the 'no treatment control' with those of the 'sham TENS control' (Chapter 4) on pain threshold and tolerance. As shown in Table 5.11a there were no significant differences between the two control treatments and one would speculate that these results justify the use of a 'no treatment control' in this study.

Table 5.11a: A comparison of control treatments. Mean ± SEM pain threshold and pain tolerance values (s) in the 'no treatment' control and 'sham TENS' control.

PAIN THRESHOLD	**30 min**	**60 min**	**90 min**	**120 min**
No treatment	15.8 ± 2.3	15.9 ± 2.3	16.7 ± 2.2	20.2 ± 4.2
Sham TENS	10.8 ± 1.4	12.8 ± 3.1	14.5 ± 4.1	15.5 ± 3.6
Significance:	n.s	n.s	n.s	n.s
PAIN TOLERANCE	**30 min**	**60 min**	**90 min**	**120 min**
No treatment	97.2 ± 19.1	106.3 ± 21.4	105.9 ± 21.2	86.3 ± 19.3
Sham TENS	110.9 ± 26.4	107.8 ± 28.3	123.6 ± 29.7	115.0 ± 27.9
Significance:	n.s	n.s	n.s	n.s

Pain threshold and tolerance for all eligible subjects

Analysis of the data using the mean ± SEM change from the pre-treatment baseline in eligible subjects revealed a significant effect on pain threshold for both standard and light reflexology when compared to the 'no treatment' (control). These results are comparable with those found in the earlier ice pain study (Chapter 4, Figure 4.1). The Pitman test Table 5.4a, showed significant differences between standard reflexology *vs* control during trials 2 – 4 (t=30-90min) which is consistent with the effect shown between standard reflexology *vs* sham TENS (control) in Chapter 4. Of

interest however is that in the light reflexology *vs* control arm the differences were less consistent. There was a significant treatment effect immediately post treatment (t-0 min) but the light reflexology treatment did not become significantly different to control again t= 90 and t=120 min post treatment, thus highlighting variability in the treatment effects.

Unlike the results of Chapter 4 the ANOVA for change from the pre-treatment baselines on pain tolerance was not significantly different for either standard or light reflexology when compared to the no treatment (control). The Pitman test however, Table 5.5a, did reveal a significant effect of standard reflexology treatment at t=60 and t=120 min post treatment, but no significance was found when comparing light reflexology *vs* control. It is important to mention however, that the results of this experiment revealed large inter-individual variations in the responses with respect to time (Figures 5.1a and 5.2a), and this is an effect that is not uncommon in many clinical studies (Roth-Isigkeit et al., 2001, Williams, 2008).

Heart Rate

An increased heart rate is often associated with the emotional component of pain (Applehans and Luecken, 2008) but there is mixed evidence for its relationship to the intensity of the pain experience (Moltner *et al.*, 1990, Mizushima *et al.*, 2003, Colloca *et al.*, 2006, Bossart *et al.*, 2007). For example, a decrease in sympathetic activity has been implicated in anti-nociceptive responses in human subjects during vaginal self stimulation (Martinez-Gomez *et al.*, 1988). In a study comparing the effects of vaginal stimulation with exercise it was established that increased heart rate from exercise did not produce increases in analgesia, whilst analgesia was present during vaginal stimulation but there was no increase in heart rate (Martinez-Gomez *et al.*, 1988). The heart rate responses observed during this experimental procedure would suggest that they were unrelated to the analgesic responses obtained from standard and light reflexology treatments. The ANOVA for change from pre-treatment baseline of the pre-plunge heart rate showed a decrease in heart rate particularly following light reflexology and suggests that perhaps light reflexology has a small but significant effect on autonomic activity which was not shown following standard reflexology. Despite this, the results show that whilst both standard and light reflexology can induce an anti-nociceptive effect, the light

reflexology also decreases heart rate and has the possibility of additional benefits for relaxing subjects.

Subjective rating

The subjective rating data showed there were no significant differences between the treatments for effect on levels of arousal, anxiety or discomfort. However it is noteworthy that 76% and 84% of subjects perceived standard and light reflexology respectively, to have a positive benefit on their pain threshold and tolerance levels. The results also showed that more of the subjects' enjoyed the light reflexology than the standard reflexology and this may have added to the perceived efficacy of the treatment. Whilst subjects identified side-effects of treatment this effect may be attributed to expectancy; for example providing subjects with a list of side-effects may have caused such symptoms to manifest (Roscoe *et al.*, 2006). The side-effects listed were those most commonly reported by patient's following reflexology in clinical practice.

Eysenck Personality Questionnaire (EPQ)

The results for pain threshold and tolerance identified that some subjects responded to reflexology early and others responded at a later time. According to the Eysenck theory, extroverts are people who are externally seeking, in other words they seek external stimulation and gratification from their environment (Matthews and Gilliland, 1999). On the other hand, introverts are classified as internally seeking and generally prefer their own company (Mitchell, n.d.). The modified EPQ was used to elicit information that may show a relationship between personality and early and late onset of responses. Ashton *et al.* (1984) found no significant relationship between E-scores and baseline threshold and tolerance in an experiment of different TENS frequencies and acupuncture in cold-induced pain where the mean E-scores were 15.2 ± 4.8SD. In the present study the average ± SEM E-score of all 25 subjects was 13.25 ± 1.04 but there was no correlation between the E-scores and pain tolerance values for both light and standard reflexology. These generally high E-scores of the individual subjects who took part in the study indicate that they were on the extrovert dimension of the introversion/extroversion side of the EPQ (Mitchell, n.d., Matthews and Gilliland, 1999). This is not surprising because they were unpaid volunteers and it is likely that the personality or type of person who volunteers for

this type of study are seeking external stimulation which is consistent with their E-scores in this modified EPQ. This may again raise certain questions about the outcomes of the study.

Conclusion

The results of this study confirm and extend those in Chapter 4 and show that the effects of treatment are not dependent on the mode of reflexology (standard or light) used in the study. However, the Pitman test did not show much change presumably because there were such large inter-individual variations between the subjects. The majority of subjects displayed bi-phasic responses to the effects of standard and light reflexology on pain threshold and tolerance with respect to time (Figures 5.1a and 5.2a). For example, some subjects showed maximum pain tolerance scores in the early time period following treatment and others showed maximum responses at a later time period following treatment. Therefore, traditional methods of graphically representing and analysing the data as shown by summary mean ± SEM graphs can result in a distorted interpretation of the treatment effect. Thus, the effect of treatment may be hidden (Matthews *et al.*, 1990). Chapter 5B therefore, will introduce an alternative and maybe controversial method of analysis which extrapolates further the effects of reflexology on pain threshold and tolerance.

Chapter 5B

AN ALTERNATIVE STATISTICAL ANALYSIS ON THE EFFECTS OF STANDARD AND LIGHT REFLEXOLOGY IN AN ICE PAIN EXPERIMENT

5.1B RATIONALE

In Chapter 5a the data were analysed using ANOVA and the Pitman test. However there were large inter-individual variations between the subjects which may have affected the true interpretation of the results obtained. Bi-phasic responses to the effects of both standard and light reflexology on pain threshold and tolerance with respect to time was shown by the majority of subjects as depicted in Figures 5.1a and 5.2a. When Ashton *et al. (1980)* looked at the effects of bi-phasic responses to treatment they were looking at different doses and in this experiment the observations were made at different times. Traditional methods of graphically representing and analysing the data as shown by summary mean ± SEM graphs can result in a distorted interpretation of the treatment effect. Chapter 5B therefore, will introduce an alternative means of analysing the data which may be controversial and open to debate.

As shown in the raw data for pain threshold and tolerance scores of the individual subject's, Figures 5.1a and 5.2a (Chapter 5A), there was great inter-individual variation in the results. Thus, for example some subjects displayed an early increase in pain threshold whilst others showed a late increase with similar results obtained for pain tolerance. Representation and analyses of the results as a change from baseline is therefore less meaningful because of the individual differences in the responses of the subjects to reflexology (Matthews et al., 1990). Thus, for example, if the pain tolerance scores of a subject that were high at 30 min and low at 120 min were averaged with that of another subject whose scores were low at 30 min and high at 120 min, the scores at each time point would cancel each other out and the means result would not reflect the true effects of the treatment. This is a problem faced by many researchers who work with human subjects where there are large

individual differences in the manner in which the subjects respond to various treatments (Ashton et al., 1980, Carlsson, 2002, Fillingim, 2005). This can introduce problems with the analysis and many small treatment effects may be overlooked (Westerhuis et al., 2010) even with the addition of the permutation test.

Ashton *et al.* (1980) went some way to address this problem. They found that intravenous administration of nicotine produced biphasic responses in the magnitude of a brain slow potential known as the contingent negative variation (CNV) with respect to dose of drug. Furthermore, they found that there were individual differences in the responses to nicotine. For some subjects, low doses of nicotine produced a large increase in the magnitude of the CNV and higher doses produced a decrease, while the reverse was true for other subjects. Averaging the data at each dose, as is normal for dose-response studies, would have produced distorted results. Instead, they constructed dose-response curves by choosing 4 points for each subject: i) the change in CNV magnitude from control at the minimum dose of nicotine given, ii) the change in CNV magnitude from control that produced the largest (maximum) increase in CNV magnitude, iii) the dose at which the dose crossed the baseline (the cross over point), and iv) the change in CNV magnitude from control that produced the largest (minimum) decrease in CNV magnitude.

5.1.1b Computation of tables and graphs for standard and light reflexology

The reflexology data from the present experiment was treated in a way that was not dissimilar to the manner in which Ashton *et al*. (1980) expressed and analysed their results. The data presented for the individual subjects in Figures 5.1a and 5.2a above for pain threshold and tolerance were used to compute the graphs for standard and light reflexology. Three points were chosen, i) baseline, ii) minimum and iii) maximum.

Standard reflexology pain threshold and tolerance

i) Baseline. Table 5.1b shows the mean ± SEM pre-treatment baseline threshold (s) and tolerance (s) for control and standard reflexology. The data on the graphs (Figures 5.1b and 5.2b) were calculated as the mean ± SEM change

from the baseline scores for threshold (Figure 5.1b) and tolerance (Figure 5.2b) relative to the control scores for each subject.

ii) Minimum. Tables 5.2b and 5.3b show the mean ± SEM minimum and maximum pain threshold (s) and tolerance (s) recorded for all eligible subjects and the mean ± SEM time after standard reflexology when this occurred. The corresponding mean ± SEM scores recorded under control conditions at this time are also shown. The data shown on the graphs (Figures 5.1b and 5.2b) were calculated as the mean ± SEM change in the minimum threshold (Figure. 5.1b) and tolerance (Figure 5.2b) scores recorded for each subject given standard reflexology from the corresponding control score, and the mean ± SEM latency at which this occurred.

iii) Maximum. Tables 5.2b and 5.3b show the mean ± SEM maximum pain threshold (s) and tolerance (s) respectively for all eligible subjects together with the mean ± SEM time after standard reflexology when this occurred. The corresponding mean ± SEM scores recorded under control conditions at this time are also shown. The data on the graphs (Figures 5.1b and 5.2b) were calculated as the mean ± SEM change in the maximum threshold (Figure 5.1b) and tolerance (Figures 5.2b) scores recorded for each subject given standard reflexology from the corresponding control score, together with the mean ± SEM latency at which maximum pain threshold and tolerance was achieved.

5.1.2b Results obtained for standard reflexology

Pain Threshold

Table 5.1b shows the results for pre-treatment baseline scores for the standard reflexology and control treatments. Analysis of the data (paired t-test) showed there were no significant differences in baseline values. There were however significant differences, see Table 5.2b, in the mean minimum and the mean maximum results between control and standard reflexology. The mean minimum pain threshold scores revealed there were significantly lower pain threshold values following standard reflexology compared with the control treatment, ($p<0.01$). The mean maximum

pain threshold values were significantly increased after standard reflexology compared with the 'no treatment' control ($p<0.01$).

Pain Tolerance

The pre-treatment baseline values for pain tolerance are illustrated in Table 5.1b. There were no significant differences between the control and standard reflexology treatments. The effects on the mean minimum and maximum pain tolerance (s) relative to control for standard reflexology are shown in Table 5.3b. The results (paired t-test) indicate higher mean minimum pain tolerance values for the control group, albeit just outside of significance ($p<0.056$) and a significant increase on the mean maximum pain tolerance ($p<0.01$) for standard reflexology. The results observed on mean minima and maxima pain threshold and tolerance values relative to control indicate that whilst standard reflexology produces anti-nociception there is also a small nociceptive effect of treatment.

Table 5.1b: Mean ± SEM baseline scores (s) for standard reflexology and control.

Baselines – A	**Control**	**S.Reflex**	**T-test**
Pain Threshold	14.0 ± 2.4	11.3 ± 1.3	n.s
Baselines – B	**Control**	**S.Reflex**	**T-test**
Pain Tolerance	98.2 ± 19.9	99.3 ± 22.0	n.s

Table 5.2b: Mean ± SEM change in minimum and maximum pain threshold scores (s) relative to control for standard reflexology (S.Reflex) together with mean ± SEM latency (min).

PAIN THRESHOLD MINIMUM			
Minimum Time	*Control*	*S.Reflex*	*T-test*
43.2 ± 9.5 min	18.7 ± 3.64	12.1 ± 1.8	p<0.01
PAIN TRESHOLD MAXIMUM			
Maximum Time	*Control*	*S.Reflex*	*T-test*
68.4 ± 8.2 min	14.5 ± 2.28	29.5 ± 5.5	p<0.01

Table 5.3b: The mean ± SEM change in minimum and maximum pain tolerance scores (s) relative to control for standard reflexology (S.Reflex) and mean ± SEM latency (min). *=p<0.056 n.s. for control treatment.

PAIN TOLERANCE MINIMUM			
Minimum Time	*Control*	*S.Reflex*	*T-test*
43.2 ± 8.5 min	110.3 ± 22.6	92.9 ± 19.9	n.s*
PAIN TOLERANCE MAXIMUM			
Maximum Time	*Control*	*S.Reflex*	*T-test*
62.4 ± 9.2 min	93.4 ± 18.7	166.8 ± 23.4	p<0.01

Light Reflexology Pain Threshold and Tolerance

As for Standard reflexology, three points were chosen and calculated, i) baseline, ii) minimum and iii) maximum.

i) Baseline. Table 5.4b shows the mean ± SEM baseline threshold (s) and tolerance (s) respectively for control and light reflexology recorded prior to treatment. The data on the graphs shown in Figures 5.1b and 5.2b were calculated as the mean ± SEM change in the baseline scores for threshold (Figure 5.1b) and tolerance (Figure 5.2b) relative to the control scores for all eligible subjects.

ii) Minimum. Tables 5.5b and 5.6b show the mean ± SEM minimum pain threshold (s) and tolerance (s) respectively for all eligible subjects. The mean ± SEM latency period after light reflexology when this occurred, together with the corresponding mean ± SEM threshold (s) and tolerance (s) recorded under control conditions at this time. The data on the graphs shown in Figures 5.1b and 5.2b were calculated as the mean ± SEM change in the minimum threshold (Figure 5.1b) and tolerance (Figure 5.2b) scores and the mean ± SEM time at which this occurred for the subjects given light reflexology from the corresponding control score.

iii) Maximum. The mean ± SEM maximum threshold (s) and tolerance (s) are shown in Tables 5.5b and 5.6b respectively. The data show the mean ± SEM time after light reflexology when this occurred together with the corresponding mean ± SEM for the control treatment. The data on the graphs shown in Figures 5.1b and 5.2b were calculated as the mean ± SEM change in the maximum threshold (Figure 5.1b) and tolerance (Figure 5.2b) recorded

for each subject given light reflexology from the corresponding control, and the mean ± SEM time at which this occurred.

5.1.3b Results obtained for light reflexology

Pain Threshold

Table 5.4b shows the baseline scores for pain threshold and tolerance. The results indicated that there were no significant differences in the pain threshold and tolerance baseline scores. The results of a paired t-test for minimum pain threshold however, revealed that the mean minimum pain threshold for the 'no treatment' control was significantly higher ($p<0.01$) than for the light reflexology treatment (Table 5.5b). The mean maximum pain threshold analysis revealed a significant effect of light reflexology ($p<0.05$).

Pain Tolerance

The results of the paired t-test are shown in Table 5.6b for mean minimum and maximum pain tolerance (s). The results show a significantly lower effect on mean minimum pain tolerance (s) for light reflexology ($p<0.01$) and a significant increase in mean maximum pain tolerance scores for light reflexology ($p<0.01$). The results of the light reflexology treatment are similar to those observed for standard reflexology and indicate both nociceptive and anti-nociceptive effects of treatment.

Table 5.4b: Mean ± SEM baseline scores (s) for control and light reflexology.

Baselines – A	**Control**	**L.Reflex**	**T-test**
Pain Threshold	14.0 ± 2.4	11.7 ± 1.6	n.s
Baselines – B	**Control**	**L.Reflex**	**T-test**
Pain Tolerance	98.2 ± 19.9	101.9 ± 19.2	n.s

Table 5.5b: The mean ± SEM change in the minimum and maximum pain threshold scores (s) relative to control for light reflexology (L.Reflex) together with the mean ± SEM latency (min).

PAIN THRESHOLD MINIMUM			
Minimum Time	*Control*	*L.Reflex*	*T-test*
58.8 ± 9.1 min	18.2 ± 2.8	13.2 ± 1.4	p<0.01
PAIN THRESHOLD MAXIMUM			
Maximum Time	*Control*	*L.Reflex*	*T-test*
73.2 ± 9.0 min	13.0 ± 1.7	26.4 ± 5.8	p<0.05

Table 5.6b: The mean ± SEM change in the minimum and maximum pain tolerance scores (s) relative to control for light reflexology (L.Reflex) together with the mean ± SEM latency (min).

PAIN TOLERANCE MINIMUM			
Minimum Time	*Control*	*L.Reflex*	*T-test*
44.4 ± 7.7 min	114.2 ± 20.0	88.5 ± 18.1	p<0.01
PAIN TOLERANCE MAXIMUM			
Maximum Time	*Control*	*L.Reflex*	*T-test*
54.0 ± 9.0 min	99.0 ± 18.0	165.9 ± 23.6	p<0.01

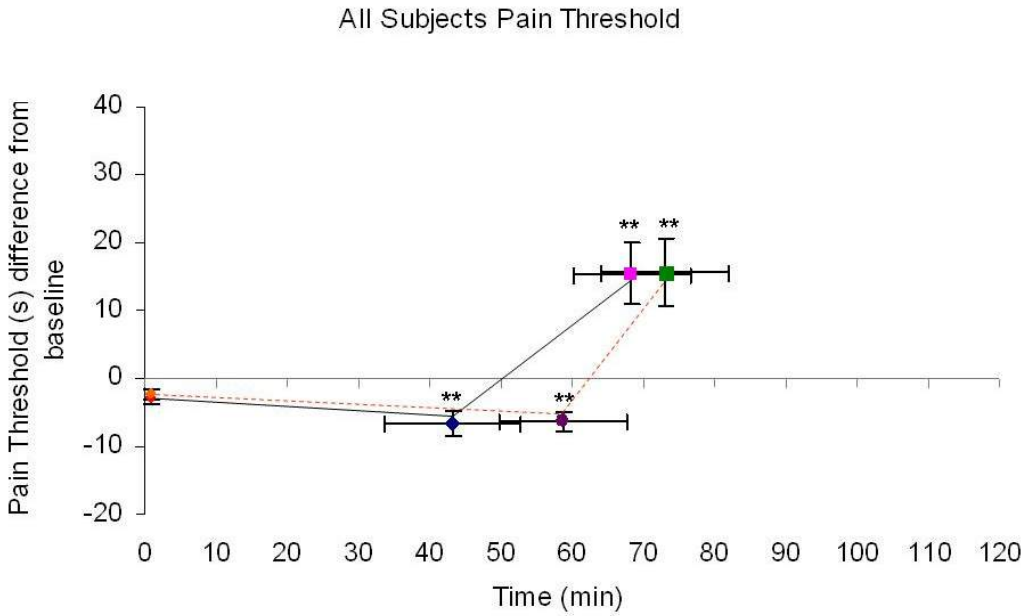


Figure 5.1b: The mean ± SEM change from pre-treatment baselines in minima and maxima pain threshold (s) relative to control, *n=25*. Horizontal lines show ± SEM for time (min) and the vertical lines represent ± SEM as the pain threshold (s) difference from baseline. **p<0.01 minimum for control. **p<0.01 maximum for standard reflexology, *p<0.05 maximum for light reflexology. Standard Reflexology = ● Minimum ■ Maximum ◆ Baseline. Light Reflexology ● Minimum ■ Maximum ◆ Baseline

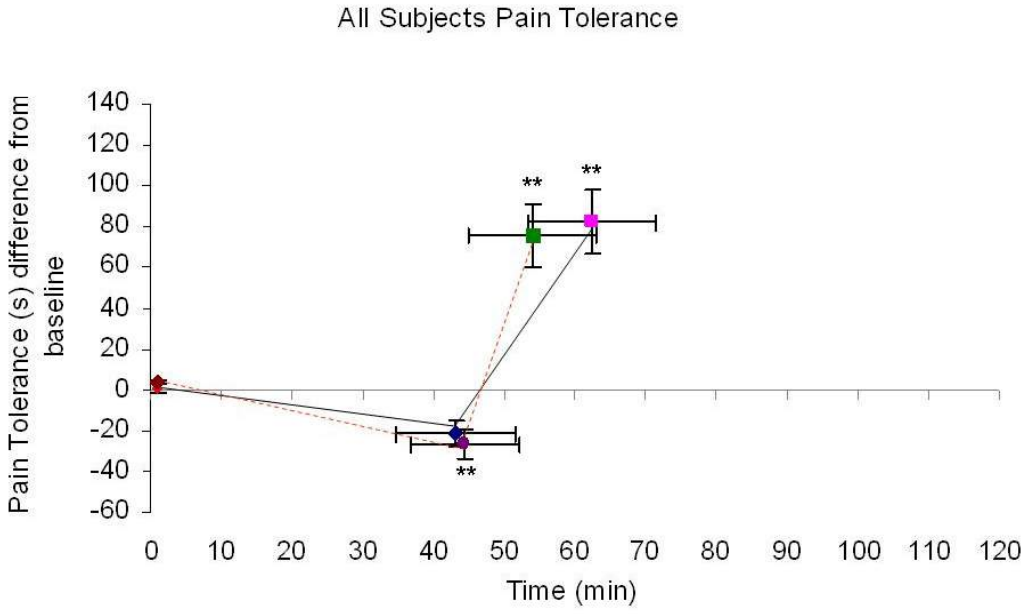


Figure 5.2b: The mean ± SEM change in baseline minima and maxima pain tolerance (s) relative to control, *n=25*. Horizontal lines show ± SEM for time (min) and the vertical lines represent ± SEM as the pain tolerance (s) difference from baseline. **p<0.01 minimum for control. **p<0.01 maximum for standard and light reflexology. Standard Reflexology = ● Minimum ■ Maximum ◆ Baseline. Light Reflexology ● Minimum ■ Maximum ◆ Baseline

5.1.4b Comparison of results obtained for light and standard reflexology

A comparison of the results for the analysis (paired t-test) of standard and light reflexology pain threshold (s) is shown in Table 5.7b. Results of the analysis for pain tolerance (s) are shown in Table 5.8b. The comparison between the two modalities of reflexology showed there were no significant differences between them in terms of (a) the mean minima and maxima threshold and tolerance (s), and (b) the mean latency at which the mean minima and maxima threshold and tolerance occurred.

Table 5.7b: The mean ± SEM change in minimum and maximum pain threshold scores (s) for standard (S. Reflex) and light (L. Reflex) reflexology and the mean ± SEM latency (min) at which this occurred.

MINIMUM LATENCY			**PAIN THRESHOLD**		
S.Reflex	*L.Reflex*	*T-test*	*S.Reflex*	*L.Reflex*	*T-test*
43.2 ± 9.5	58.8 ± 9.1	n.s.	12.1 ± 1.8	13.2 ± 1.4	n.s.
MAXIMUM LATENCY			**PAIN THRESHOLD**		
S. Reflex	*L. Reflex*	*T-test*	*S. Reflex*	*L. Reflex*	*T-test*
68.4 ± 8.2	73.2 ± 9.0	n.s	29.5 ± 5.5	26.4 ± 5.8	n.s

Table 5.8b: The mean ± SEM change in minimum and maximum tolerance scores (s) for standard (S. Reflex) and light (L. Reflex) reflexology and the mean ± SEM latency (min) at which this occurred.

MINIMUM LATENCY			**PAIN TOLERANCE**		
S. Reflex	*L. Reflex*	*T-test*	*S. Reflex*	*L. Reflex*	*T-test*
43.2 ± 8.5	44.4 ± 7.7	n.s.	92.9 ± 19.9	88.5 ± 18.1	n.s
MAXIMUM LATENCY			**PAIN TOLERANCE**		
S.Reflex	*L.Reflex*	*T-test*	*S.Reflex*	*L. Reflex*	*T-test*
62.4 ± 9.2	54.0 ± 9.0	n.s	166.8 ± 23.4	165.9 ± 23.6	n.s

5.2B RESPONDERS AND NON-RESPONDERS TO REFLEXOLOGY TREATMENT

It is possible to further refine the way the data can be analysed by considering separately, subjects who are considered as "responders" and those who are considered to be "non-responders". For example, the literature for pain studies using acupuncture and hypnosis indicates that approximately 20 – 30% of subjects can be considered non-responders to treatment (Montgomery et al., 2000, Sandrini et al., 2000, Carlsson, 2002, Jensen and Patterson, 2006, Milling, 2008). An examination of the individual responses to reflexology indicated that of the 25 eligible subjects, 6 of the subjects (6, 7, 10, 11, 15 and 25) showed almost no response to reflexology and were classified as "non-responders", while the remaining 19 (1, 2, 3, 4, 5, 8, 9, 12, 13, 14, 16, 18, 20, 21, 22, 24, 27, 28 and 30) displayed responses to reflexology and were classified as "responders". The criteria for classifying a subject as a non-responder, was based on pain tolerance scores for standard reflexology. Where the score was less than 10s at any of the post-treatment intervals, compared with the corresponding control score, a subject was classified as a non-responder. By contrast, responders were those subjects whose pain tolerance scores for standard reflexology was greater than 10s at any of the post-treatment intervals when compared with corresponding control scores.

5.2.1b Results obtained for responders of reflexology

The baseline, minimum and maximum scores were calculated for the responders as indicated in Section 5.1.1b. The results for the responders are shown in Tables 5.9b – 5.12b and Figures 5.3b (pain threshold) and 5.4b (pain tolerance).

Pain Threshold

Baseline scores for pain threshold (s) are shown in Table 5.9b and showed that there were no significant differences between the responders in either the standard or light reflexology when compared to the 'no treatment' (control).

Table 5.9b: Mean ± SEM responder pain threshold baseline scores (s).

BASELINES	Control	S. Reflex	T-test	Control	L. Reflex	T-test
Pain Threshold	15.2 ± 3.1	12.1 ± 1.6	n.s	15.2 ± 3.1	12.6 ± 1.8	n.s

Table 5.10b and Figure 5.3b show the results obtained for the mean minimum and maximum ± SEM for pain threshold following standard and light reflexology when compared to the control. A paired t-test of the results showed a significantly higher mean minimum pain threshold (s) value following the 'no treatment' control ($p<0.01$) when compared to both the standard and light reflexology. The mean maximum pain threshold (s) however was significantly higher for standard and light reflexology ($p<0.01$) when compared to the 'no treatment' control.

Table 5.10b: Responders pain threshold (s). The mean ± SEM change in minimum and maximum pain threshold scores (s) and the mean ± SEM time (min) at which the minima and maxima occurred, compared to the control.

STANDARD REFLEXOLOGY – PAIN THRESHOLD

Minimum Time	**Control**	**S. Reflex**	**T-test**
42.6 ± 11.4 min	20.3 ± 4.04	13.0 ± 2.23	p<0.01
Maximum Time			
69.5 ± 10.0 min	16.4 ± 2.5	34.4 ± 6.9	p<0.01

LIGHT REFLEXOLOGY – PAIN THRESHOLD

Minimum Time	**Control**	**L. Reflex**	**T-test**
58.4 ± 10.4 min	20.9 ± 3.5	14.0 ± 1.8	p<0.01
Maximum Time			
75.8 ± 9.2 min	13.3 ± 2.0	32.1 ± 7.1	p<0.01

Pain Tolerance

Baseline scores for pain tolerance (s) are shown in Table 5.11b and the results revealed there were no significant differences in baselines between control and either standard or light reflexology and the 'no treatment' control.

Table 5.11b: Mean ± SEM responder pain tolerance baseline scores (s).

BASELINES	**Control**	**S. Reflex**	**T-test**	**Control**	**L. Reflex**	**T-test**
Pain Tolerance	98.3 ± 22.0	92.6 ± 23.4	n.s	98.3 ± 22.0	97.5 ± 18.3	n.s

The mean minimum and maximum ± SEM for pain tolerance in responders are shown in Table 5.12b and Figure 5.4b. Analysis of the results paired t-test) revealed that the mean minimum pain tolerance scores for the control treatment were higher, albeit non-significant compared with the standard reflexology treatment. When the

mean minimum control scores were compared to the light reflexology treatment however, there was a significant increase in pain tolerance for the control treatment ($p<0.01$). Analysis of the mean maximum pain tolerance scores indicated there were significant increases in pain tolerance values for both standard and light reflexology ($p<0.01$) when compared to the no treatment control.

Table 5.12b: Responders pain tolerance (s). The mean ± SEM change in minimum and maximum pain tolerance scores (s) and the mean ± SEM time (min) at which the mean minima and maxima occurred when compared to the control treatment.

STANDARD REFLEXOLOGY – PAIN TOLERANCE

Minimum Time	**Control**	**S. Reflex**	**T-test**
50.5 ± 10.4 min	104.2 ± 19.6	86.1 ± 19.4	n.s
Maximum Time			
60.0 ± 10.5 min	79.9 ± 13.0	181.8 ± 24.8	p<0.01

LIGHT REFLEXOLOGY – PAIN TOLERANCE

Minimum Time	**Control**	**L. Reflex**	**T-test**
48.9 ± 7.9 min	110.6 ± 20.6	78.4 ± 16.2	p<0.01
Maximum Time			
53.7 ± 10.4 min	90.1 ± 16.3	181.6 ± 24.9	p<0.01

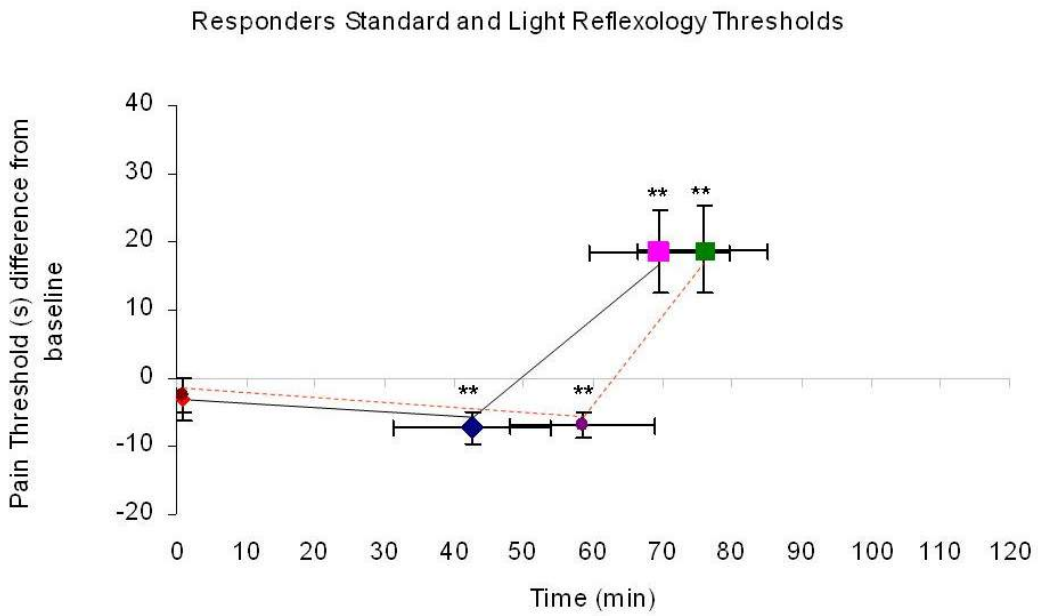


Figure 5.3b: The mean ± SEM change from pre-treatment baselines in minima and maxima pain thresholds (s) relative to control for responders, *n=19*. **p<0.01 mean minimum for 'no treatment' control. **p<0.01 mean maximum for standard and light reflexology. Horizontal line shows ± SEM for differences in time (min). Vertical lines represent ± SEM for differences in pain threshold (s). Standard Reflexology = ● Minimum ■ Maximum ◆ Baseline. Light Reflexology = ● Minimum ■ Maximum ◆ Baseline

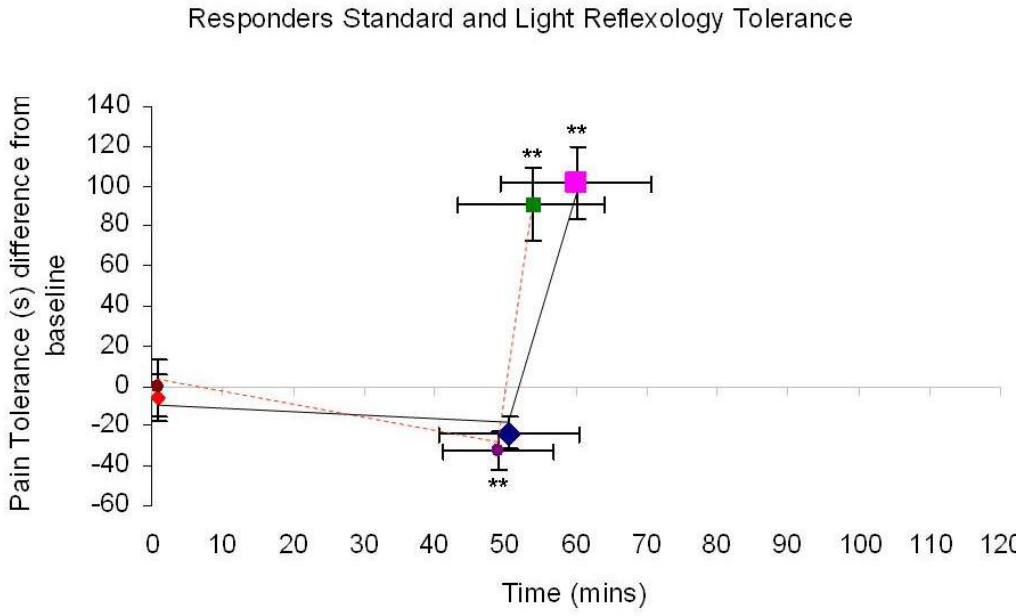


Figure 5.4b: The mean ± SEM change from pre-treatment baselines in minima and maxima pain tolerance (s) relative to control for responders, *n=19*. **p<0.01 minimum for control compared to light reflexology. **p<0.01 maximum for standard and light reflexology. Horizontal line shows ± SEM for differences in time. Vertical lines represent ± SEM for differences in pain threshold scores. Standard Reflexology = ● Minimum ■ Maximum ◆ Baseline. Light Reflexology = ● Minimum ■ Maximum ◆ Baseline

5.2.1b Results obtained for non-responders of reflexology

As previously indicated, the method for selecting baseline, minimum and maximum values is shown in Section 5.3.2. The Tables 5.13b – 5.16b and the Figures 5.5b (pain threshold) and 5.6b (pain tolerance) illustrate the results for the non-responders.

Pain Threshold

Baseline pain threshold (s) values for the non-responders are shown in Table 5.13b. The results of a paired t-test revealed no significant differences at baseline between the standard and light reflexology treatments when compared to the 'no treatment' control.

Table 5.13b: Mean ± SEM non-responder pain threshold baseline scores (s).

BASELINES	Control	S. Reflex	T-test	Control	L. Reflex	T-test
Pain Threshold	10.3 ± 2.4	8.8 ± 2.7	n.s	10.3 ± 2.4	8.7 ± 3.1	n.s

Table 5.14b and Figure 5.5b show the results obtained for pain threshold (s) for standard and light reflexology in the non-responders. Analysis of the data (paired t-test) showed significant decreases in the mean minimum pain threshold following standard reflexology when compared to the 'no treatment' control, ($p<0.01$) but there were no significant differences between the 'no treatment' control and light reflexology. In addition the mean maximum pain threshold (s) was significantly higher for standard reflexology ($p<0.01$) when compared to control, but not for the light reflexology in non-responder subjects.

Table 5.14b: Non-responders pain threshold (s). The mean ± SEM change in minimum and maximum pain threshold (s) together with the mean ± SEM time (min) at which the mean minimum and maximum scores occurred relative to the no treatment control.

STANDARD REFLEXOLOGY

Minimum Time	**Control**	**S.Reflex**	**T-test**
45.0 ± 20.3 min	13.7 ± 2.9	9.2 ± 2.1	p<0.01
Maximum Time			
65.0 ± 15.7 min	8.5 ± 0.8	14.0 ± 1.1	P<0.01

LIGHT REFLEXOLOGY

Minimum Time	**Control**	**L.Reflex**	**T-test**
60.0 ± 22.4 min	9.8 ± 1.5	10.5 ± 0.8	n.s
Maximum Time			
65.0 ± 27.4 min	12.2 ± 3.4	8.2 ± 2.2	n.s

Pain Tolerance

Table 5.15b shows the mean ± SEM pain tolerance (s) baseline scores for the 'no treatment' control compared with standard and light reflexology. A paired t-test of the results showed there were no significant differences in baseline values between the treatments.

Table 5.15b: Mean ± SEM non-responder pain tolerance (s) baseline scores.

BASELINES	**Control**	**S. Reflex**	**T-test**	**Control**	**L. Reflex**	**T-test**
Pain Tolerance	97.8 ± 53.2	120.7 ± 62.3	n.s	97.8 ± 53.2	116.0 ± 63.8	n.s

Table 5.15b and Figure 5.6b show the results obtained for pain tolerance for standard and light reflexology in the non-responders. Analysis of the data (paired t-test) revealed there were no significant differences in either the mean minimum or the mean maximum pain tolerance scores between the 'no treatment' (control) either the standard or light reflexology treatments.

Table 5.16b: Non-responders pain tolerance (s). The mean ± SEM change in minimum and maximum pain tolerance (s) together with the mean ± SEM time (min) at which the mean minimum and maximum scores occurred relative to no treatment control.

STANDARD REFLEXOLOGY

Minimum Time	**Control**	**S. Reflex**	**T-test**
20.0 ± 13.9 min	129.8 ± 61.0	114.5 ± 64.3	n.s
Maximum Time			
70.0 ± 21.9 min	136.0 ± 57.5	119.2 ± 62.8	n.s

LIGHT REFLEXOLOGY

Minimum Time	**Control**	**L. Reflex**	**T-test**
30.0 ± 22.4 min	125.5 ± 61.0	120.7 ± 62.2	n.s
Maximum Time			
55.0 ± 21.5 min	127.0 ± 61.1	116.3 ± 63.7	n.s

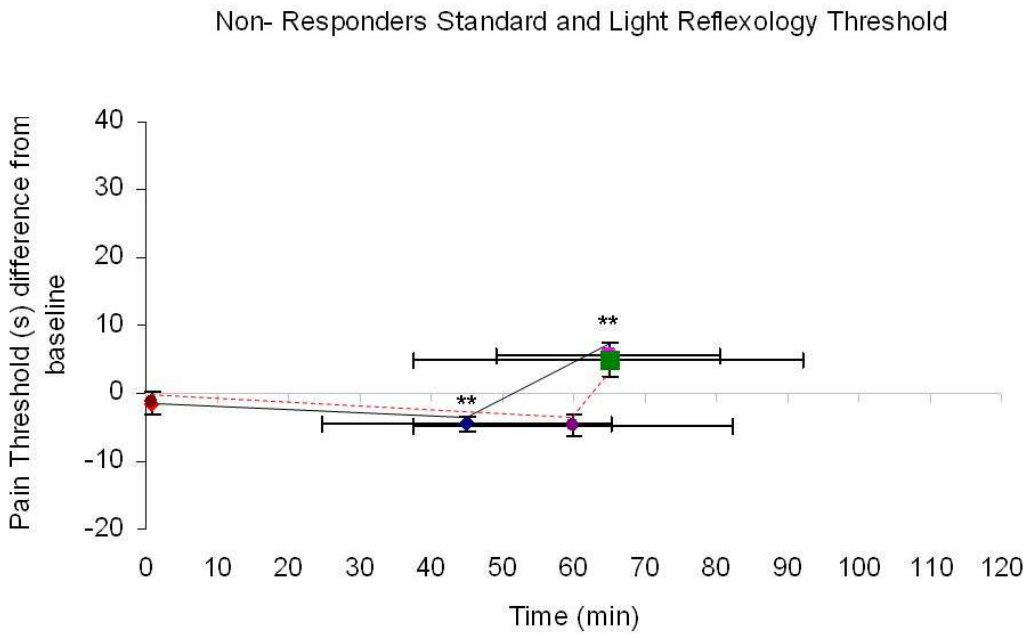


Figure 5.5b: The mean ± SEM change from pre-treatment baselines in minima and maxima pain thresholds (s) relative to control for non-responders, *n=6*. **p<0.01 mean minimum for control compared to standard reflexology. **p<0.01 mean maximum for standard reflexology compared to control. Horizontal line shows ± SEM for differences in time (min). Vertical lines represent ± SEM for differences in pain threshold (s). Standard Reflexology = ● Minimum ■ Maximum ◆ Baseline. Light Reflexology = ● Minimum ■ Maximum ◆ Baseline.

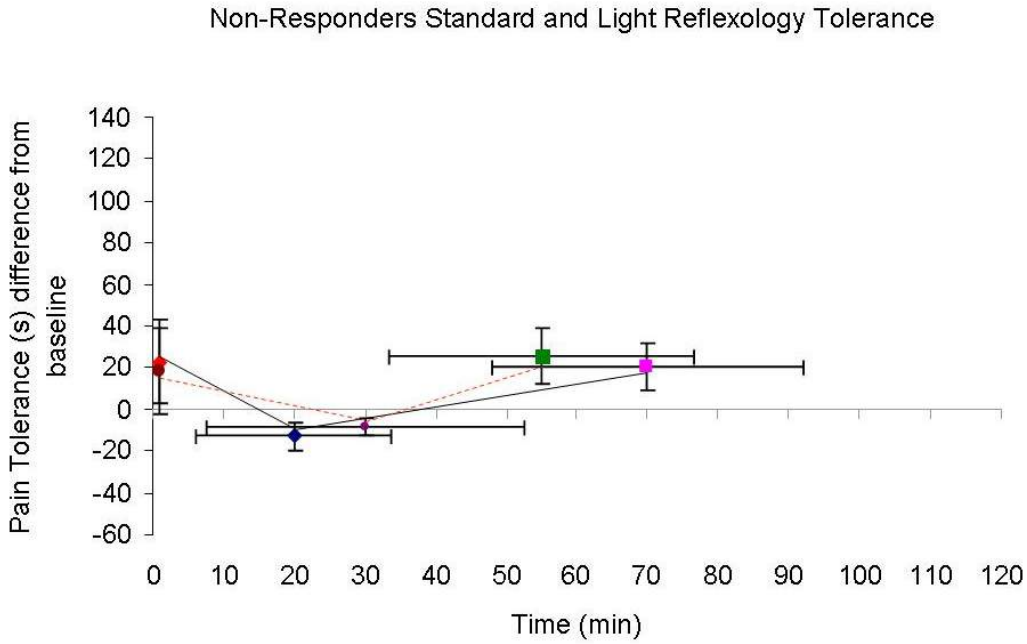


Figure 5.6b: The mean ± SEM change from pre-treatment baselines in minima and maxima pain tolerance (s) relative to control for non-responders, *n=6*. Horizontal lines show mean ± SEM for differences in time (min). Vertical lines represent ± SEM for differences in pain threshold (s). Standard Reflexology = ● Minimum ■ Maximum ◆ Baseline. Light Reflexology = ● Minimum ■ Maximum ◆ Baseline

5.3B DISCUSSION

Pain threshold and tolerance

The method used by Ashton *et al.* (1980) was adapted to analyse the data from Chapter 5A in a more comprehensive way. The results showed a significant anti-nociceptive effect of standard and light reflexology on mean maximum pain threshold and tolerance which occurred between 60 – 90 min post treatments. The effect is consistent with the result for pain threshold and tolerance in Chapter 4 (Figures 4.1 and 4.2). However, the results also revealed a small but significant nociceptive effect of treatment which occurred some 20 min earlier. This effect was not apparent in the results of the minimum and maximum analysis carried out for Chapter 4 (see Appendix C), which may reflect the difference in the subject group. A comparison between the two modes of reflexology treatments on both the treatment and latency of effect (Section 5.1.4b) revealed no significant differences. This is an important point since it reveals no disparity between the effects of the pressures applied, *i.e.* standard or light, or the latency at which the effect occurs.

A possible criticism of this method of analysing the data is that by choosing, for example, the maximum tolerance scores for standard reflexology, one is biasing the analysis in a fashion that would produce significant results. In other words the argument may run that the maximum score for each subject may occur in a random or unpredictable manner at different times, and by averaging these scores (irrespective of the time when they occurred) they will produce a 'peak mean value' that will come out as significant in a t-test. However, the counter argument is that if the control values at each of these times, *i.e.* when the tolerance scores were at maximum, also run in a random or unpredictable manner, then the mean scores should be similar to those obtained with reflexology. In order to test this prediction more fully the effects of 'reversing the procedure' by taking the maximum control scores and matching them with scores obtained after reflexology for each subject, was statistically evaluated. If the method that was used for the analysis was biased as discussed, then the prediction would be that the mean minimum or maximum control scores should be significantly greater than those obtained for reflexology. The results of such analyses showed that there was no significant difference between control and reflexology scores. Thus, for example, the maximum pain tolerance for the controls

was 129.7 ± 22.8 s and for standard reflexology was 155.7 ± 26.2 s (n.s). Thus, the method used here which was adapted from Ashton *et al.* (1980) appears to be statistically sound and shows the multiplicity and diversity of treatment effects across the subject group.

It is well known that in Western populations approximately 20 – 30% of subjects will not respond to CAM treatments, such as acupuncture and hypnosis (Sandrini et al., 2000, Montgomery et al., 2000, Carlsson, 2002). Out of the remaining 25 subjects included in this study, six were classified as non responders based on their lack of any positive affects on pain tolerance scores, recorded under controlled conditions (see results section for further details (Section 5.3.4). Thus, results obtained for standard and light reflexology in this study were analysed in two ways, i) where the data from all 25 subjects were included in the analyses, and ii) where the data from subjects who were classified as (responders) or (non-responders) were analysed separately. The latter method of analysis was considered to be a refinement of the procedure. The justification for the validity of this approach is based on pain tolerance for standard reflexology. If for example, a subject demonstrated pain tolerance values of less than 10 s greater than those for the control treatment at any of the post treatment intervals, they were classified as a non-responder. The question however is whether or not this is a justifiable way of separating the population of a responder and non-responder. When using the Ashton *et al.* (1980) method of analysis for minimum and maximum values we demonstrated that by reversing the sequence (see note 4 above) outcomes were not significantly changed and thus the analysis was sound. However, the method of selecting responders and non-responders was based on pain tolerance and although there was a significant effect of standard reflexology on maximum pain threshold in non-responders, there were no significant effects on pain tolerance. This suggests perhaps, that these 'non-responders' may have responded differently to the other mode of treatment, or perhaps that they responded early and subsequently showed no effect. It is likely therefore, that this method of analysis can unleash the real effects of reflexology for future studies.

Conclusion

These results extend the observations made in Chapters 4 and 5A but they are complex and suggest a bi-phasic response to reflexology that may be both nociceptive and anti-nociceptive. However, this may not always be the case as the minimum and maximum results of Chapter 4 have shown (Appendix C). The nociceptive effect is weak and occurs at an earlier period whereas the anti-nociceptive effect is very strong which indicates that reflexology is producing a clear analgesic effect. Furthermore, this method of analysis may reveal more detail about the effects of these treatments that other standard methods of analysis may miss with this type of data.

CHAPTER 6

MECHANICAL REFLEXOLOGY VS SHAM TENS (CONTROL) IN AN ICE PAIN EXPERIMENT

6.1 INTRODUCTION

Tactile therapies are known to produce a number of physiological responses including changes in heart rate (Drescher *et al.*, 1980) and blood pressure (Gleeson and Timmins, 2005). There is also some evidence that they can alter the perception of pain, stress, anxiety and depression (Cassileth and Vickers, 2004).

The use of mechanical stimulators however, is largely associated with experiments in the elderly, those who are bedridden and in space astronauts who experience atrophy of skeletal muscles (Kyparos *et al.*, 2005). Commercially available machines are more readily attainable today and there is scientific evidence for their use in the improvement of circulatory disorders (Green *et al.*, 2008). In a study by Priplata *et al.* (2003) viscoelastic gels with vibrating elements were embedded under the foot to assess their efficacy in enhancing feedback and reducing postural sway. In another study nine healthy subjects underwent mechanical stimulation to the sole of the foot to assess the specific benefits of improving neuromuscular activity in the human erect proprioceptive feedback responses (Kavounoudias *et al.*, 2001). Both these studies were carried out to observe the control of the human erect posture which is of benefit to patients at risk of falls. Layne *et al.* (2002) used a dynamic foot stimulus device to apply 172 kPa of pressure to three sites on the sole of the foot for 250 ms; the medial, lateral and heel regions. They observed that mechanical stimulation of the feet can attenuate muscle atrophy and functionality from loss of weight-bearing activity. The information was thought to be a valuable contribution to existing passive exercise programmes in space astronauts.

However, the only sources of literature for the use of a mechanical stimulation to monitor the effects of reflexology, were carried out to evaluate heart rate changes in normal healthy subjects (Joseph *et al.*, 2004). Subjects (n=20) between the ages of 17-21 underwent mechanical stimulation with a device known as a ‘massager

scroller', applied to the sole of both feet just below the toes for 20 minutes. Electro-cardiogram measurements were recorded and the results showed that heart rate variability became more random, with a trend toward chaos. Chaos in heart rate variability is a positive aspect of cardiac dynamics because the fluctuations show a better state of health.

The experiments carried out in Chapters 4 and 5 have shown that manually applied reflexology significantly increases pain threshold and tolerance levels following a noxious cold stimulus. However, it is not known how much was a response to human touch and therapist interaction, and how much was the reflexology stimulation. Indeed, tactile stimulation and talking to a patient is known to impact on physiological functions such as heart rate, blood pressure and temperature (Kessler *et al.*, 2006, Degirmen *et al.*, 2009, Liechti, 1998, Fishman *et al.*, 1994, Malville *et al.*, 2008, Hertenstein *et al.*, 2006, Bufalari *et al.*, 2007). The present study was therefore carried out to apply a mechanical form of reflexology using the Scholl Ionic Rejuvenator Massager in volunteers without the application of any human tactile stimulation.

6.2 AIMS

The purpose of this experiment was to use a mechanical reflexology-like stimulus to stimulate reflex points on the sole of the foot in a group of healthy pain free volunteers. The principal aims were to identify whether a) the therapist was necessary for the effect of treatment and b) mechanical reflexology-like stimulation affected pain threshold and tolerance levels in an ice pain experiment.

6.3 METHOD

6.3.1 Design

In this two period cross-over design subjects participated in mechanical reflexology and sham TENS (control). Treatments were administered one week apart at the same time of day for each subject.

6.3.2 Demographics

Eighteen subjects were recruited to the experimental procedure, one subject did not meet the inclusion criteria, two subjects did not commit to their scheduled appointments and five changed their minds. A total of 12 subjects (8 female and 4 male) were randomised to receive either mechanical reflexology or sham TENS (control) in a cross-over design method. The mean ± SEM age of the subjects was 23.3 ± 2.1 (range 18 – 36). Nine of the subjects were from the first year undergraduate group of University students, two were academic staff members and another was from the post-graduate group of students. Ten of the subjects were Caucasian and two were black African. The ambient room temperature was recorded at 22°C ± 1°C. All subjects participating in the experimental procedures were both TENS and reflexology naïve. Subjects who completed the study were given a financial reward for their participation and to encourage further recruitment the first year undergraduates were also informed that knowledge of CAM therapies would be beneficial when selections were made for their pharmacy practice registrations.

6.3.3 Procedure

On entering the laboratory subjects were invited to sit in an upright office chair without arms whilst the monitoring equipment for heart rate was attached. The experimental timeline took the following format and is shown in Table 6.1. During a 5-minute rest period the subjects completed question one on the subjective rating questionnaire, signed the consent form and answered questions from the consultation sheet. After completing the appropriate documentation the first baseline heart rate measurements were recorded thus, prior to immersion of the hand in ice (pre), after the call for pain threshold (during) and immediately after removal of the hand (post) from the ice. Baseline data were taken for pain threshold (the time until the subject feels the initial pain sensation) and pain tolerance (the time until the subject can no longer tolerate the noxious stimulus). After a 10-minute rest period the treatment commenced.

Table 6.1: Experimental timeline with a total experimental time of 180 min.

KEY: HR=heart rate, PThr=pain threshold, Tol=pain tolerance.

Pre treatment				Treatment		Post treatment period											
0 – 15 min				15 - 35		35 – 180 min											
10				**30**		**50**		**70**		**90**		**110**		**130**			
Forms completed	Ice plunge - HR PThr/Tol	Subjective Rating	Rest period	20 min treatment + Ice plunge , HR, PThr, Tol	Subjective Rating	Ice plunge - HR PThr/Tol	Subjective Rating	Ice plunge - HR	Subjective Rating	Ice plunge - HR PThr/Tol	Subjective Rating	Ice plunge - HR PThr/Tol	Subjective Rating	Ice plunge - HR PThr/Tol	Subjective Rating		

Mechanical reflexology or sham TENS (control) was continued for 20-minutes, during which time the subjects remained upright in the chair. The 20-minute time restriction is recommended by Scholl in their literature describing the use of the equipment and this time scale was therefore adopted for both treatments. The procedure for both treatments is documented previously in chapter 2, (sub-sections 2.3.5 and 2.3.8). The heart rate was monitored immediately prior to, during and post ice plunge every 20 minutes. A total of seven heart rate, pain threshold and tolerance measurements were amassed across the entire experimental procedure. All treatments were administered 7 days apart at the same time of day for each subject.

6.3.4 Data analysis

In line with the analysis of the results in Chapter 5a, the data obtained in this experiment was first of all analysed in terms of the mean ± SEM results with respect to time.

Subjects with high pain threshold values (*i.e.* greater than 40s in control treatment) were eliminated from the analysis (Chapter 2, Section 2.4.1) and this included seven subjects (1, 4, 5, 8, 9, 10, and 12). The data for the remaining five subjects revealed large differences in baseline values between the two treatments for pain tolerance. To address this problem, further data analysis involved normalising the baseline data for pain threshold and tolerance. Data were then analysed in terms of the percentage change from the adjusted baselines. Heart rate calculations were analysed using a simple change from baseline, as baselines were not significantly different and there was no need to normalise the data. Pitman permutation tests were carried out to test

for equal variances in the paired data. The Pearson product moment correlation coefficient statistic was used on baselines to assess the relationship between each session. The subjective rating questionnaires were analysed using the Wilcoxon sign rank test for non-parametric matched pairs and are shown as median, 1st and 3rd quartiles with an exact 2-tailed significance value.

6.4 RESULTS

6.4.1 Pain threshold and tolerance

The analyses of the raw data for pain threshold in terms of the mean ± SEM with respect to time are represented in Table 6.2.

Table 6.2: Mean ± SEM for pain threshold (s), by treatment and by time showing pre-treatment baselines, a single observation made during treatment and five successive post treatment observations each at 20 minute intervals. *n=5.* There were no significant main effects of treatment ($F_{(1,4)}$=1.2201,n.s.) no significant effect of time ($F_{(5,20)}$=1.1988,n.s.) and there was no treatment x time interaction ($F_{(5,20)}$=0.2646,n.s.).

Time ⇨	10 min	30 min	50 min	70 min	90 min	110min	130 min
Treatment	*Baseline*	*During treatment*	*Post treatment x 5*				
Control	13.2±4.7	11.5±3.2	13.3±4.6	13.8±5.2	9.0±1.4	9.5±2.8	11.3±2.6
M. Reflex	6.2±1.4	9.6±3.1	12.2±3.4	8.0±1.8	9.0±3.3	8.0±2.3	9.6±2.3

Pain threshold

Pearson product-moment correlations for the pain threshold baselines revealed the data were below the level of significant correlation (r = +0.21, df = 5, n.s) but a students paired *t*-test showed they were not significantly different (p=0.16, n.s), thus there was a reasonable level of reliability between sessions for baseline data.

The result illustrated in Figure 6.1 represents the percentage change from pre-treatment baseline where the baseline was normalised prior to analysis. The data reflect the results of the five eligible subjects. The ANOVA revealed that there were no significant main effects of treatment ($F_{(1,4)}$=3.6004,n.s.), time ($F_{(5,20)}$=1.8670,n.s.) nor was there any treatment x time interaction ($F_{(5,20)}$=0.6923,n.s.). Of interest however is the effect of mechanical reflexology on pain threshold during the treatment period where it increases by 66% on the baseline, compared to just 15% for

sham TENS (control), furthermore it remains higher, albeit non-significantly throughout the treatment period.

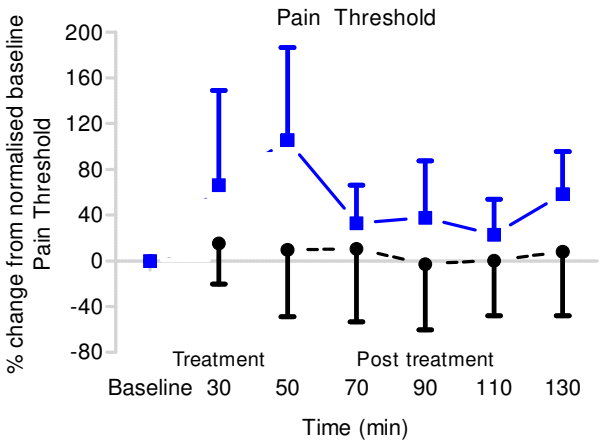


Figure 6.1: The mean ± SEM pain threshold effect of mechanical reflexology and sham TENS (control) shown as a % change from pre-treatment normalised baselines, *n=5*. Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Mechanical Reflexology

Table 6.3 represents the result of the Pitman tests carried out on the pain threshold. The results showed that there were no significant differences between the two treatments at any of the time points.

Table 6.3: Pitman permutation test for change from pre-treatment normalised baseline in pain threshold for mechanical reflexology showing the post treatment effects when compared to a sham TENS (control), *n=5*. Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

Post-treatment time	**30 min**	**50 min**	**70 min**	**90 min**	**110 min**	**130 min**
F-ratio	5.495	1.932	3.599	1.148	1.423	1.110
N =	5	5	5	5	5	5
Pearson	0.498	-0.811	-0.904	0.613	-0.147	0.062
Pitman	1.915	0.993	2.779	0.152	0.310	0.091
p-value	ns	ns	ns	ns	ns	ns

Pain Tolerance

Table 6.4 represents the analysis of the raw data in terms of the mean ± SEM results with respect to time.

Table 6.4: Mean ± SEM for pain tolerance (s), by treatment and by time showing pre-treatment baseline, one observation made during the treatment and five successive post treatment observations each at 20 minute intervals. *n=5.* There were no significant main effects of treatment ($F_{(1,4)}$=4.3938,n.s.) time ($F_{(5,20)}$=1.8271,n.s.) nor any treatment x time interaction ($F_{(5,20)}$=0.1673,n.s.).

Time ⇨	10 min	30 min	50 min	70 min	90 min	110min	130 min
Treatment	*Baseline*	*During treatment*	*Post treatment x 5*				
Control	96.2± 59.1	101.8± 59.0	128.6± 57.0	126.2± 58.2	127.4± 59.1	122.2± 57.3	148.2± 61.5
M. Reflex	77.8± 54.5	72.8± 34.2	102.4± 46.9	109.0± 48.3	97.6± 45.8	88.2± 42.7	104.4± 46.3

Baseline calculations using the Pearson product-moment correlation revealed the data to be significantly correlated (r = +0.99, df = 5, p<0.01) but a students paired *t*-test showed the data were significantly different at baseline p<0.05. Whilst there was good correlation for baselines between treatments, the observation that the *t*-test indicated a significant difference suggests that inter-session realibility was poor. It was considered appropriate therefore to express the data as a percentage change from baseline (Vickers, 2001).

Figure 6.2 shows the results of the ANOVA for the percentage change from the normalised baseline. The results showed that there were no significant differences between the two treatments ($F_{(1,4)}$=5.7231,n.s.). The standard errors are extremely large thus showing great inter-individual variation in subject responses for pain tolerance following mechanical reflexology and sham TENS (control). There was no effect of time ($F_{(5,20)}$=1.0524,n.s.) and there were no treatment x time interactions ($F_{(5,20)}$ =0.2046,n.s.).

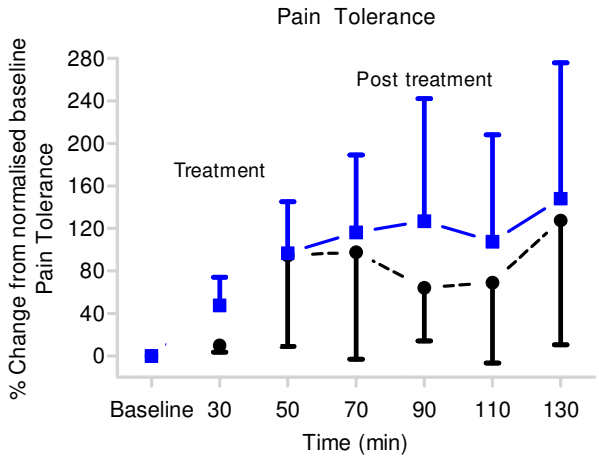


Figure 6.2: The mean ± SEM pain tolerance (s) effect of mechanical reflexology and sham TENS (control) shown as a % change from pre-treatment normalised baselines, *n=5*. Vertical lines illustrate +/- SEM. ●=Sham TENS (control) ■=Mechanical Reflexology

Table 6.5 shows the results of the Pitman test which suggests significant differences between sham TENS (control) and mechanical reflexology during the treatment period (t=30min) and also at t=90min, which is equivalent to 60min post treatment. However there are large standard errors in the data, suggesting the result is unreliable.

Table 6.5: Pitman permutation test for change from pre-treatment normalised baseline in pain tolerance for mechanical reflexology showing the post treatment effects when compared to a sham TENS (control), *n=5*. Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

Post-treatment time	**30 min**	**50 min**	**70 min**	**90 min**	**110 min**	**130 min**
F-ratio	18.933	3.089	1.898	5.362	1.766	1.195
N =	5	5	5	5	5	5
Pearson	0.295	0.888	0.738	0.907	0.958	0.984
Pitman	3.736	2.239	0.838	3.876	1.761	0.896
p-value	**0.05**	ns	ns	**0.05**	ns	ns

Subject 11 was the only subject to demonstrate no change in pain tolerance values, having reached the maximum 300s permitted during the trial. However, the criteria for removing subjects from the analysis were based on pain threshold levels. There is therefore a possibility that in such a small group, this subject together with the large inter-individual variation between subjects may have compromised the results.

To further evaluate this, computation of the data using the minimum and maximum analysis carried out as per Chapter 5b was used, the result is shown in Appendix F.

6.4.2 Heart rate responses to mechanical reflexology

Analysis of data in terms of the mean ± SEM results with respect to time.

The raw data analyses for the effects of treatment on heart rates (bpm) are illustrated in Table 6.6 and show the effects of treatment on pre ice plunge, during ice plunge and post ice plunge heart rates (bpm).

Table 6.6: Mean ± SEM for heart rate (bpm), by treatment and by time showing the pre-treatment baseline, the single observation made during treatment and the five successive post treatment observations each at 20 minute intervals. *n=5.* Pre plunge heart rate revealed that there were no significant main effects of treatment ($F_{(1,4)}$=5.1135,n.s.) there was a significant effect of time ($F_{(5,20)}$=3.5836, p<0.05.) but there was no treatment x time interaction ($F_{(5,20)}$=0.8994,n.s.). During treatment there were no significant main effects of treatment ($F_{(1,4)}$=0.0049,n.s.), no significant effects of time ($F_{(5,20)}$=1.2663,n.s.) and no treatment x time interactions ($F_{(5,20)}$=0.5758,n.s.). Post plunge heart rate however, revealed that whilst there were no significant effects of treatment ($F_{(1,4)}$=0.3612,n.s.) there were significant effects of time ($F_{(5,20)}$=3.4490, p<0.05.) and significant treatment x time interactions ($F_{(5,20)}$=2.9968,p<0.05).

Time ⇨	*Pre-treatment baselines*		
Treatment	*Pre plunge*	*During plunge*	*Post plunge*
Control	91.2±9.6	89.8±8.9	89.6±6.0
M Reflex	83.8±7.6	87.8±7.5	82.4±6.2

Time ⇨	*During treatment*		
Treatment	*Pre plunge*	*During plunge*	*Post plunge*
Control	86.4±5.1	81.2±3.5	82.6±6.6
M Reflex	82.6±3.8	83.2±4.9	86.0±4.6

		Post treatment x 6				
Treatment	**Time ⇨**	50 min	70 min	90 min	110 min	130 min
Control	*Pre plunge*	83.2±5.2	82.2±4.4	80.0±5.7	84.6±6.0	79.0±7.4
	During	83.4±5.3	83.2±4.5	81.2±3.8	81.8±5.8	80.4±4.8
	Post	82.6±7.7	82.4±7.6	81.0±7.1	83.0±6.8	78.2±7.4
M Reflex	*Pre plunge*	76.8±4.4	82.4±3.1	78.8±4.3	78.0±5.7	70.6±4.0
	During	82.2±5.3	83.2±3.8	78.8±4.9	84.2±5.5	80.8±4.7
	Post	77.6±4.7	83.0±4.6	80.2±5.9	75.6±5.1	76.6±5.3

Heart rate pre ice plunge

A Pearsons product-moment correlation on the baselines revealed the data were just outside the level of significant correlation (r = +0.85, df = 5, n.s), but a paired *t-test*

showed no significant differences between the baselines (p=0.18, n.s.) and thus there was good inter-session reliability between the two treatments.

Figure 6.3 shows the result of a two-way ANOVA on the change (not normalised) from pre-treatment baselines for the pre-plunge heart rates (bpm). There were no significant main effects of treatment ($F_{(1,4)}$=0.6767,n.s.). There was a slight decrease in heart rate over time ($F_{(5,20)}$=3.5836,p<0.05) and this is supported by the Pitman analysis shown in Table 6.7. There was however no treatment x time interaction ($F_{(5,20)}$ =0.8993,n.s.).

Table 6.7: Pitman permutation test for change from pre-treatment normalised baseline in the pre-plunge heart rate for mechanical reflexology showing the post treatment effects when compared to a sham TENS (control). Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value= probability of significance.

Post-treatment time	**30 min**	**50 min**	**70 min**	**90 min**	**110 min**	**130 min**
F-ratio	1.739	1.430	2.054	1.795	1.082	3.387
N =	5	5	5	5	5	5
Pearson	0.618	0.796	0.931	0.269	0.601	0.997
Pitman	0.618	0.515	0.175	0.533	0.085	16.933
p-value	ns	ns	ns	ns	ns	**0.01**

Heart rate during ice plunge

A Pearsons product-moment correlation on the baselines revealed the data were just below the level of significance (r = +0.81, df = 5, ns) but a students *t-test* revealed there were no significant differences (p=0.68, n.s.), thus showing good inter-session reliability in the baseline data.

Figure 6.4 shows the result of the ANOVA as a change from pre-treatment baselines (not normalised) for the effects of treatment on the subject's heart rate (bpm) during the ice plunge. The result revealed that there were no significant main effects of treatment ($F_{(1,4)}$=0.3146,n.s.) or time ($F_{(5,20)}$=1.2663,n.s.) and there was no treatment x time interaction ($F_{(5,20)}$ =0.5758,n.s.). This result is supported by the Pitman test shown in Table 6.8.

Table 6.8: Pitman permutation test for change from pre-treatment normalised baseline in the heart rate during the ice plunge for mechanical reflexology showing the post treatment effects when compared to a sham TENS (control). Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

Post-treatment time	**30 min**	**50 min**	**70 min**	**90 min**	**110 min**	**130 min**
F-ratio	1.624	1.688	2.533	1.250	1.289	1.324
N =	5	5	5	5	5	5
Pearson	0.840	0.816	0.727	0.945	0.565	0.659
Pitman	0.784	0.794	1.215	0.595	0.268	0.324
p-value	ns	ns	ns	ns	ns	ns

Heart rate post plunge

A Pearsons product-moment correlation on the baselines for heart rates post ice plunge showed that the data were not significantly correlated (r = +0.69, df = 5, ns). A student's *t-test* showed no significant differences between baselines (p=0.16, n.s.) and therefore good inter-session reliability was obtained.

ANOVA on the change from pre-treatment baselines (not normalised) for post ice plunge heart rate (bpm) is illustrated in Figure 6.5. The analysis showed that there were no significant main effects of treatment ($F_{(1,4)}$=1.5263,n.s.) but over time heart rates following sham TENS (control) were lower than those following the mechanical reflexology ($F_{(5,20)}$=3.4490,p<0.05). The analysis also showed a significant treatment x time interaction ($F_{(5,20)}$ =2.9968,p<0.05). Of interest however is that neither a students paired *t-test* nor the Pitman test shown in Table 6.9 supports this significance and suggests that the ANOVA may have produced a false positive result.

Table 6.9: Pitman permutation test for change from pre-treatment normalised baseline in the heart rate post ice plunge for mechanical reflexology showing the post treatment effects when compared to a sham TENS (control). Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

Post-treatment time	**30 min**	**50 min**	**70 min**	**90 min**	**110 min**	**130 min**
F-ratio	2.015	2.676	2.699	1.461	1.797	1.974
N =	5	5	5	5	5	5
Pearson	0.714	0.902	0.861	0.813	0.788	0.956
Pitman	0.886	2.055	1.763	0.569	0.837	2.047
p-value	ns	ns	ns	ns	ns	ns

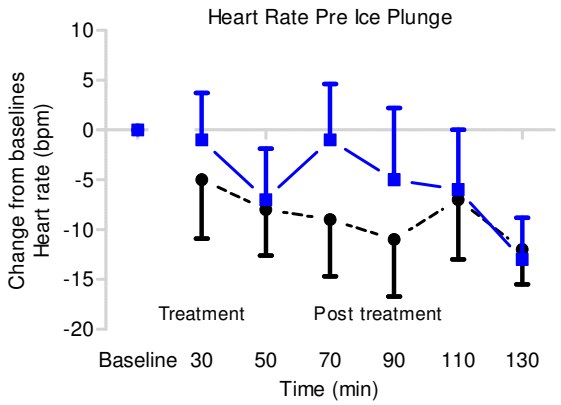


Figure 6.3: The effect of mechanical reflexology on mean pre ice plunge heart rate, shown as a change from the pre-treatment baseline, *(n=5)*. Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Mechanical Reflexology

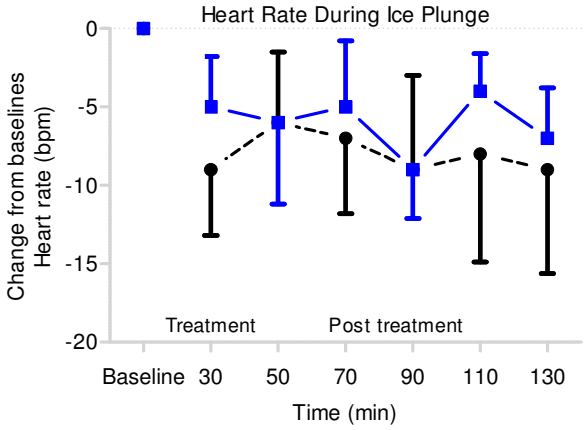


Figure 6.4: The effect of mechanical reflexology on mean heart rate observed during the ice plunge shown as a change from the pre-treatment baseline, *(n=5)*. Vertical lines illustrate +/- SEM. ●=Sham TENS (control) ■=Mechanical Reflexology

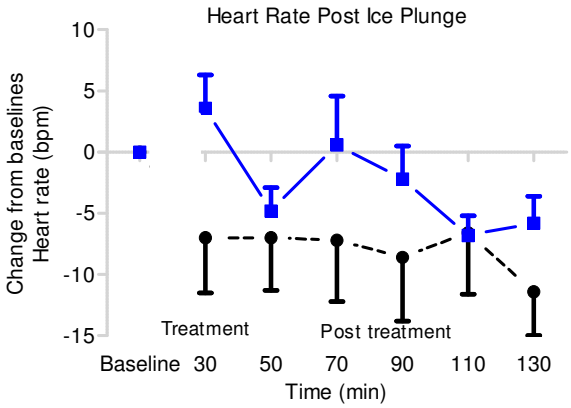


Figure 6.5: The effect of mechanical reflexology on mean heart rate observations post ice plunge shown as a change from the pre-treatment baseline, *(n=5)*. Vertical lines represent +/- SEM. ●=Sham TENS (control) ■=Mechanical Reflexology

6.4.3 Subjective rating analyses

The data for the subjective rating questionnaires was analysed using the Wilcoxon sign rank non-parametric statistic for matched pairs. The test revealed no significant differences between the treatments for the three subjective measurements of arousal, anxiety or discomfort during the ice plunge. The results for the median, 1st and 3rd quartiles and are shown in Table 6.10 and the Wilcoxon sign-rank test scores are shown in Table 6.11. When subjects were asked if they felt the treatment had improved their pain threshold and tolerance levels, 57% felt that both sham TENS (control) and mechanical reflexology stimulation had helped improve their responses to the ice plunge.

Table 6.10: Subjective rating analysis. Result for the two treatments showing the median. The 1st and 3rd quartiles appear in brackets, *(n=5)*. S.TENS = Sham TENS (control), M.Reflex = Mechanical Reflexology. The ratings were categorised thus: 4 = very high, 3 = high, 2 = normal, 1 = below normal

	30	**50**	**70**	**90**	**110**	**130**
AROUSAL						
S.TENS	2 (2,2)	2 (2,3)	2(2,3)	2 (2,3)	2 (2,2.25)	2 (2, 2)
M.Reflex	2 (2,2.5)	2 (2,2.5)	2 (2,2.5)	2 (2,2.5)	2 (2,2.5)	2 (2,2.5)
ANXIETY						
S.TENS	1 (1,2)	1 (1,1.5)	1 (1, 1.5)	1 (1, 2)	1 (1,2)	2 (1,2)
M.Reflex	2 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	2 (1, 2.5)	1 (1, 2.5)
DISCOMFORT						
S.TENS	3 (2.5,3)	3 (3,3.5)	3 (3,4)	3 (3,4)	3 (3,4)	4, (3,4)
M.Reflex	2 (2,3)	3 (3,3)	3 (3, 3)	3 (2.5,3.5)	3 (3,4)	3 (3,4)

Table 6.11: The Wilcoxon sign-rank test scores. Exact significance (2-tailed)

Post treatment time →	**30**	**50**	**70**	**90**	**110**	**130**
AROUSAL	1.000	.625	1.000	1.000	1.000	0.625
ANXIETY	1.000	1.000	1.000	1.000	.500	1.000
DISCOMFORT	1.000	1.000	0.625	0.625	1.000	1.000

Feedback Questionnaires

Of the five subjects included in the experimental analysis only four returned their feedback questionnaires. Results are presented in Figure 6.6. Side-effects reported on the feedback questionnaires included muscular aches and pains not usual for the subject, increased vaginal discharge, improved energy, improved sleep and an increase in skin blemishes not usual for the subject. Results for the overall rating subjects applied for each treatment are shown in Figure 6.7. Of the four who returned their forms only two enjoyed the mechanical reflexology session and the same two reported improved sleep from the treatment.

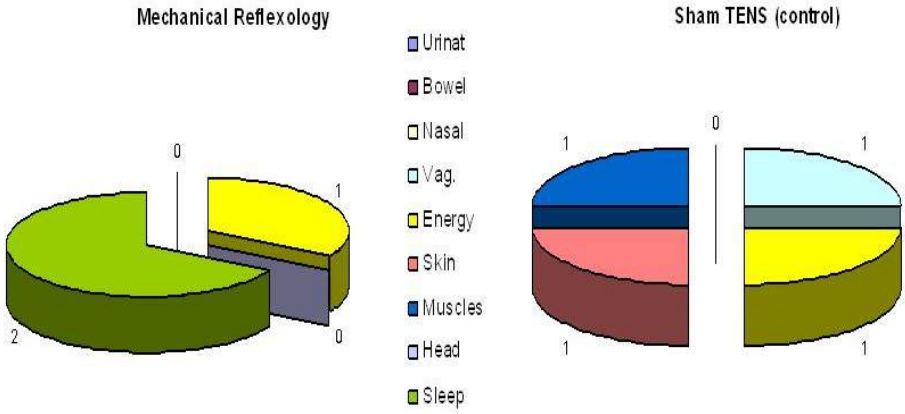


Figure 6.6: Illustration of the result of feedback questionnaires indicating side-effects experienced by subjects to the treatments, *n=5*.

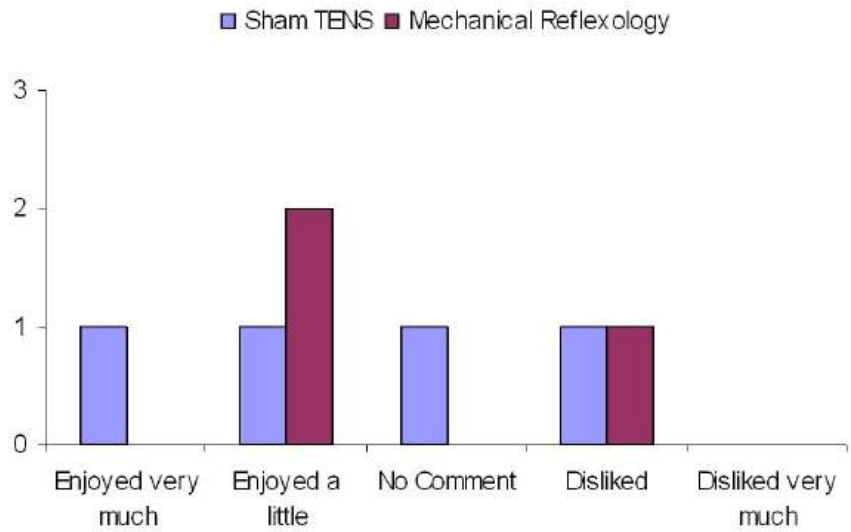


Figure 6.7: The results of the overall rating assigned to either sham TENS (control) or mechanical reflexology treatment, *n=5*.

6.5 DISCUSSION

This experiment has examined the effect of mechanical reflexology stimulation in an ice pain experiment in healthy human subjects. The aims of which were to measure the effects of mechanical stimulation on pain threshold and tolerance and to reflect upon the necessity of the therapist.

Before discussing the results of the experiment, mention should be made with regard to the difficulties encountered during the experimental procedures.

1. The initial recruitment of subjects drew interest from 59 first year pharmacy students. However, when e-mails were sent explaining the ice pain procedure and the time commitment involved, 41 of these withdrew. Of the remaining 18 subjects only 12 participated. Of these 12, 7 were found to have pain threshold values higher than 40s for their control treatment and were thus, eliminated from the analysis. This left just 5 subjects and the data from these subjects revealed large variations in the baseline, which were significantly different for pain tolerance ($p<0.05$). In normal circumstances where baseline values are significantly different one would choose to perform an analysis of covariance (ANCOVA), however, this method of analysis may invalidate the post treatment results, especially in such a small group of subjects (Vickers, 2001, van Breukelen, 2006). To overcome this difficulty in analysis, baselines for pain threshold and tolerance were normalised.
2. There were also other factors to consider in this experiment. The first consideration was the average age of the group. This group of subjects had a mean ± SEM age of 23.2 ± 2.0 years. By comparison in the subjects used in Chapter 4 it was 37.4 ± 2.5 years and in Chapter 5, 36.3 ± 2.0 years. The second consideration is that subjects used in this experiment were paid to participate and were coerced to volunteer with the suggestion that '*it would look good on their CV when they do their pharmacy registration year*'. Subjects who were paid to participate in the experiment may not have complied with the instructions as well an unpaid volunteer. This in turn may have affected the number of subjects who had to be removed from the trial.
3. Whilst there are a number of commercially available mechanical stimulators readily attainable, finding the appropriate equipment proved a little more

challenging. The eventual purchase of the Scholl Ionic Foot Rejuvenator Massager was the most cost-effective and easily obtainable means of inducing the effects needed to treat the subjects. The negative side to this however, is that it also limited the amount of time for stimulation. In manually applied treatments the session is generally 45 min in length as was used in the other ice pain experiments for Chapters 4, 5a and 7. The instructional leaflet provided with the equipment however, placed a 20 min limitation on its use. This may therefore have affected the outcome. Whilst it may have been possible to run two machines concurrently to obtain an almost equivalent time period, this was not deemed appropriate because of the manufacturer's limitation.

Pain threshold and tolerance results

Results obtained in the previous experiments (Chapters 4 and 5a) have shown that 45 min of standard and light reflexology applied manually, significantly increased pain threshold (Chapters 4 and 5a) and tolerance (Chapter 4). With such a small number of subjects and a shorter treatment session it was difficult to obtain a true evaluation of the efficacy of mechanical reflexology. However, ANOVA for percentage change from normalised baselines did not show any significant effects of treatment on pain threshold or tolerance. The effect of mechanical reflexology on pain threshold particularly during stimulation is interesting as it shows a mean increase of 66% on the baseline compared with just 15% in the sham TENS (control). Pain thresholds after mechanical reflexology remain higher throughout the experimental procedures, albeit non-significantly. There was a general trend for an increased pain tolerance in both treatment groups although the Pitman test, Table 6.5, showed there was significant variation between the treatments during the stimulation (t=50min) period ($p<0.05$) and also at t=90min or rather 60min post-treatment, ($p<0.05$) for mechanical reflexology. This result is in line with that seen for pain tolerance in Chapter 4 following manually applied reflexology. There were however, large standard errors and the subject group was small in this experiment, one cannot therefore rely on the data obtained for the efficacy of mechanical reflexology in this regard.

Green *et al.* (2008) have indicated that the strength of a 10 min percutaneous mechanical stimulation used to measure blood pooling (n=18), was equivalent to 51% of the subjects' pain threshold. The Scholl Ionic Foot Rejuvenator Massager used in this experiment, provided two stimulus strengths, low and high. All subjects were treated on the low stimulus, although it is not known what value was attributed to a low stimulus in relation to the subjects' normal pain threshold. It is possible therefore, that the strength of stimulation could have influenced the results.

Heart Rate

The heart rate observations were taken prior to, during and post ice plunge, before, during and after treatments. The effect of treatment revealed no significant differences and this is contrary to the literature which showed a decrease on the R-R interval during percutaneous mechanical stimulation (Green *et al.*, 2008). However, that experiment was carried out without the use of ice pain. This result is consistent with the literature indicating that there is no relationship between analgesia and heart rate (Martinez-Gomez *et al.*, 1988).

Subjective rating

There were no significant differences in levels of arousal, anxiety or discomfort during the ice immersions and these results compare favourably with those observed following standard reflexology procedures in Chapter 5a. Two of the four subjects who returned their feedback questionnaires reported that they had experienced improved sleep and one person reported an increase in energy levels. Similarly in the control responses one person reported these side-effects. Such responses are not unusual when presented with a list of possible reactions to treatment (Roscoe *et al.*, 2006).

Placebo Effect

De Pascalis *et al.* (2002) have shown that the contribution of suggestibility and expectation to placebo analgesia in an experimental setting, depends on the suggestibility of the subject group. This group of subjects were much younger than the other experimental groups used in Chapters 4 and 5. Perhaps in a group with less life experience they were more open to the suggestion that sham TENS (control) would stimulate nerve fibres that alleviate pain, and perhaps together with the visual

impact of the equipment this was powerful enough to induce a certain level of expectancy in this group of subjects (Kaptchuk *et al.*, 2000). It is possible therefore that such an expectancy produced the better results from the control treatment.

Conclusion

It has been difficult to draw any real conclusions from this experiment since the subject group was small and there was a wide range of variability in responses to treatment. Nonetheless in the five subjects who were eligible for analysis the experiment showed that mechanical reflexology may produce some transient benefits for an increase in pain threshold during the stimulating period and in pain tolerance following the stimulating period.

This experiment has however produced no further clarity for the effect of the therapist and one is drawn back to the question as to whether the efficacy of reflexology is in the touch of the skin, the pressure applied or in the therapeutic relationship. Further studies with a much larger cohort in which mechanical reflexology and manual reflexology are directly compared with one another will provide a better measure of the therapist's role in treatment and the efficacy of mechanical stimulation for pain threshold and tolerance.

CHAPTER 7

EFFECTS OF REPEATED REFLEXOLOGY TREATMENTS IN AN ICE PAIN EXPERIMENT IN HEALTHY HUMAN SUBJECTS

7.1 INTRODUCTION

Reflexology practitioners generally recommend and indeed, are taught, that a course of treatments is preferable to a single session, believing that a single session does little more than relax the patient (Marquardt, 1984, Lett, 2000, Porter, 1997). The overall number of treatment sessions is often assessed on a week by week basis and thus depends on many other factors.

Reflexology treatments have been utilised for a number of chronic conditions, but there is little evidence to suggest that it has anything more than a transient effect on physiological parameters such as blood pressure and heart rate (Oleson and Flocco, 1993, Siev-Ner *et al.*, 2003, Wilkinson *et al.*, 2006, Mackereth *et al.*, 2008). There are however, a limited number of studies in the literature where pain has been the primary outcome measure.

In a study by Poole *et al.* (2007), 243 chronic low back pain patients participated in either six weeks of Morrell reflexology, primary muscle relaxation or continued their usual care. The subjects were randomised to receive approximately 1-hour of treatment over a six – eight week period. A variety of subjective data were collected prior to treatment, at 6 weeks and at a 6-month follow-up. Results showed there were no significant differences between the groups, but there was a trend of lower pain scores in the reflexology group over time. In a pilot study of 15 low back pain patients, Quinn *et al*. (2007) investigated the effects of six 40 min sessions of precision reflexology with six sessions of foot massage, given at weekly intervals. Administration of precision reflexology used all known reflex points on the foot and especial attention was given to the spine reflexes. The foot massage used the same reflex points but avoided the spinal reflexes. Not surprisingly the results were insignificant, probably due to the poor sham choice.

In a four week cross-over design study Hodgson *et al*. (2008) compared the effects of four, 30 min reflexology treatments with four, 30 min friendly visits, in 21 nursing home patients with mild to moderate dementia. The primary outcome measure was physiological distress, measured by salivary ά-amylase (sAA) (Rohleder *et al.*, 2004). Secondary outcome measures included observed pain, measured by the Checklist of Nonverbal Pain Indicators (CNPI). This checklist was designed for cognitively impaired elders and is a behavioural observation scale of six items, rated as presence or absence of pain (Feldt, 2000). Observed affect was also measured using the Apparent Affect Rating Scale (Lawton *et al.*, 1996). This scale was developed to assess the state of positive and negative moods in older patients with Alzheimer's disease. The results of this study revealed a significant decrease in observed pain and sAA, which was most noticeable in weeks 3 and 4.

It has been noted that single treatment trials of reflexology do not represent standard clinical practice (Nahin and Straus, 2001) and it is important to evaluate the full benefits of reflexology from continued use.

7.2 AIMS

This experiment was carried out to measure the effects of standard reflexology on pain threshold and tolerance levels in healthy human volunteer subjects exposed to repeated immersion of the non-dominant hand into crushed ice. The main questions for the investigation were whether a) standard reflexology produces a sustained effect over three weeks of treatment, b) there was any tolerance to the treatment, *i.e.* was there a decrease in effect over time and, c) subjects become more sensitive to treatment. Subjective evidence was obtained through subjective ratings and feedback questionnaires.

7.3 METHOD

7.3.1 Design

Subjects were randomised to receive either three consecutive weekly standard reflexology treatments or three consecutive weekly sham TENS (control) treatments given in a cross-over design over a 6 week period with a minimum one week dry-out period. The randomisation method is described earlier in Chapter 2 (sub-section 2.2.5).

7.3.2 Demographics

This six week experiment recruited eleven female subjects, one subject dropped out after the first session leaving a total of ten female subjects. Mean ± SEM age of the subjects was 38.5 ± 3.6 years (range 26-51). No attempt was made to fix menstrual cycle phase and all subjects had previous experience of both the reflexology and sham TENS (control) procedure. All subjects who completed the study were given a monetary reward for their participation.

7.3.3 Procedure

Subjects had previously been consulted with regard the experimental protocol and were invited to sign the relevant consent form. A short consultation was taken prior to starting the experiment. Subjects sat upright in the Lafuma chair (see Figure 2.1, Chapter 2) and were fitted with the heart rate monitor and blood pressure equipment, following which baseline readings for blood pressure and heart rate were observed. Subjects were introduced to the subjective rating questionnaire and completed the first section of the form. Subsequent questions were completed following each successive ice immersion. Ten minutes of rest followed in order to allow the subject to acclimatize to the experimental environment. Further heart rate measurements were recorded at 10-minute intervals throughout the experimental procedure and immediately prior to, during and immediately following immersion of the subjects' non-dominant hand into the crushed ice. Blood pressure was recorded once at baseline, immediately prior to the treatment before being reclined to the semi-recumbent position, at 5-minutes post treatment after resuming an upright position and at 5 minutes after the final ice plunge. Subjects were seated upright in the Lafuma chair and feet were placed flat on the ground when each reading was taken. To allow for changes in blood-flow between the reclined position and the seated position a period of 5 minutes elapsed before the reading was taken.

Subjects completed one ice immersion cycle prior to treatment of either standard reflexology or sham TENS (control) and four cycles post treatment. Each cycle post treatment lasted 30-minutes and subjects immersed their non-dominant hand for a maximum of 5-minutes, although they were not informed of this time limitation. During the reflexology and sham TENS (control) subjects were reclined in the Lafuma chair for a total of 45-minutes whilst the treatments were performed, Table

7.1 illustrates the timeline of the experimental procedure. This procedure was adopted with each of the subjects for three consecutive weeks, followed by a minimum one week rest period before the subjects were swapped over to the opposite treatment. The procedure remained the same throughout all visits. Time of day was held constant for the experimental procedures, across all weeks, for the individual subjects. The subjects were provided with a feedback questionnaire and were asked to complete the form within 24 hours post treatment and then return it to the investigator at their next visit.

Table 7.1: Experimental timeline with a total experimental time of 160 min.
Abbreviations: PThr = Pain Threshold, PTol = Pain Tolerance, HR = Heart Rate, BP = Systolic and Diastolic blood pressure

Pre treatment			Treatment		Post treatment							
0 – 15 min			15 - 60 min		61		90		120		160	
Baseline			45 min duration		+ 0 mins		+ 30 mins		+ 60 mins		+ 90 mins	
Forms + baseline HR/BP	HR/BP PThr, Tol	Subjective rating	Treatment – HR every 10 min	Subjective rating	PThr, PTol HR + 5mins = BP	Subjective rating	PThr, PTol, HR	Subjective rating	PThr, PTol, HR	Subjective rating	PThr, PTol, HR +5 min = BP	Subjective rating
Heart Rate was observed prior, during and post each ice immersion in addition to every 10 mins												

7.3.4 Data analysis

In line with the analysis of the results in Chapters 5a and 6, the initial data analysis was performed using ANOVA, in this experiment a 3-way ANOVA with one between-subjects factor (i.e. treatment) and three within-subjects factors (i.e. time, group and period). The results of the 3-way ANOVA are shown in Appendix G. The data were subsequently subjected to analysis using a change from pre-treatment baseline. Pearson product-moment correlations were carried out on the baseline data and Pitman tests were used to establish any differences at the individual time points.

Subjects with high pain threshold values (*i.e.* greater than 40s in control treatment) were eliminated from the analysis (Chapter 2, Section 2.4.1) and this included two subjects (5, 10). A third subject was eliminated from the analyses due to non-compliance (6), *i.e.* an inability to complete the experimental procedures within the given timeframe. The data for the remaining seven subjects is shown.

The subjective rating questionnaires were analysed using the Wilcoxon sign rank test for non-parametric matched pairs and are shown as median, 1st and 3rd quartiles with an exact 2-tailed significance value.

7.4 RESULTS

7.4.1 Pain threshold and tolerance

A three-way ANOVA of the results for the mean ± SEM with respect to time is shown in Appendix G, there were no significant differences shown.

Pearson product-moment correlations for the pain threshold baselines revealed the data were below the level of significant correlation at period 1 (r = -0.21, df = 7, n.s), and period 3 (r = +0.34, df = 7, n.s). However, a student's t-test on the results during the two periods revealed no significant differences period 1 p=0.94, n.s. and period 3 p=0.78, n.s. During period 2 the data were significantly correlated (r = +0.77, df = 7, p<0.05), but a t-test showed no significant difference (p=0.34, n.s). Therefore the inter-session reliability was poor and this may be due to the 4-week gap between cross-over.

Pain Threshold

Figure 7.1 illustrates the effect of treatment over the three treatment periods on the mean ± SEM pain threshold (s) shown as a change from the pre-treatment baseline scores. The 3-way ANOVA, shown in Table 7.2 revealed there were no significant differences between the standard reflexology and sham TENS (control) treatments in terms of pain threshold.

Table 7.2: A summary of the 3-way ANOVA on change from pre-treatment baselines for pain threshold (s), *n=7*. Abbreviations: Df = degrees of freedom, F-ratio = Fischer exact score, p-value = probability of significance.

Category	**Df**	**F-ratio**	**p-value**
Group (Between subjects) →	1,12	0.029	ns
Period (Within subjects) ↓	2,24	0.310	ns
Group x Period	2,24	0.378	ns
Time	3,36	1.896	ns
Group x time	3,36	0.672	ns
Time x period	6,72	0.967	ns
Group x time x period	6,72	0.567	ns

Pain Threshold

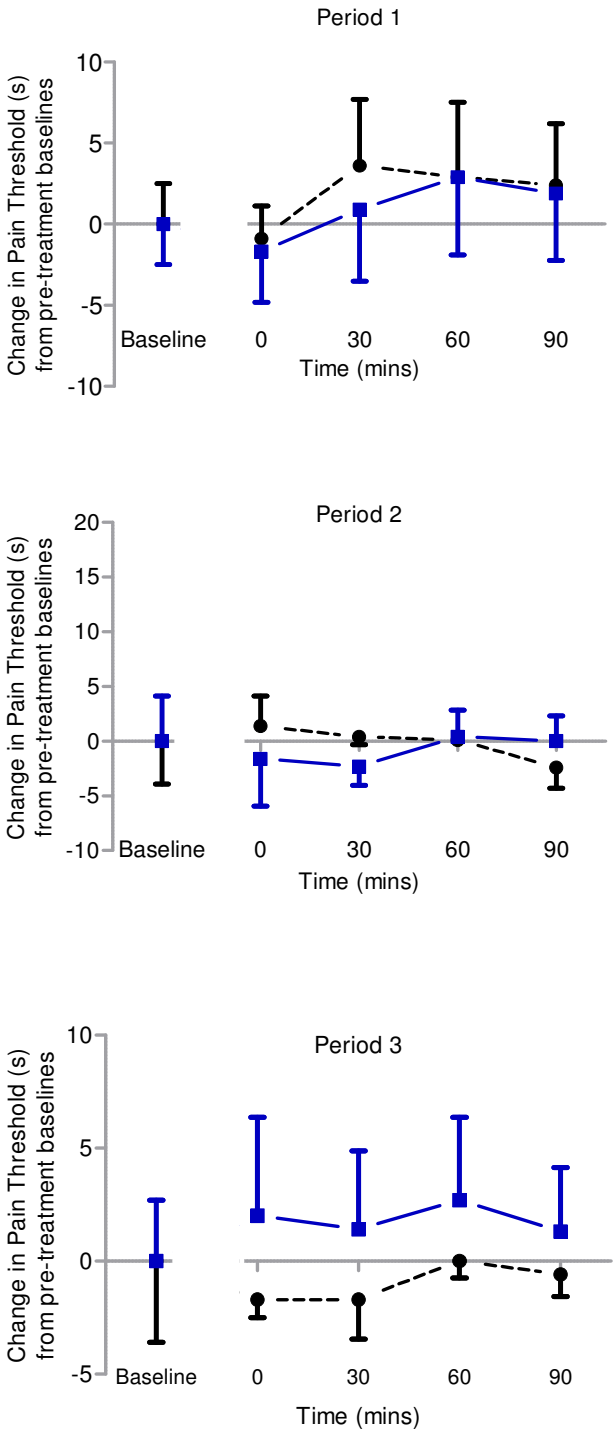


Figure 7.1: The effects of treatment on mean ± SEM pain threshold (s) over the three treatment periods shown as a change from the pre-treatment baselines, *n=7*. Vertical lines represent +/- SEM. ●=Sham TENS (control)■=Standard reflexology,.

In contrast to the overall 3-way ANOVA, the Pitman permutation test shown in Table 7.3 showed that there may be some significant differences in the variance between the two populations. In period 2, for example, pain threshold was higher following the sham TENS (control) than for the standard reflexology at t=30 and t=60 min. In period 3 however, the increased effect on pain threshold is seen following standard reflexology at t=0min, t=60 and t=90min. However, this effect may be due to the large standard errors between the two treatments. In period 2, for example, the mean values at 60min (Figure 7.1) are very similar but in period 3 at the same time, reflexology showed a large standard error whilst for sham TENS (control) the standard error was minimal.

Table 7.3: Pitman permutation tests for change from pre-treatment baseline in pain threshold (s) for periods 1 – 3, *n=7*. The table shows the differences of the 4 post treatment effects when standard reflexology was compared to a sham TENS (control). Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability.

Period 1

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	2.406	1.168	1.088	1.191
N =	7	7	7	7
Pearson	-0.001	0.219	0.077	0.137
Pitman	1.014	0.178	0.095	0.198
p-value	ns	ns	ns	ns

Period 2

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	2.497	6.064	24.129	1.464
N =	7	7	7	7
Pearson	0.271	0.753	-0.262	-0.108
Pitman	1.101	3.495	5.455	0.431
p-value	ns	**0.05**	**0.01**	ns

Period 3

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	29.195	3.892	24.171	8.525
N =	7	7	7	7
Pearson	0.920	-0.679	0.076	0.711
Pitman	14.895	2.233	5.284	4.102
p-value	**0.01**	ns	**0.01**	**0.01**

Pain Tolerance

The 3-way ANOVA on the raw data is shown in Appendix G and revealed that there were no significant differences between the treatments.

Pearson product-moment correlations for the pain tolerance baselines revealed the data were not significantly correlated at period 1 (r = +0.43, df = 7, n.s), but a t-test showed the data were not significantly different (p=0.85, n.s). The correlation was strong in periods 2 (r = +0.88, df = 7, p<0.01), t-test (p=0.26, n.s), and 3 (r = +0.90, df = 7, p<0.01), t-test (p=0.18, n.s) suggesting there was overall, good inter-session reliability which is unusual given the 4-week difference in cross-over.

Figure 7.2 illustrates the result of the 3-way ANOVA for the effects of treatment on pain tolerance and is shown as a change from the pre-treatment baseline, whilst Table 7.4 shows a summary of the ANOVA.

Table 7.4: A summary of the 3-way ANOVA on change from pre-treatment baselines for pain tolerance (s), *n=7*. Abbreviations: Df = degrees of freedom, F-ratio = Fischer exact score, p-value = probability of significance

Category	**Df**	**F-ratio**	**p-value**
Group (Between subjects) →	1,12	4.387	ns
Period (Within subjects) ↓	2,24	2.633	ns
Group x Period	2,24	0.354	ns
Time	3,36	0.192	ns
Group x time	3,36	0.367	ns
Time x period	6,72	1.642	ns
Group x time x period	6,72	0.679	ns

The result of the ANOVA showed that there were no significant effects of either standard reflexology or sham TENS (control). However Figure 7.2 shows a general anti-nociceptive trend of standard reflexology and this is supported by the result of the Pitman test, Table 7.5. In contrast there was a trend toward an increase in pain (nociceptive effect) following the sham TENS (control) particularly in periods 2 and 3, Figure 7.2.

Pain Tolerance

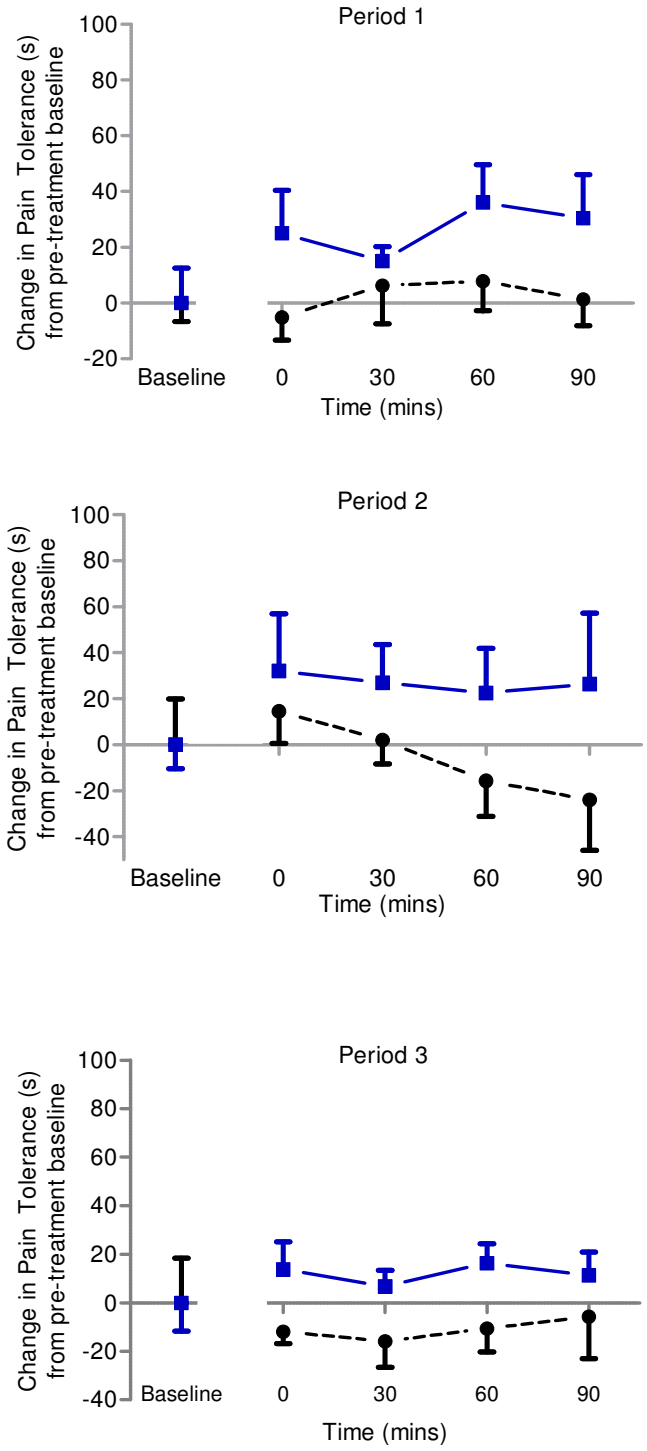


Figure 7.2: The effects of treatment on mean ± SEM pain tolerance (s) over the three treatment periods shown as a change from the pre-treatment baselines, *n=7*. Vertical lines represent +/- SEM. ●=Sham TENS (control), ■=Standard reflexology.

Table 7.5 shows that in period 1 for example, there was a significant difference between the two treatments showing that the pain tolerance levels were higher following the standard reflexology than for sham TENS (control) t=30 min), $p<0.05$. In period 2 there were no significant differences at any of the time points but Figure 7.2 clearly shows a nociceptive effect of sham TENS (control) over time. In period 3 there was a significant increase following standard reflexology at t=0min, immediately post treatment, reflecting the effect seen in Chapter 5a for standard reflexology.

Table 7.5: Pitman permutation tests for change from pre-treatment baseline in pain tolerance (s) for periods 1 – 3, *n=7*. The table shows the differences of the 4 post treatment effects when standard reflexology was compared to a sham TENS (control). Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

Period 1

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	3.569	7.130	1.643	2.663
N =	7	7	7	7
Pearson	-0.603	-0.279	0.016	-0.576
Pitman	1.908	2.673	0.561	1.395
p-value	ns	**0.05**	ns	ns

Period 2

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	3.169	2.638	1.573	1.980
N =	7	7	7	7
Pearson	0.101	-0.186	-0.716	0.106
Pitman	1.370	1.147	0.732	0.783
p-value	ns	ns	ns	ns

Period 3

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	5.403	2.547	1.447	3.237
N =	7	7	7	7
Pearson	-0.652	-0.393	-0.201	0.761
Pitman	2.796	1.179	0.424	2.144
p-value	**0.05**	ns	ns	ns

7.4.2 Results obtained for heart rate responses

The statistical analysis of the raw data showing the mean ± SEM with respect to time for pre, during and post ice plunge is shown in Appendix G.

Baseline data

As there were two baseline observations prior to the first ice immersion it was possible to carry out test-retest reliability statistics using Pearson's product-moment correlation. Results showed that there was variation in baseline correlations which

may have been due to the activity of the subject prior to commencing the trials. It was deemed appropriate therefore to take the second baseline as the point from which to calculate the change. Results of the correlations for the second baseline measurement were: In period 1 the data were significantly correlated (r = +0.92, df = 7, p<0.01), but there was also a significant difference between the baselines when a students t-test was used (p<0.01). In period 2 there was no correlation between baselines (r = +0.16, df = 7, ns) but a t-test revealed no significant differences (p=0.35, n.s.). Period 3 also showed that the baselines were not significantly correlated (r = +0.36, df = 7, ns) but a t-test revealed the data were not significantly different (p=0.19, n.s). Therefore the data between sessions was reliable for periods 2 and 3 but not for period 1, and this not surprising since there was a minimum 4-week gap between the cross-over sessions.

Pre ice plunge

A 3-way ANOVA on the change from the second baseline was calculated. The result of the ANOVA for the pre-plunge heart rate is shown in Table 7.6 and Figure 7.3. There were no significant effects of treatment, but there was a significant decrease in heart rate over time ($F_{(3,36)}$ =8.607,p<0.01) which may be attributable to the effects of relaxation.

Table 7.6: A summary of the 3-way ANOVA on pre plunge heart rate (bpm). The data are shown as a change from the pre-treatment baselines, n=7. Abbreviations: Df =degrees of freedom, F-ratio = Fischer exact score, p-value =probability of significance.

Category	**Df**	**F-ratio**	**p-value**
Group (Between subjects) →	1,12	0.037	ns
Period (Within subjects) ↓	2,24	0.827	ns
Group x Period	2,24	2.764	ns
Time	3,36	8.607	0.01
Group x time	3,36	1.075	ns
Time x period	6,72	0.343	ns
Group x time x period	6,72	1.178	ns

The Pitman tested data shown in Table 7.7 did not reveal anything other than that which was seen in the ANOVA.

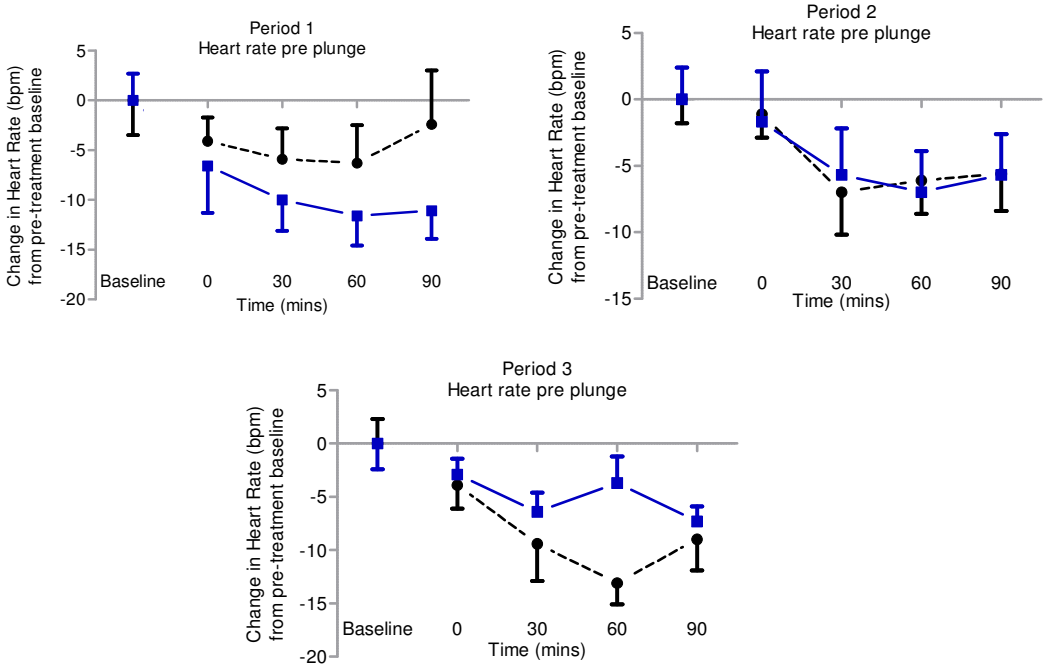


Figure 7.3: The mean ± SEM on pre ice plunge heart rate (bpm) for the three treatment periods, shown as a change from the baseline, *n=7*. Vertical lines illustrate +/- SEM. ● = Sham TENS (control), ■ = Standard reflexology.

Table 7.7: Pitman permutation tests for the change from pre-treatment baseline in heart rate prior to the ice plunge for periods 1 – 3, *n=7*. The table shows the differences of the four post treatment effects when standard reflexology was compared to a sham TENS (control). Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value= probability of significance.

Period 1

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	3.863	1.009	1.616	3.876
N =	7	7	7	7
Pearson	0.279	0.313	0.472	0.507
Pitman	1.696	0.011	0.615	1.896
p-value	ns	ns	ns	ns

Period 2

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	4.595	1.135	1.548	1.224
N =	7	7	7	7
Pearson	0.518	0.456	0.633	0.220
Pitman	2.193	0.160	0.637	0.233
p-value	ns	ns	ns	ns

Period 3

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	2.217	3.8549	1.527	4.112
N =	7	7	7	7
Pearson	0.620	0.751	0.757	0.899
Pitman	1.166	2.462	0.731	3.934
p-value	ns	ns	ns	**0.05**

During Ice plunge

The result of the ANOVA calculated for the effect of treatment on heart rate during the ice plunge is shown in Table 7.8 and Figure 7.4. The data revealed that there were no significant differences between the two treatments of standard reflexology and sham TENS (control). This result is confirmed by the Pitman test shown in Table 7.9.

Table 7.8: A summary of the 3-way ANOVA for the during ice plunge heart rate (bpm). The data are shown as a change from the pre-treatment baselines, *n=7*. Abbreviations: Df =degrees of freedom, F-ratio = Fischer exact score, p-value =probability of significance.

Category	**Df**	**F-ratio**	**p-value**
Group (Between subjects) →	1,12	0.293	ns
Period (Within subjects) ↓	2,24	1.260	ns
Group x Period	2,24	0.740	ns
Time	3,36	0.794	ns
Group x time	3,36	0.305	ns
Time x period	6,72	0.529	ns
Group x time x period	6,72	1.229	ns

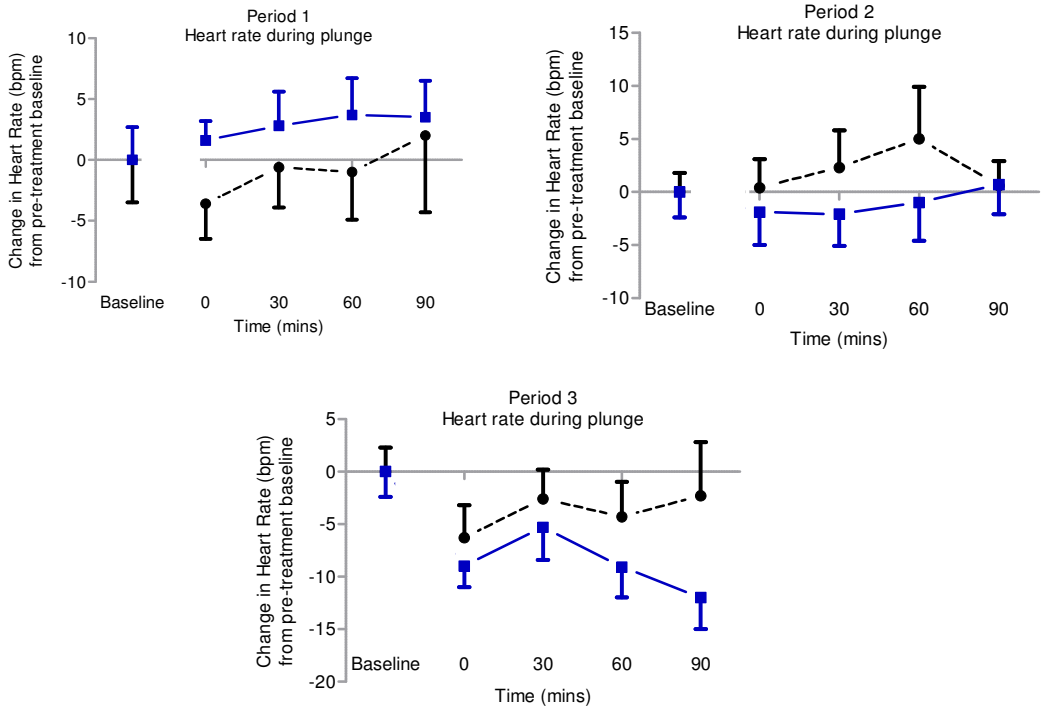


Figure 7.4: The mean ± SEM during ice plunge heart rate (bpm) for the three treatment periods, shown as a change from the baseline *n=7*. Vertical lines illustrate +/- SEM. ● = Sham TENS (control), ■ = Standard reflexology.

Table 7.9: Pitman permutation tests for the change from pre-treatment baseline in heart rate during the ice plunge for periods 1 – 3, *n=7*. The table shows the differences of the four post treatment effects when standard reflexology was compared to a sham TENS (control). Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

Period 1

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	3.209	1.413	1.124	3.304
N =	7	7	7	7
Pearson	0.742	0.151	0.776	0.664
Pitman	2.058	0.393	0.208	1.896
p-value	ns	ns	ns	ns

Period 2

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	1.320	1.380	1.917	1.488
N =	7	7	7	7
Pearson	0.712	0.758	0.503	-0.050
Pitman	0.444	0.555	0.858	0.448
p-value	ns	ns	ns	ns

Period 3

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	1.730	2.855	1.612	1.134
N =	7	7	7	7
Pearson	0.686	0.724	0.590	0.540
Pitman	0.854	1.780	0.669	0.167
p-value	ns	ns	ns	ns

Post ice plunge

The result of the 3-way ANOVA on the post ice plunge heart rate as a change from baseline is shown in Table 7.10 and Figure 7.5. There were no significant differences in the effect of treatment following either standard reflexology or sham TENS (control). This result has been verified using the Pitman test shown in Table 7.11.

Table 7.10: A summary of the 3-way ANOVA on post ice plunge heart rate (bpm). The data are shown as a change from the pre-treatment baseline, *n=7*. Abbreviations: Df =degrees of freedom, F-ratio = Fischer exact score, p-value =probability of significance.

Category	**Df**	**F-ratio**	**p-value**
Group (Between subjects) →	1,12	0.112	ns
Period (Within subjects) ↓	2,24	0.420	ns
Group x Period	2,24	2.452	ns
Time	3,36	1.500	ns
Group x time	3,36	1.231	ns
Time x period	6,72	0.992	ns
Group x time x period	6,72	1.074	ns

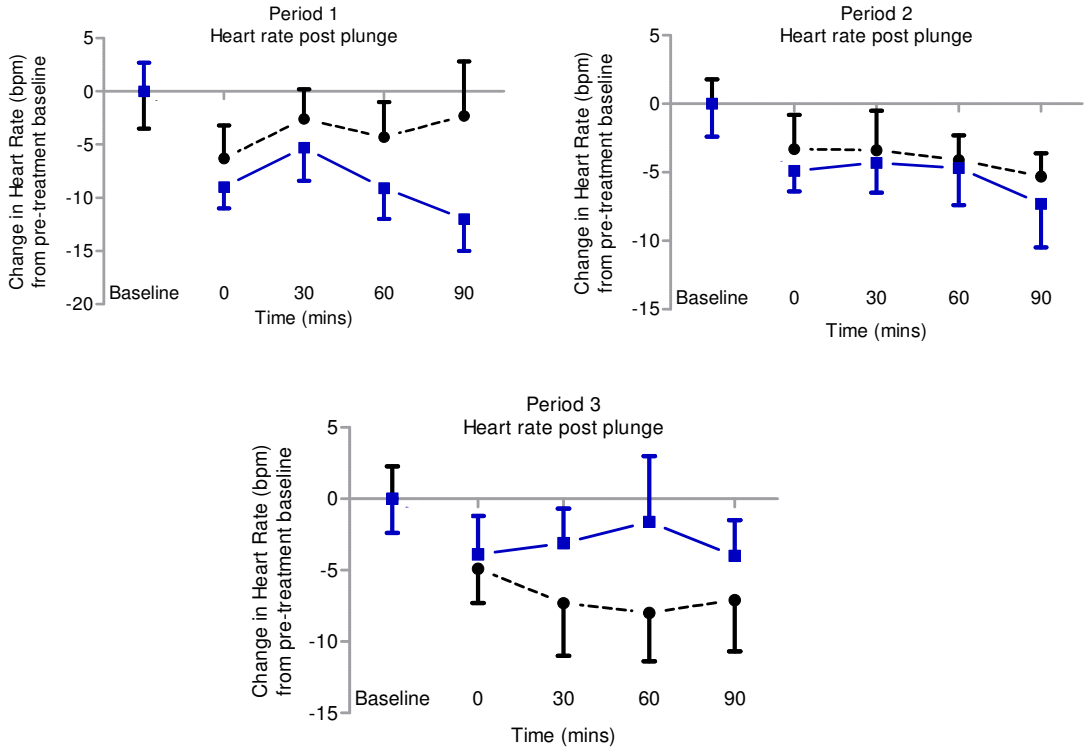


Figure 7.5: The mean ± SEM post ice plunge heart rate (bpm) for the three treatment periods, shown as a change from the baseline, *n=7*. Vertical lines illustrate +/- SEM. ● = Sham TENS (control), ■ = Standard reflexology

Table 7.11: Pitman permutation tests for the change from pre-treatment baseline in heart rate post ice plunge for periods 1 – 3, *n=7*. The table shows the differences of the four post treatment effects when standard reflexology was compared to a sham TENS (control). Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability, p-value = probability of significance.

Period 1

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	2.575	1.185	1.300	2.953
N =	7	7	7	7
Pearson	0.501	0.846	0.668	0.657
Pitman	1.268	0.357	0.396	1.687
p-value	ns	ns	ns	ns

Period 2

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	2.680	1.754	2.241	3.655
N =	7	7	7	7
Pearson	0.340	0.329	0.641	0.502
Pitman	1.220	0.674	1.208	1.795
p-value	ns	ns	ns	ns

Period 3

Post-treatment time	**0 min**	**30 min**	**60 min**	**90 min**
F-ratio	1.265	2.302	1.792	1.995
N =	7	7	7	7
Pearson	0.711	0.536	0.833	0.789
Pitman	0.376	1.137	1.196	1.284
p-value	ns	ns	ns	ns

7.4.3 Results obtained for blood pressure

Mean ± SEM with respect to time are shown in detail in Appendix G, however the results showed that there was a significant effect of time for both systolic ($F_{(2,24)}$ =3.698,p<0.05) and diastolic blood pressures ($F_{(1,12)}$ =9.116,p<0.01) but there were otherwise no significant differences between the treatments.

When subjects first entered the room their blood pressure was measured and found to be generally high, a second measurements was therefore taken 15 minutes after entering the room and immediately prior to being reclined for treatment. The second measurement was used as the baseline measurement. When baseline reliability statistics were carried out the data showed that systolic blood pressure in period 1 was not significantly correlated (r = +0.27, df = 7, ns) but a students t-test showed there was no significant differences (p=0.16, n.s.). In period 2 the data were significantly correlated (r = +0.79, df = 7, p<0.05), however a t-test also showed the data were significantly different at baseline (p<0.01). In period 3 the data were below the level of significant correlation (r = +0.39, df = 7, ns), but the t-test showed the data were not significantly different (p=0.60, n.s), thus there was a good level of reliability overall between sessions.

Diastolic blood pressure baseline calculations for period 1 revealed the data were just below the level of significance (r = +0.68, df = 7, ns) but the students t-test showed they were not significantly different (p=0.44, n.s.). In period 2 (r = +0.39, df = 7, ns) there was no significant correlation but the t-test showed they were not significantly different (p=0.61, n.s). This was also true in period 3 (r = +0.51, df = 7, ns), t-test (p=0.73, n.s.) demonstrating good reliability in baseline data between sessions.

Pulse pressure which is based on the difference between systolic and diastolic pressures, also revealed no significant correlations but t-tests showed they were not significantly different. Period 1 (r = +0.68, df = 7, ns), students t-test (p=0.31, n.s.), period 2 (r = +0.06, df = 7, ns), t-test (p=0.19, n.s.) and period 3 (r = +0.47, df = 7, ns), t-test (p=0.44, n.s). The results of the change from the pre-treatment baseline are illustrated in Figures 7.6 – 7.8 for systolic, diastolic and pulse pressure respectively.

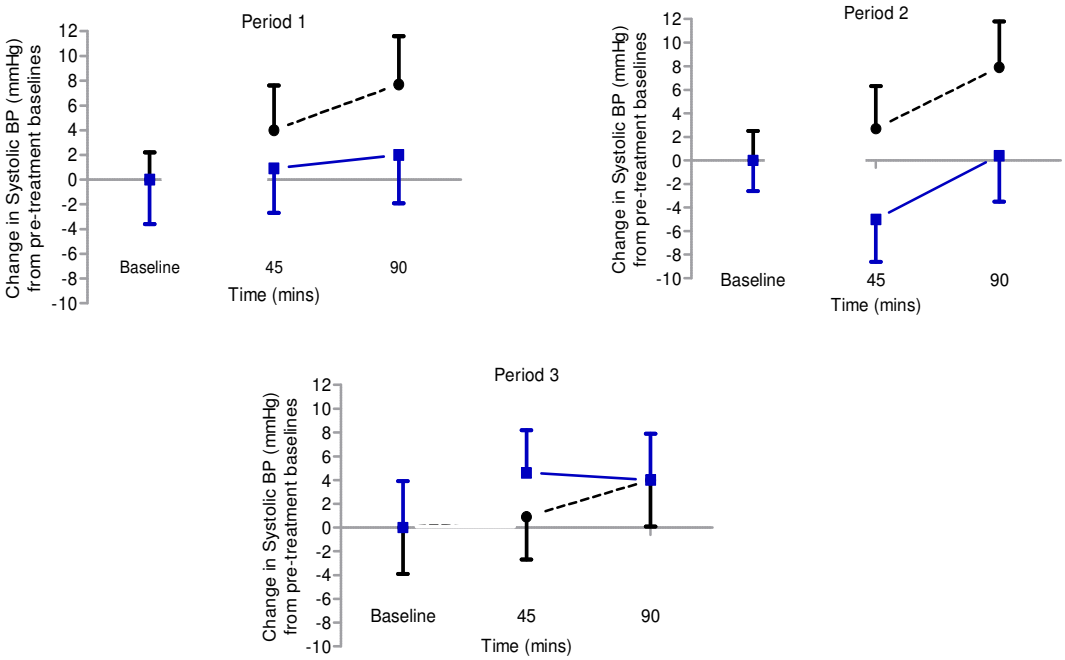


Figure 7.6: Mean ± SEM for the effects of treatment on systolic blood pressure (mmHg) across the three treatment periods, shown as a change from pre-treatment baseline, *n=7*. Vertical lines illustrate +/- SEM. ● = Sham TENS (control), ■ = Standard reflexology.

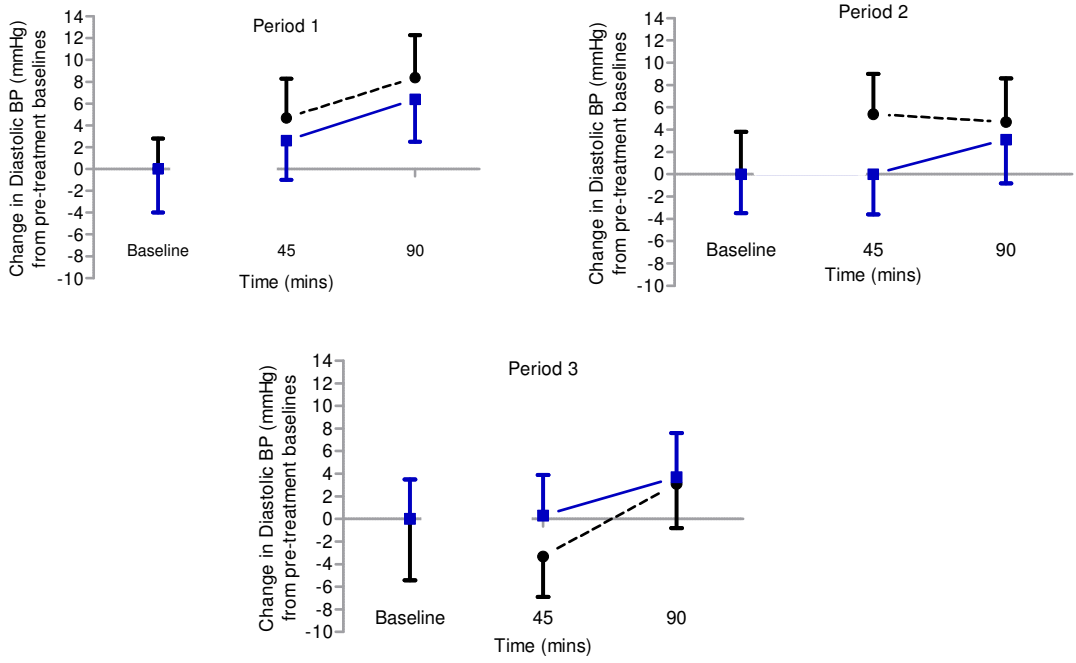


Figure 7.7: Mean ± SEM for the effects of treatment on diastolic blood pressure (mmHg) across the three treatment periods, shown as a change from pre-treatment baseline, *n=7*. Vertical lines illustrate +/- SEM. ● = Sham TENS (control), ■ = Standard reflexology.

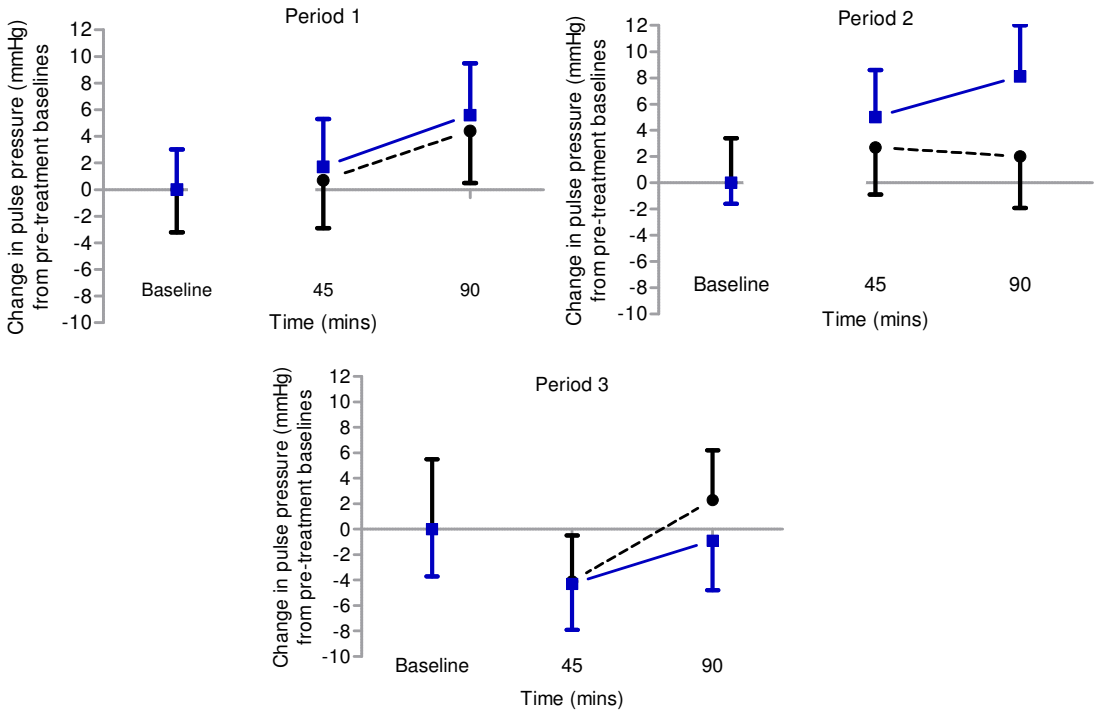


Figure 7.8: Mean ± SEM for the effects of treatment on pulse pressure (mmHg) across the three treatment periods, shown as a change from pre-treatment baseline, *n=7*. Vertical lines illustrate +/- SEM. ● = Sham TENS (control), ■ = Standard reflexology.

The ANOVA for the change on the pre-treatment baselines for systolic, diastolic and pulse pressure is shown in Table 7.12. The results showed that there were no significant effects on systolic blood pressure or on pulse pressure, there was however a significant effect of time on diastolic blood pressure ($F_{(1,12)}$ =9.553,p<0.01)

Table 7.12: A summary of the 3-way ANOVA for the systolic, diastolic blood pressures and pulse pressure (mmHg). The data are shown as a change from baseline, *n=7*. Abbreviations: Df =degrees of freedom, F-ratio = Fischer exact score, p-value =probability of significance.

Category – SYSTOLIC BP	**Df**	**F-ratio**	**p-value**
Group (Between subjects) →	1,12	1.526	ns
Period (Within subjects) ↓	2,24	0.296	ns
Group x Period	2,24	1.262	ns
Time	1,12	3.179	ns
Group x time	1,12	0.353	ns
Time x period	2,24	1.015	ns
Group x time x period	2,24	0.253	ns

Category – DIASTOLIC BP	**Df**	**F-ratio**	**p-value**
Group (Between subjects) →	1,12	0.279	ns
Period (Within subjects) ↓	2,24	2.047	ns
Group x Period	2,24	0.820	ns
Time	1,12	9.553	**0.01**
Group x time	1,12	0.024	ns
Time x period	2,24	1.238	ns
Group x time x period	2,24	1.007	ns

Category – PULSE PRESSURE	**Df**	**F-ratio**	**p-value**
Group (Between subjects) →	1,12	1.008	ns
Period (Within subjects) ↓	2,24	0.917	ns
Group x Period	2,24	0.142	ns
Time	1,12	0.033	ns
Group x time	1,12	0.476	ns
Time x period	2,24	3.259	ns
Group x time x period	2,24	0.111	ns

Pitman tests on the change from baseline for systolic blood pressure showed there were significant variations between standard reflexology and sham TENS (control) at the end of period 1 ($p<0.05$) with an increased effect following the sham TENS (control) treatment. There were no differences observed for diastolic blood pressure, but there was a significant difference between the systolic and diastolic pressures (pulse pressure) immediately following the treatment period, but none of the effects were sustained across all treatment periods.

Table 7.13: Pitman permutation tests for the change from pre-treatment baseline in systolic and diastolic blood pressure and pulse pressure (mmHg) for periods 1 – 3, *n=7*. The table shows the differences of the two post treatment effects when standard reflexology was compared to a sham TENS (control). Abbreviations: F-ratio = Fisher Exact test, Pearson=Pearson product-moment correlation coefficient, Pitman=permutation test for variability.

SYSTOLIC BP	**Period 1**		**Period 2**		**Period 3**	
Post-treatment time	**45 min**	**90 min**	**45 min**	**90 min**	**45 min**	**90 min**
F-ratio	1.911	7.425	2.673	1.119	1.438	1.705
N =	7	7	7	7	7	7
Pearson	-0.477	0.141	0.774	0.452	0.030	0.025
Pitman	0.839	2.663	1.809	0.141	0.409	0.604
p-value	ns	**0.05**	ns	ns	ns	ns

DIASTOLIC BP	**Period 1**		**Period 2**		**Period 3**	
Post-treatment time	**45 min**	**90 min**	**45 min**	**90 min**	**45 min**	**90 min**
F-ratio	1.086	2.181	1.760	2.174	1.144	2.072
N =	7	7	7	7	7	7
Pearson	-0.206	0.594	-0.260	0.623	0.145	-0.139
Pitman	0.095	1.112	0.663	1.139	0.153	0.841
p-value	ns	ns	ns	ns	ns	ns

PULSE PRESSURE	**Period 1**		**Period 2**		**Period 3**	
Post-treatment time	**45 min**	**90 min**	**45 min**	**90 min**	**45 min**	**90 min**
F-ratio	8.590	2.139	1.919	1.166	1.406	2.714
N =	7	7	7	7	7	7
Pearson	-0.422	-0.065	0.723	0.291	-0.567	-0.592
Pitman	3.194	0.873	1.075	0.180	0.465	1.444
p-value	**0.05**	ns	ns	ns	ns	ns

7.4.6 Subjective rating analyses

The data for the subjective rating questionnaires were analysed using the Wilcoxon sign rank test for non-parametric statistics of matched pairs. The median, 1st and 3rd quartiles are shown Table 7.14. The results of the analysis revealed no significant differences between the groups for the subjective measurements of arousal, anxiety or discomfort. Exact significance (2-tailed) results are shown in Table 7.15.

Table 7.14: Subjective rating analysis. Results are shown for the three treatment periods and two treatment groups. Brackets show the 1st and 3rd quartiles. The ratings were categorised thus: 4 = very high, 3 = high, 2 = normal, 1 = below normal

AROUSAL	**Period 1**	**Period 2**	**Period 3**
Sham TENS	2(2,2)	2 (2,2)	2(2,2)
Reflexology	2(2,2)	2(2,2)	2(2,2)
ANXIETY			
Sham TENS	1(1,2)	2(1,2)	2(1,)
Reflexology	2(1,2)	2(1,2)	2(1,2)
DISCOMFORT			
Sham TENS	3(2,3)	3(3,3)	2.5(2,3)
Reflexology	3(2,3)	2.5 (2,3)	3(2,3)

Table 7.15: Wilcoxon sign-rank test scores. Exact significance (2-tailed) for the subjective ratings of arousal, anxiety and discomfort during ice plunge. P=Period.

Post treatment time →	**Period**	0	30	60	90
AROUSAL	**P1**	1.000	1.000	1.000	1.000
	P2	1.000	1.000	0.500	1.000
	P3	1.000	1.000	1.000	1.000
ANXIETY	**P1**	1.000	1.000	1.000	1.000
	P2	0.625	1.000	1.000	1.000
	P3	1.000	1.000	1.000	1.000
DISCOMFORT	**P1**	1.000	1.000	1.000	1.000
	P2	0.250	0.125	1.000	0.625
	P3	1.000	0.500	1.000	1.000

At the end of each experimental session subjects were asked to reply to the final question on the subjective rating questionnaire. *Do you think that the treatment had any overall effects on your responses to the two parameters that were measured during each trial?* The two parameters were confirmed to refer to pain threshold and pain tolerance. In period one, six subjects felt that reflexology had affected their pain threshold and tolerance, in period two, four subjects felt an improvement from reflexology and in period three the number returned to six subjects. These subjective comments do not reflect actual responses to the treatment.

Feedback questionnaires

The results of the analysis of the feedback questionnaires are shown in Figure 7.9. The main outcome of the side-effects appears to be an improvement in the sleep pattern of subjects. This improvement is demonstrated following both standard reflexology and sham TENS (control) which may simply imply that the rest and relaxation afforded to them in their normal busy day produced a soporific effect not normally experienced by them. However it is interesting to note that across the three periods the side-effects reported by the subjects decreased.

In addition to the side-effects listed, subjects were asked to rate their overall treatment experience. The results are shown in Figure 7.10 and illustrate that the majority of the subjects enjoyed the standard reflexology treatment and some subjects also enjoyed the sham TENS (control). This may add to the idea that the effect is more about rest and relaxation than the treatment itself.

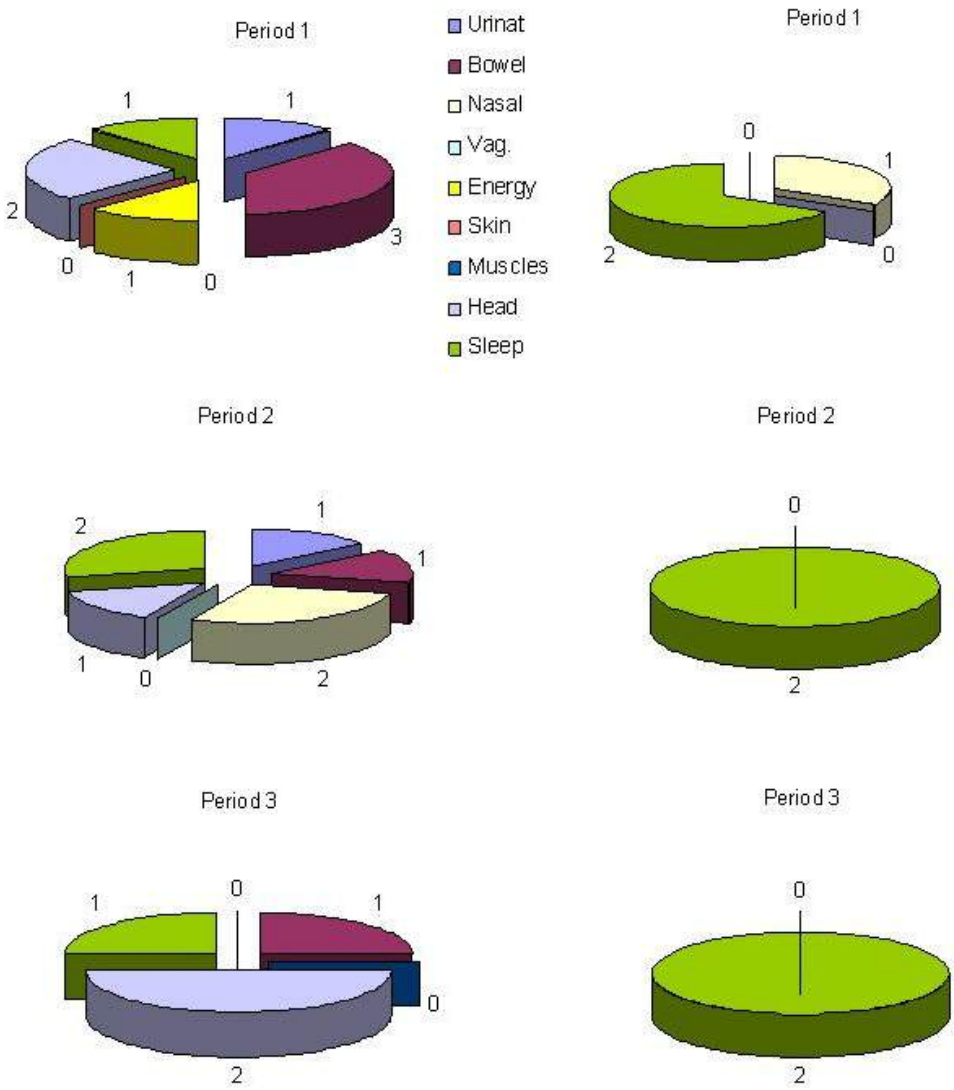


Figure 7.9: Illustration of the results of feedback questionnaires, *n=7*. Charts show the side effects subjects claim to have experienced following either standard reflexology, in the left hand column, or sham TENS (control), in the right hand column.

Figure 7.10: Illustration of the subject ratings giving their overall treatment experience, *n=7*. Control = Sham TENS (control). Sreflex = Standard Reflexology.

Subjects were also invited to make any additional comments in relation to their treatment. The following comments were made after their sham TENS (control) experience: -

- *Definitely slept better*
- *Had period 2 days after treatment, had previously been more than 2 weeks late.*
- *Had improved appetite.*

Subjects made the aforementioned comments after the standard reflexology treatments: -

- *Felt very relaxed*
- *Generally less joint pain, especially my knees, though this could be due to more exercise and strengthening the muscles around the knee.*
- *Good to help me relax*
- *It seems to help stop the eczema on my foot from itching, my sleep has improved after each treatment and I didn't feel tired after reflexology.*
- *Cramp at night in my right calf for two nights.*
- *Experienced different levels of pain during the ice plunge, skin first, then fingers, bones, then throbbing tips of fingers. After reflexology I found I had to concentrate more to feel these differences – before reflexology it was more obvious and more obvious with TENS.*
- *I enjoyed reflexology and would be more interested in finding out more about it. It was also nice to have one to one attention away from work/home etc.*

7.5 DISCUSSION

The principal aim of this experiment was to investigate the effect of standard reflexology on pain threshold and tolerance using ice pain as a noxious stimulus. Specifically, whether a) standard reflexology produced a sustained effect over three weeks of treatment b) there was any tolerance to treatment and c) subjects became more sensitive to the effects of treatment.

1. There were a number of difficulties in recruiting subjects to this experimental procedure. Initially the recruitment was aimed at subjects attending sessions

for one three hour period once a week for six weeks. However, previous recruitment experience warned of the problems that might ensue if this timescale was adopted. The results from the previous experiments (Chapter 5b) showed that the latency for the minimum and maximum pain threshold and tolerance levels was less than 120 minutes, therefore a two hour session once a week was thought to be more achievable.

2. One of the difficulties of managing cross-over trials is the effects of carry-over, where the effects in one period can be carried over to subsequent periods (Senn, 1993). However, the literature for reflexology suggests that the effects of treatment are transient to within each session (Wilkinson *et al.*, 2006, Mackereth *et al.*, 2008). Therefore period effects were ruled out.
3. The subjects used in this experiment had all been recruited on previous occasions and had prior experience of both the standard reflexology and the sham TENS procedures which introduced a level of bias to the results. In addition subjects completing the experiment were given a monetary reward which was not given in the other standard reflexology experiments.
4. The initial recruitment of 11 female subjects was reduced to just 7 subjects because one subject left the study after the first session, two of the subjects had pain threshold levels above the normal range (see Chapters 2 and 5a), and one subject was unable to attend the second part of the treatment programme on a regular basis or within the timeframe allotted for the experiment.

Pain threshold and tolerance

The data for this experiment were initially analysed using the mean ± SEM with respect to time. The results for pain threshold and tolerance revealed no significant main effects across the treatment periods in either pain threshold or pain tolerance.

Baseline data showed some significant correlations but one should bear in mind that the data from subjects in this cross-over experiment were taken four weeks apart. In this respect it is unlikely that they would be similar as the long period between treatments may well have seen change in the subject's physiology. It is surprising therefore to see any correlation in the baselines.

When the data were analysed as a change from the pre-treatment baseline there appeared to be a cumulative effect of standard reflexology on pain threshold which showed a slight improvement in the third period of treatment. In contrast, pain tolerance showed a decrease in the effects of standard reflexology compared with sham TENS (control) toward the third period.

The ANOVA for pain threshold did not show any significant differences between the treatments but the Pitman test showed significant improvements in pain threshold following reflexology in period 2 t=30 and t=60 min post treatment (Table 7.3) and immediately post treatment (t=0min) and at t=60 and t=90 min in period 3. However, period 2 shown in Figure 7.1 showed that there were no real effects of reflexology treatment, especially since there were large standard errors and this might suggest that subjects were drawn from different populations, thus this result may not be clinically relevant.

The ANOVA for pain tolerance showed no significant differences but the Pitman test showed significant increases in the anti-nociceptive effect for pain tolerance following standard reflexology in periods 1 and 3 (Table 7.5). This effect of reflexology on pain tolerance compares well with the results of the earlier experiments (Chapters 4 and 5a). One should bear in mind however that this was a small group of subjects with previous experience of both reflexology and sham TENS (control). They were paid to participate in the experiment and this may have impacted on the result. Of significance however is that the mean sham TENS (control) scores were below the baseline, whilst for the standard reflexology treatment they were not. In addition it is worth taking into account the 4 week gap between cross-over which may have made a difference to the variances between the two populations, as shown by the Pitman results.

Hodgson (2008) showed significant cumulative decreases in observed pain, using the Checklist of Nonverbal Pain Indicators, which was most noticeable in weeks 3 and 4. Although this experiment appears to show a cumulative increase in the anti-nociceptive effect for pain threshold in period 3; because of the large SEM and the small number of subjects this may not be of any real relevance. Studies utilizing

larger subject groups may support a cumulative effect and should be carried out in future experiments.

Further statistical methods of analysis using the mean minimum and maximum criteria set out in Chapter 5b, section 5.1.1b were used (Appendix H) to analyse this small subject group and provided further evidence for both nociceptive and anti-nociceptive effects of reflexology treatment on pain threshold and tolerance. The results showed there was a small nociceptive effect of standard reflexology on mean minimum pain threshold, Figure H1A and there were significant improvements in the mean maximum pain tolerance, Figure H4A following standard reflexology. These results reflect those shown from the earlier experiment (Chapter 5b).

Basal physiological changes

There were significant time effects on pre plunge heart rate and diastolic blood pressure readings but there were otherwise no significant differences between standard reflexology and sham TENS (control) for any of the physiological observations taken during the experimental procedure. This result is supported by the work of others in the literature (Wilkinson *et al.*, 2006, Mackereth *et al.*, 2008) and suggests that standard reflexology produces an effect of relaxation in the subjects that is retained within each session, but it does not appear to produce cumulative effects on basal physiological function that may be of any long-term benefit. However, the benefits of relaxation alone may be sufficient to justify reflexology as a benefit to those suffering from chronic unrelenting pain.

Subjective analyses

The results for the subjective rating analyses did not reveal any differences in the levels of arousal, anxiety or discomfort across the three treatment periods and these results are consistent with those of the earlier experiments. In terms of the side-effects mentioned, the different reactions to treatment reduced across the periods for the reflexology treatment, but in the sham TENS (control) treatment there were consistent results for improved sleep in two of the seven subjects, likely indicating a level of relaxation from their encounter. Most of the subjects enjoyed their reflexology treatment experience and this may suggests a possible benefit for future pain management.

Conclusion

This experiment has shown that ongoing reflexology treatments may produce an increase in the anti-nociceptive response. There was a general trend for an increase in the mean pain threshold and tolerance which was similar to the findings in the earlier experiments of Chapters 4 and 5a. However, there was some drop-off in the cumulative effect on pain tolerance and this may be due to the small number of subjects in the experiment and the large variability in responses. The effect of standard reflexology on basal physiological function showed there was no evidence for a cumulative effect on either heart rate or blood pressure. Further research on a larger cohort of different groups over an extended period may demonstrate a more conclusive outcome.

CHAPTER 8

GENERAL DISCUSSION

8.1 INTRODUCTION

The principal aim of this thesis was to test whether reflexology treatments could attenuate pain threshold and tolerance in an acute ice pain experiment with healthy human subjects.

8.1.1. Introduction

Pain is considered a problem of global proportion and is an ongoing medical concern, not only because the costs are greater than almost any other health condition, but because the number of people affected by chronic pain alone, accounts for more than 10% of the UK population (Phillips, 2009). Furthermore, it has been suggested that some forms of acute pain are increasingly difficult to manage (Stephens *et al.*, 2003) and the side-effects to current pain medications has been implicated in the search for alternative methods of pain relief (Ernst, 2005, Brunelli and Gorson, 2004). Pain ranks as the highest concern both physically and emotionally in cancer sufferers (Peace and Manasse, 2002) and many of the Complementary and Alternative Medicines (CAM) have become increasing popular, particularly in palliative care, where there is a need for both emotional and physical support (Foundation for Integrated Health, 2000, Thompson and Feder, 2005). Reflexology is one of a number of complementary therapies becoming more commonly used in healthcare and is gaining in importance, particularly for clinical conditions (Wilkinson, 2002). In the clinical setting, reflexology takes a holistic approach to the treatment of pain so that it is reviewed from multiple levels of concern to the patient. Treatment generally includes a complete 'package of care' reviewing lifestyle, diet and exercise and thus addresses the possible cause and not just the presenting symptoms. This research presented a challenge to examine the benefits of reflexology for the management of pain in a laboratory environment without the benefit of the care package or the holistic approach.

As is usual for research, there were a number of challenges and other issues that had to be dealt with and some have already been discussed. However, it is appropriate at this point to reiterate some of those issues and challenges and to elaborate the effects they had on the overall outcomes of research.

8.1.2 Challenges and Limitations

Recruitment challenges

The recruitment of subjects set the greatest challenge of all in these experiments. In the first three experiments (Chapters 3, 4 and 5a) all of the subjects were unpaid volunteers. Further recruitment to the experiments was extremely difficult and for the mechanical reflexology experiment (Chapter 6) and the chronic ice pain experiment (Chapter (7), a monetary incentive was arranged. In offering such an incentive however, it is possible that a completely different type of volunteer was recruited, which may have had an effect on the experimental results. It is probable that part of the reluctance in people to volunteer may have been the ice plunge, but may also have been the total time commitment required for participation. The recruitment was made even more difficult because some of the subjects who did volunteer were unable to attend at the same time of day for the different treatments, and it is usual in experiments of this type to maintain a certain level of constancy.

Recruitment bias

There was a large bias toward a female population in this research with a ratio of 6:1 females to males, but an attempt to recruit more males into the study met with some resistance. Those who did volunteer either did not attend their scheduled appointment, had pain threshold levels of 300s in the control treatment or provided an excuse not to participate. The ratio of females to males fits the model for seekers of CAM therapies but it does not necessarily encompass a good selection of the general community (Ernst and White, 2000). On the plus side however, although women are said to have reduced pain threshold and tolerance for experimentally induced pain in comparison to men (Jackson *et al.*, 2005, Fillingim, 2005), they are considered to be the best human model for pain studies. Furthermore their responses may be more clinically relevant than for males (Fillingim *et al.*, 1999, Greenspan *et*

al., 2007) so that the results obtained in this research study will likely transfer to a clinical environment.

Attrition rate

The rate of attrition in randomised clinical trials is said to affect the credibility of the results and in many non-drug trials the attrition rates can vary by as much as 20% (Kane *et al.*, 2007). In the largest controlled trial of reflexology in which 243 subjects were recruited, attrition was just 3% (Poole *et al.*, 2007) whilst in a study of 503 subjects using auricular acupuncture for alcohol dependence, the attrition rate was 29% (Bullock *et al.*, 2002). In this research study the attrition rate was 11% overall and given the type of experiment the subjects undertook, it does not seem unreasonable. The reasons for attrition varied between the experiments but included such things as, a) the time commitment was too great, b) dislike of ice pain, c) inability to attend in the timescale allotted to the experimental sequence, d) did not meet inclusion criteria following initial consultation.

Pain threshold range limitations

The normal range ± SD for pain threshold was found to be 15.0 ± 7 – 22.0 ± 19s (Ashton *et al.*, 1984, Johnson and Din, 1997, Smith *et al.*, 2008) and so any subject participating in any of the experiments, who demonstrated pain threshold values higher than the 40s in the control group, were eliminated from the analysis and this was probably due to non-compliance, see below. This added to the attrition rates for the experiments and to the effects on the statistical analysis, since it was only after they had participated in the experiments that such values could be established.

Compliance

Subjects were advised not to partake of caffeinated drinks of any sort, prior to attending the experiments and some of the subjects did not comply with this request. This may have changed their pain threshold results to reflect scores that were higher than the normal range. Other subjects were unable to complete the experimental procedures within the allotted timeframe of the experiment, *i.e.* breaks in between scheduled visits were longer than one week. Some were unable to attend at their scheduled time, resulting in attendance at a different time of day to their first visit. Furthermore, it is also possible that some of the subjects did not follow the ice

plunge instructions correctly. Such non-compliance with procedures and anomalies with pain threshold values meant a further loss of subjects adding to the recruitment problems and reducing further the number of subjects included in the analyses.

Non-specific effects of reflexology treatment

One of the possible major limitations in any study where there is close contact between a patient and the therapist providing the treatment, is the relationship between them (Ong and Banks, 2003). Such a relationship has been interpreted as having a large placebo effect. Indeed, being listened to is an extremely important part of the healing process (Brody, 2000). In order to avoid some of the pitfalls associated with the patient-therapist relationship, subjects in this research study were discouraged from discussing their personal health issues and there was no attempt to provide support on health matters. Subjects were free to talk throughout the experimental periods except during the ice plunge. Not all subjects wanted to talk, some were quiet, some more chatty. Under the different trials however, they would talk as was appropriate to their general personality. A single therapist provided the treatment for all experimental conditions and this is regarded as a good method of controlling outcomes, and is certainly not exceptional in studies of this type (Castel *et al.*, 2007). The difficulty with such an arrangement is that a single therapist provides no personality variable and no treatment variable and so does not represent the true population of practitioners. One may argue therefore that the results may be attributed to the skills of the therapist and not the treatment (Hodgson, 2000) and as such this becomes a limitation to the experimental outcomes.

8.1.3 Selection of suitable control methods

It is well known that effective control methods are extremely difficult to achieve in CAM treatments and much of the research literature for reflexology claims to use control methods of reflex points on the feet that are unrelated to the area of treatment (Brygge *et al.*, 2001, Evans *et al.*, 1998, Mur *et al.*, 2001). However, in these experiments the whole foot was used to perform the reflexology treatments and so finding a suitable control treatment was extremely difficult. The literature for acupuncture experiments has shown similar difficulties in this regard. For example,

Ashton *et al.* (1984) used an orally administered lactose tablet as the control for acupuncture, whilst others have used a relatively new control method known as the Park Sham Device for acupuncture (Park *et al.*, 2002). In reflexology experiments, investigators have used foot massage as a control treatment but have found when measuring physiological function, that the treatments were too alike to differentiate the results (Hodgson, 2000, Quinn *et al.*, 2007). This research required a method of control that would not contaminate reflex points on the feet, *i.e.* 'sham reflexology', but one that would be believable as an active treatment for experiments of this type. Other methods of control were considered, for example simply holding the feet, but this was deemed inappropriate because it was felt that subjects would too easily detect an inactive treatment. Hand reflexology was also ruled out because the hand was being used for the ice immersions and thus, this may have altered sensitivity within the limb.

When reviewing the literature on CAM therapies it was noted that a sham Transcutaneous Electrical Nerve Stimulation (TENS) had been used successfully in studies comparing the use of different frequencies of TENS in pain management (Chesterton *et al.*, 2003, Claydon *et al.*, 2008). It was important that the subjects bought into the idea of the control treatment, and Kaptchuk (2000) has shown that 'medical looking' devices can increase the placebo effect in clinical trials. In order that the subject believed in the treatment, a device that outwardly convinced them they were receiving an active treatment was required. The Malden Electronics Digitial Timer device (Figure 2.2, Chapter 2) met that requirement and in order to further convince the subjects of an active treatment they were led to believe that the TENS equipment could stimulate nerve fibres that do not exist, *i.e.* they were told that TENS activates the d-delta 2 fibres. They were also told that some forms of TENS were barely perceptible and that they may only sense a very light tingling sensation, or in some individuals, nothing at all. To encourage the perception of active treatment, dials on the equipment were tweaked from time to time and subjects were asked if they experienced an increase in the sensation. The vast majority of subjects believed the equipment was a real CAM treatment and this was reflected in the subjective outcomes for the experiments in which it was used.

A ‘no treatment’ control method was used in Chapter 5a in order to observe the effects of reflexology over and above that of the placebo (sham TENS). Ideally the experimental design should have included both the placebo and the ‘no treatment’, together with reflexology and a positive control such as active TENS. However, because of the difficulty in recruitment this design was untenable. However, it was possible, because of the similarities in the study designs, to retrospectively compare the results of the sham TENS from Chapter 4, with the no treatment control used in Chapter 5a. The analysis (Table 5.11a, Chapter 5a, Section 5.4) showed there were no significant differences. Whilst neither the sham TENS nor the no treatment controls are equivalent to sham reflexology, there is evidence that massaging the feet and using non-defined reflex points may cause some analgesic effect (Grealish *et al.*, 2000, Mur *et al.*, 2001).

8.1.4 Ice pain

The selection of an appropriate mechanism for inducing acute pain in healthy human subjects was of paramount importance to this research in order to achieve both physiological and psychological effect. Ice pain has previously been used in experimental pain conditions for both acupuncture (Ashton *et al.*, 1984) and hypnosis (Houle *et al.*, 1988) and provides a valid reference in clinical pain (Chen *et al.*, 1989). It is widely used in cardiac medicine to establish vascular regulation (Mizushima *et al.*, 2003, Siegrist *et al.*, 2006) and because of its unpleasantness mimics autonomic reactions normally associated with chronic pain (Mitchell *et al.*, 2004). Measurements were recorded for pain threshold (the least amount of pain a subject can withstand before finding it painful) and pain tolerance (the greatest amount of pain a subject can withstand before taking evasive action). There is some evidence that subjects do not habituate to cold pain (Ingersoll and Mangus, 1992, Agostinho *et al.*, 2008) but to control for this effect, a time limit of 5 minutes was placed on the ice immersion test. This method of inducing pain was considered the most reliable for the measurements required of the study, *i.e.* pain threshold and tolerance, as it involves both the Aδ and C-fibres, without creating any lasting tissue damage to subjects involved in the experiments (Simone and Kajander, 1997, Hirsch and Liebert, 1998). Other methods of inducing pain in the subjects were considered, such as pressure (Chesterton *et al.*, 2003, Sjolund and Persson, 2007, Kowalczyk *et*

al., 2009), heat (Kong *et al.*, 2005, Agostinho *et al.*, 2008) or ischemic pain (Benedetti *et al.*, 2003) but such methods do not have the same validated reliability and ice pain is considered to have more clinical relevance (Kim *et al.*, 2004).

8.2 EXPERIMENTAL RESULTS

The experiments carried out in this research are the first of their kind in the field of reflexology. There are no previous studies in the literature for measuring the effects of reflexology on acute pain induced in healthy human subjects. In addition, measurements were taken for the pressure applied during reflexology stimulation (shown in Miscellaneous Chapter) and the physiological responses to reflexology. There are no previous studies where these measurements have been recorded as a stand-alone measurement in reflexology.

Pain threshold and tolerance

Chapter 4

Change from baseline results in the first of the ice pain experiments (Chapter 4, Section 4.4.1, Figure 4.1) showed there was a significant increase in pain threshold ($F_{(1,14)}$=4.5958, p<0.05) following the reflexology treatment when compared to sham TENS (control), together with a significant effect over time ($F_{(3,42)}$=3.9736, p<0.05). Since both the active and control treatments increased together over time, one may propose this was due to habituation to the ice. However when the effects of habituation were examined in four subjects who underwent repeated daily ice immersions over four days (see Appendix E), the results showed subjects did not habituate. If there was habituation to the ice pain, then one would expect to see this in both pain threshold and pain tolerance and this is not apparent from the results of Chapter 4, Figures 4.1 and 4.2. Furthermore, the results for pain tolerance revealed a significant increase in the anti-nociceptive effects of reflexology treatment ($F_{(1,14)}$=5.1095, p<0.05) (Chapter 4, Section 4.4.2, Figure 4.2) together with a significant effect of time ($F_{(3,42)}$=3.2505, p<0.05) which occurred at between 60 and 120 min post treatment. One may conclude therefore, that when compared to a sham TENS (control), which produced a nociceptive effect on pain tolerance (Figure 4.2),

reflexology significantly increased the anti-nociceptive effects of both pain threshold and pain tolerance.

Chapter 5a

In the second of the ice pain experiments (Chapter 5a) the raw data results were not clear-cut. The first ice pain experiment (Chapter 4) utilised a standard reflexology procedure and compared it with a sham TENS procedure. In the second ice pain experiment however, (Chapter 5a) a slightly different procedure was adopted. There were two modalities of reflexology, a standard and light pressure and these were each compared to a 'no treatment' control. When the results for Chapter 5a were analysed using the change from baseline approach they were similar to the results observed in Chapter 4, showing an increased pain threshold for both standard and light reflexology when compared to the no treatment control ($F_{(2,48)}$=4.7152, p<0.05). There was also a significant effect of time for both standard and light reflexology ($F_{(4,96)}$=4.2059, p<0.01). At 90 min post treatment the standard reflexology treatment increased the pain threshold by as much as 13s, whilst light reflexology increased pain threshold by 9s when compared to the no treatment control at this time. The results for pain tolerance however do not match those observed in Chapter 4 and showed no significant differences for either standard or light reflexology when compared to the no treatment (control).

There were however, large inter-individual differences in pain responses as shown by the individual subject graphs (Chapter 5a, sub-section 5.3.1, Figures 5.1a and 5.1b). The data showed that if a subject responded to treatment with a high pain tolerance value at 30 min and low pain tolerance value at 120 min, and another subject showed response values that were low at 30 min and high at 120 min, the results would cancel one another out if they were averaged against one another in the normal way, and produce results that were not valid. Thus, representing the data for the group effects as mean ± SEM with respect to time probably produces a distorted view of the results.

To address such variations it was necessary to carry out further analysis on the results and therefore the Pitman permutation test was adopted. This test is used to test for equal variances in paired data (Pitman, 1939, Bland, 2000). Furthermore it

helps provide an exact distribution free significance, thus controlling for errors in cross-over designed trials (Gresty *et al.*, 2003, Good and Xie, 2008, Howell, 2010). Results of the Pitman test revealed that both standard and light reflexology significantly improved the anti-nociceptive effects for pain threshold (Table 5.4a) but only the standard reflexology improved the anti-nociceptive effects for pain tolerance (Table 5.5a), which is in keeping with the results of Chapter 4.

Chapter 5b

Despite using these various analyses the large variations shown in Figures 5.1a and 5.2a would suggest that the data cancel one another out, as mentioned above. Therefore another alternative and perhaps controversial method of analysis was presented in Chapter 5b. Ashton *et al.* (1980) described a method which took into account the biphasic effects of treatment; similar to those represented by Chapter 5a. A modified version of their method was used to analyse the data further. In this modified method, three points were selected, i) baseline, ii) minimum – representing the change in pain threshold and tolerance responses relative to the control that produced the minimum value and, iii) maximum – representing the change in pain threshold and tolerance relative to control that reflected the maximum values. The results showed significant increases in the mean maximum pain threshold and tolerance (s) values thus, exhibiting an anti-nociceptive effect (Figure 5.1b and 5.2b) for both standard and light reflexology. However, the results also showed the possibility that there was a initial but small nociceptive effect of treatment on mean minimum pain threshold for standard and light reflexology and on mean minimum pain tolerance for light reflexology. This may be because some subjects found the pressure of the reflexology painful and thus some responded better to the lighter touch. The data from the first ice pain experiment (Chapter 4) were clear cut, but the results were reanalysed to conform to the methods used in Chapter 5b, as using the method of mean ± SEM with respect to time, small changes may have been lost. The results are shown in Appendix C and reveal similar responses to those observed in Chapter 5b. The only difference for the data of Chapter 4 was that there was no significance on mean minimum pain threshold or tolerance levels. This suggests that the weak nociceptive effect established in Chapter 5b does not occur in all subjects and may therefore be dependent upon the subject themselves.

One may question the justification of the validity of this analytical approach, suggesting that the data were biased toward maximum values for standard reflexology. However, in defence of this, the maximum values for the 'no treatment' control group were matched with the scores obtained for the standard reflexology treatment after they were statistically evaluated. Thus, if the analysis used was biasing results then the 'no treatment' (control) would produce statistically higher values. The results showed that this was not the case (see Chapter 5a, Section 5.4, point 5), thus ensuring that the method used, was statistically valid.

The analyses of the data in terms of the minimum and maximum values for pain threshold and tolerance, revealed no differences between the two modalities of reflexology, and the maximum latencies for pain threshold and tolerance. This result is in contrast with the literature for both TENS and acupuncture, where the strength or intensity of the stimulus is known to significantly affect the outcomes (Ashton *et al.*, 1984, Chesterton *et al.*, 2003, Claydon *et al.*, 2008, Le Bars and Willer, 2002).

This modified method of analysis therefore, produces two very clear responses, a nociceptive response and an anti-nociceptive response. By using this method one can fully appreciate the biphasic effects of reflexology that under normal methods of analysis, *i.e.* mean ± SEM with respect to time, would have missed. This method of analyses could be used by other CAM therapies, such as acupuncture where other such biphasic responses have been observed (Backer *et al.*, 2002, Kong *et al.*, 2005).

Responders and non-responders to reflexology

The individual subject data showed that although there was a difference in the latency of response, there was also a difference in who did and did not respond to treatment. It is not the first time this effect has been demonstrated in complementary therapies and in Western populations approximately 20-30% will not respond to CAM treatments (Carlsson, 2002). A wide magnitude of responses has been demonstrated in acupuncture, TENS and hypnosis experiments (Ashton *et al.*, 1980, Sandrini *et al.*, 2000, Carlsson, 2002, Koke *et al.*, 2004, Jensen and Patterson, 2006, Claydon *et al.*, 2008). However this situation is not unique to CAM therapies and Lasagna and Beecher, quoted in (Wan *et al.*, 2001) are said to have documented the inability in up to 33% of human patients to respond to the pain relieving effects of

10mg of morphine, whilst others have observed the existence of responders and non-responders to non-steroidal anti-inflammatory medications as reported by Scott, quoted in (Wan *et al.*, 2001).

To further refine the analysis in this subject group they were divided into responders and non-responders, based on their pain tolerance value. For example, any subject showing an increase of more than 10s relative to control for standard reflexology, in any of the post treatment intervals was included as a responder. Conversely anyone whose pain tolerance for standard reflexology was less than 10s relative to control was classified as a non-responder. Having established the criteria for selecting responders and non-responders, their results were subjected to the minimum and maximum criteria mentioned above. The results for the responders were similar to those observed when all subjects were included. Surprisingly, those subjects classified as non-responders showed a very small but significant increase in minimum pain threshold and maximum pain tolerance following standard reflexology but not for light reflexology. In this instance, it may be that some of the subjects respond only to the standard reflexology, whilst others respond to both. Kong *et al.* (2005) showed when assessing the psycho-physiological outcomes to 7 minutes of manual, electro, and sham acupuncture treatment that out of 11 subjects who underwent the three conditions, 5 were considered responders and 6 were considered non-responders. Of the 5 responders only 3 showed a significant analgesic response to manual acupuncture whilst the other 2 responded to electro-acupuncture. They concluded by adding that the effects of acupuncture may be dependent on both the subject and the mode of administration, indicating that the response to acupuncture may be a trait characteristic. In summary these data raise another important aspect to reflexology research and demonstrate that whilst light reflexology seems suited to some subjects, others respond better to standard reflexology.

Chapter 5b was the only experiment in which responders and non-responders were separated for analysis and one may question the validity of doing this, however in the other experiments the subject groups were too small and so dividing subjects may have introduced large errors in the results. Dionne *et al.* (2005) suggest such a method of analysis in pain experiments is a much better way of measuring individual

responses to analgesia. In particular individual analysis identifies variation in efficacy that would otherwise be undetected.

It is not known what predisposes an individual to respond to a certain treatment, but there is some suggestion that genetics may play a role. For example, Moore *et al.* (2009) have indicated that less than 50% of patients with neuropathic pain achieve satisfactory pain relief with just one therapy. There is also evidence that codeine has no effect if an individual is unable to metabolise it to morphine (Moore *et al.*, 2009, Williams *et al.*, 2002). The effect of responders and non-responders make it extremely problematic for CAM research to establish the true effects of treatment and future studies should take this point into consideration when calculating the numbers needed to treat and evaluating results. Nonetheless the results reflect the differences one would normally expect from a population of pain sufferers where there are diverse and multi-dimensional variations in the pain experienced. Furthermore these results support the idea that '*one size does not fit all'* (Bandolier, 2003, Adams and Field, 2001, Apkarian *et al.*, 2009), although they are consistent with those achieved by others for reflexology, acupuncture and TENS.

Chapter 7

To test whether subjects became tolerant or sensitised to the effects of reflexology and whether the results observed in Chapters 4 and 5a could be replicated, the chronic ice pain experiment of Chapter 7 observed subjects undergoing standard reflexology treatments or sham TENS (control) over three consecutive weeks before being switched to the opposite treatment for a further three weeks. The data were first of all analysed using a 3-way ANOVA on the mean ± SEM with respect to time and subsequently as a change from the pre-treatment baseline as per previous chapters. The results of the ANOVA's showed there were no significant effects of reflexology treatment on pain threshold or tolerance when compared to the sham TENS (control). There was however a trend toward an improvement in pain threshold by the third week of treatment, suggesting the possibility of a cumulative effect of treatment. This is consistent with data observed by Poole (2007) when comparing six weeks of reflexology, primary muscle relaxation and usual care in 243 low back pain patients. The results for pain tolerance were similar but showed a general decrease in the effects of reflexology as the weeks progressed. The sham

TENS (control) treatment on the other hand appears to increase the nociceptive response showing scores that were below the baseline (Figure 7.2). The results are similar to the earlier ice pain experiments carried out in Chapter 4 and 5a but one should note that this was a small group of subjects with previous experience of both reflexology and sham TENS (control). In addition the gap between their first treatment and their cross-over into the second treatment was a minimum of 4 weeks and this may well have impacted on the variant scores at the individual time points between the two populations (Table 7.3 and 7.4).

Further analyses, using the minimum and maximum method was carried out and is shown in Appendix H. The results for this small group of subjects showed a small nociceptive effect of standard reflexology on the mean minimum pain threshold which is most apparent in period 2 (Figure H1), but a significant improvement for the mean maximum pain tolerance, shown in period 1 (Figure H4).

Data for the cumulative effects of reflexology in the management of pain is scarce and any available data shows inconsistencies in effect. For example, Siev Ner *et al.* (2003) compared reflexology and calf massage with non-specific calf massage alone and showed decreases in the intensity of parasthesia that remained significant at a 3 month follow-up, in 63 multiple sclerosis sufferers treated over eleven consecutive weeks. Poole *et al.* (2007) on the other hand, in a study of 243 chronic low back pain patients, was unable to demonstrate significant differences following six weeks of reflexology when it was compared to primary muscle relaxation (PMR) and patients usual care programme. However, despite a pain reduction in all groups over time, the greatest effect, albeit non-significant, was shown in the reflexology group. Poole considers the possibility that the lack of difference between the groups could have been due to the additional CAM treatments that patients in the PMR group and non-intervention group received during the experimental period. In a study comparing four weekly reflexology sessions with four weekly friendly visits in a cross-over study of 21 patients with mild to moderate dementia, Hodgson and Anderson (2008) were able to show significant reductions in observed pain scores measured using the Checklist of Nonverbal Pain Indicators. This scale is a behavioural observation scale for non-verbal older adults with severe cognitive impairment and contains six items rated as either presence or absence of pain. There is little to add to the literature from this small experimental group except to add that perhaps the order of treatment

may have an effect on the results. It is well known that a placebo (sham TENS) given before an active treatment is less effective than when given after an effective treatment (Benedetti *et al.*, 2003). Further research on the order effects, with large cohorts and different groups of subjects are recommended.

Chapter 6

Manually applied reflexology treatments are the most common method for providing treatments. However, there is an increasingly profitable market in the commercial industries for mechanically applied reflexology treatments. In Chapter 6 a 'Scholl Ionic Rejuvenator Foot Massager' (see Figure 2.3) was used to provide reflexology-like stimulation to healthy human subjects in an ice pain experiment. The equipment was composed of a curved bed of raised nodules with an additional circle of vibrating acupressure pads located on either side. The equipment produced two massage modes, high and low, and the low mode was used for the experiments with a running time of 20 min. Attention is drawn here to this short running time which may have introduced another variable. There was a manufacturer's recommended time limit of 20 min so these guidelines were followed. The mode of administration may prove to be a factor in the efficacy of reflexology treatments, and this was a simple way of testing its effects. Manually applied reflexology is more discriminative and is thought to elicit responses through phasic stimulation of the numerous Meissner corpuscles found in the foot sole (Kennedy and Inglis, 2002). Mechanical reflexology stimulation probably produces a stimulus that is much less discriminative and subsequently less likely to elicit a response (Tombimatsu *et al.*, 2000).

The ANOVA on the mean ± SEM with respect to time revealed there were no significant differences between the two treatments. There were however significant differences in the pain tolerance baselines, thus ANOVA on change from pre-treatment baselines would have invalidated any post treatment effects (van Breukelen, 2006). Therefore ANOVA as a change from normalised baselines was carried out and results from this analysis also revealed no significant effects on pain threshold or tolerance. After carrying out the Pitman test to test for equal variances of the paired data, the results showed no significant effects of mechanical reflexology on pain threshold. The test did reveal significant effects on pain tolerance (Table

6.5) but there were large standard errors and this was a very small group of subjects and one would recommend caution when interpreting the results. Of importance however, is the fact that one of the subjects in this group revealed pain tolerance values that reached the maximum allowed for the experiment (300s) and this may have compromised the result. To further evaluate this, the data were analysed using the minimum and maximum method adopted in Chapter 5b and these results are shown in Appendix F.

This method of analysis supports the notion that mechanical reflexology may increase the nociceptive response and are in direct contrast to the results observed in Chapter 5b, for manually applied reflexology. For example, the mean maximum pain threshold, albeit non-significant, was reached before the mean minimum pain threshold (Figure F1) and this shows that mechanical reflexology was producing a much greater nociceptive response in the subjects. One might speculate that the floating heads on the equipment caused some form of irritation to the subjects, especially since the foot arch, receiving the stimulation from the floating heads, is an extremely sensitive area of the foot (Andersen *et al.*, 2001). There are a limited number of receptor units in the area of the foot arch (Kennedy and Inglis, 2002) and perhaps without a defined or rather precise stimuli, it may be that the mechanical reflexology simply irritated the tissue. The difference in the stimulation parameters, the relaxation response attributed to manual reflexology and the normal responses achieved by touch are likely to contribute to the overall effect (Whipple and Komisaruk, 1985). However, if one makes an assumption that the mechanical stimulus is affecting mechanoreceptors in a similar way to manually applied treatments, we might speculate that the treatment given by a therapist is of greater therapeutic value and a comparison of reflexology with mechanical reflexology may be a good test for future experiments.

Autonomic responses to reflexology

The single most common theme in the reflexology literature is that any effect is due to relaxation. One would therefore expect to see significant changes in the autonomic nervous system during and perhaps following treatment. In Chapter 3 measurements were recorded for heart rate, blood pressure and temperature, all of which are functions of autonomic activity thought to be involved in the stress

response. Ice pain is known to induce stress and in a comparison study in which participants were subjected to stress with a cold pressor task (ice immersion) and a cold pressor task alone, the stress condition was shown to produce higher systolic, diastolic and heart rate values than the cold pressor task alone (Al Absi and Petersen, 2003). Observations were made therefore in order to discover whether standard reflexology without ice pain would induce stress in the subjects and thus provide evidence to critically analyse future ice pain experiments.

The effects of reflexology on blood pressure

The results of the experiment in Chapter 3 revealed there were no significant between group effects of treatment on systolic pressure but there was a treatment x time interaction on diastolic pressure ($F_{(3,39)}$=3.2010,p<0.05) with a significant increase at 40 minutes post reflexology treatment. The increased diastolic reading (Chapter 3, Section 3.4.2) at the 40 minute post treatment period was transient and one possible reason for the increase may be the change in body position from reclined to upright or perhaps to an increased level of arousal (Colloca *et al.*, 2006). In general, there were no significant effects of reflexology on blood pressure across the experiments and this is consistent with the literature (Mackereth *et al.*, 2008, Hattan *et al.*, 2002, Wang and Keck, 2004, Wilkinson *et al.*, 2006)

The effects of reflexology on heart rate

When reflexology was given without ice pain as a stressor (Chapter 3), results showed that standard reflexology significantly lowered heart rate during and following the treatment phase of the experiment ($F_{(1,13)}$=10.2677,p<0.01). Similar effects have recently been reported in the literature for acupuncture (Backer *et al.*, 2002, Sakai *et al.*, 2007, Uchida *et al.*, 2008) and indeed Sakai (2007) demonstrated, in an investigation to review the relationship between acupuncture and autonomic changes, that acupuncture manipulation significantly decreased heart rate during but not post acupuncture manipulation. These results support the general hypothesis that reflexology can induce a state of relaxation in the subjects but also suggest that it has an effect on the autonomic activity of the heart. Future studies should evaluate this under clinical conditions.

Of interest however, is the effect of reflexology in the second ice pain experiment (Chapter 5a) where two modalities of reflexology were utilised and compared with a no treatment (control). The results showed a significant decrease in heart rate pre ice plunge, post treatment (Section 5.3.3a) for both the standard ($p<0.05$) and the light reflexology treatments ($p<0.01$) when compared to the no treatment control. Furthermore, following the light reflexology treatment the effect was maintained for a further 90 min post treatment. Although the ANOVA did not show any significant differences between the treatments for heart rate following the ice immersion, a Pitman test did reveal a significant effect of light reflexology at t=60min ($p<0.05$), but this was not maintained for the remainder of the experimental procedure. Rather interestingly, there was no relationship between decreased heart rates and increased pain threshold and tolerance. This finding indicates that changes in heart rate are not related to the analgesic effects of treatment and this is consistent with the literature (Martinez-Gomez *et al.*, 1988, Bossart *et al.*, 2007).

There has been much discussion in the literature surrounding the intensity of a stimulus, which was found to positively correlate with analgesia in both TENS and acupuncture experiments (Chesterton *et al.*, 2003, Backer *et al.*, 2002, Claydon *et al.*, 2008, Han, 2004). However, the large inter-individual differences in the responses of subjects to stimulus strength were noted in the experimental procedures of Chapter 5a. The data showed that even a light touch reflexology treatment was effective in attenuating the pain from ice immersion, whilst at the same time significantly lowering heart rate. Although the light touch reflexology treatment was not evaluated in the physiological experiment, studies that review the effects of light touch reflexology on basal physiological changes may provide appropriate evidence for clinical practice which demonstrate its effect on the autonomic nervous system.

Temperature as a measure of physiological change in reflexology stimulation

Core temperature offers an insight into the effects of stress on the body systems, including stress associated with pain and inflammation (Butler and Finn, 2009, Black, 2002, Dhabhar, 2002). Indeed psychological stress is known to increase body temperature and blood pressure (Marazatti *et al.*, 1992, Endo and Shiraki, 2000, Vinkers *et al.*, 2008). The results of the experiment carried out in Chapter 3 did not reveal any significant changes in core temperature, indicating that subjects did not

find a standard reflexology treatment stressful. In addition, the effects of daily ice immersion on core temperature was measured (Appendix E) and there were no significant changes in core temperature over the course of the four day experiment.
In conclusion, the effect of reflexology treatment suggests there were no indications of a physiological stress response.

Measurement of pressures applied during reflexology stimulation

In Appendix G the effects of applied pressures during reflexology are described. Since the work is not quite complete it was inappropriate to place the text in the main body of the thesis. However, the work is both novel and interesting and therefore worthy of discussion. It is important to mention that there are no previous experiments described in the literature for the Chapter marked as Miscellaneous. Pressure applications in reflexology treatments vary between therapists, between foot types, age of patient, texture and tone of the tissue and area under treatment. There were many difficulties in acquiring the appropriate tools to measure reflexology pressure application in situ, but the Tactilus® Freeform system offered the best approach. The equipment used in the experiments involved the use of specific sensors which measured the electrical resistance between the two contacting surfaces, *i.e.* the medial thumb and the foot. Two foot types were discussed *i.e.* a normal healthy foot and a calloused foot. The measurements were obtained for a static holding pressure value, a standard dynamic pressure value and a light dynamic pressure value. Four regions of the foot were examined using the three different pressure modes, including the medial edge, foot arch, heel and ankle regions. The two dynamic pressure modes were selected in order to obtain values for standard and light reflexology treatments, as these were the two modes of reflexology used in the experiments discussed in Chapter 5a. The results showed there were similarities in the general trends for the static pressure but the normal healthy foot exhibited many peaks (periodic type response) whilst the calloused foot type showed a flat transient with less variation. In the standard dynamic pressure measurement, the cyclic pressure transient applied to the normal healthy foot followed the actual movements employed in the application of the pressure, whilst the periodicity varied for the foot regions treated. In the calloused foot however, the cyclic response of the transient did not exhibit the peaks shown in the normal healthy foot. Similar response patterns were observed with the light reflexology technique but the P_{max} (average maximum

pressure) pressure values were reduced by ≥50%. The pressure values observed during this experiment are in agreement with those for acupressure (Tedeschi, 2000) and foot acupressure (Blate, 1982) but showed distinct variations according to the underlying physiology, the texture and tone of the foot. The implications of these data indicate that perhaps future reflexology experiments should incorporate a variety of foot types in order to observe whether there is any correlation between the effects on pain threshold and tolerance and the type of foot treated. Furthermore, the effect of pressures applied by different reflexologists and a larger sample of foot types would provide useful information for future studies.

Subjective analyses as a measurement of the pain response in reflexology

Subjective responses to pain are considered the single most reliable index of the magnitude of pain (Chapman and Turner, 1986, Coghill *et al.*, 2003) but there are inconsistencies in the reflexology literature in which the subjective level of anxiety has been evaluated. Some researchers have demonstrated that it produces a significant reduction in anxiety (Hodgson and Andersen, 2008, McVicar *et al.*, 2007, Stephenson *et al.*, 2000, Stephenson *et al.*, 2007), whilst others have shown only transient effects on anxiety (Mackereth *et al.*, 2008, Quattrin *et al.*, 2006). Subjects who participated in these experiments did not show increased levels of anxiety or arousal when conducting ice pain immersions across the range of experiments. This may be due to the level of control they had over the ice plunge or perhaps to their general personality.

In Chapter 5a a modified version of the Eysenck Personality Questionnaire was used to assess whether the effects of extroversion and introversion (E-score) were correlated with pain responses. Subjects completed 41 questions of which 20 were related to the E-score. High E-scores suggest an extrovert, whilst low E-scores represent an introvert. The mean E-score of the 25 subjects who participated in this experiment was 13.25 ± 1.04 SEM, by comparison subjects in the Ashton *et al.* (1984) study which reviewed the effects of personality on acupuncture and TENS stimulation, showed E-scores of 15.2 ± 4.8 SD. Whilst both the Ashton *et al*. (1984) study and the ice pain experiment carried out in Chapter 5a may suggest that the majority of subjects were from an extrovert population, there was no correlation between personality and cold pain responses. Similarly, Ashton *et al*. (1984) also

found that there was no correlation between the E-scores and pain threshold and tolerance scores in their subjects. Rather interestingly subjects did not demonstrate any visually observed differences in their response to the standard and light reflexology, yet it was clear from their responses that a small group of subjects showed nociceptive responses in the early stages of the treatment and this may be due to personal preference for the depth of pressures applied.

In the first ice pain experiment (Chapter 4) however, there was a significant decrease in the perceived level of discomfort experienced during the ice plunge, which was not consistent across the other experiments. The possibility that this may be due to the lower number of ice immersions carried out in this experiment was considered, but the effect of tolerance to ice pain was measured to see if this affected the outcome (Appendix E). The results did not show that subjects become more tolerant to the ice pain after repeated plunging. Thus the non-significant difference in levels of discomfort seen in Chapter 4 cannot be attributed to this. It is likely therefore that the responses to the subjective elements of the experiments is a combination of personality variable, the level of control the subjects had over the pain experience and their general inquisitiveness in relation to the effects of reflexology.

The feedback questionnaires showed that a large majority of subjects indicated improved energy levels and improved sleep. Whilst this effect was seen in both sham TENS (control) and reflexology treatments, the greater effect was seen following reflexology. A recent randomised-controlled trial of reflexology has reported significant improvement in the quality of sleep in postpartum females (Li *et al.*, 2009), whose transition to motherhood often encounters sleep deprivation and sleep of poor quality. Sleep deprivation is a major concern for sufferers of chronic pain and can be extremely distressing (Tang, 2008). The percentage of patients visiting pain clinics reporting insomnia, or some other form of sleep disorder is as much as 53% and such a lack of good quality sleep is thought to have an effect on the immune system (Aggarwal *et al.*, 2006, Irwin and Miller, 2007, O'Connor *et al.*, 2009). Research to evaluate the effects of reflexology on sleep deprived pain sufferers would be useful and perhaps beneficial to the general well-being of patients in pain.

Clinical relevance of the research outcomes

The nature of these experiments made it somewhat difficult to evaluate the true clinical findings of the research but there is evidence that experimental pain responses in females are more clinically relevant than for males (Fillingim and Gear, 2004, Fillingim *et al.*, 1999), but this maybe pertinent to the type of pain induced. The limitation however is that these subjects were all healthy. They were subjected to laboratory induced acute pain without the normal psychological attributes of the pain experienced by many chronic pain sufferers attending pain clinics. The effect observed for reflexology showed an acute anti-nociceptive effect in the majority of subjects and a small nociceptive effect in a minority. However, most subjects underwent a single treatment of reflexology which may have proved insufficient for a clinically relevant result. Nonetheless reflexology appears to induce changes in some aspects of autonomic function which may prove to be of benefit to those who suffer from stress-related illnesses, including those in pain, but further research in this area is warranted.

The vast majority of experiments carried out using TENS, acupuncture and reflexology in the management of pain are often carried out against a background of drugs. The results from this research may therefore prove to be a useful adjunct to pharmacological options available in the management of pain, at least in providing the option to reduce the total intake of analgesics and in so doing, reduce the risk of unwanted side-effects (Pyati and Gan, 2007). Wiech *et al*. (2008) has indicated that patients who are more able to control their pain experience appraise it differently to those who can not. In today's society, providing patients with choice in the management of their pain is considered an option only to those who are readily able to afford it. Reflexology is certainly an option worth consideration but further experiments encompassing a chronic pain cohort with realistic life experience of pain would provide further scientific evidence for efficacy.

There is also much evidence that pressure applications can induce physiological change (Santos et al., 2003b, Fromy et al., 2000) in the body. This research has shown that reflexology stimulations produce maximum pressure values of 178 kPa which are known to initiate an exchange of ions or electrical activity in the cell membrane (Odman, 1989). The stronger the stimulus, the greater are the chances of

initiating an action potential (Neziri *et al.*, 2009) and if this is so, then it would certainly seem possible that reflexology has a place in changing the homeostatic environment. To measure this effect however, will require biochemical means, and this may be a relevant subject for future research.

Many experts in the medical field have suggested that the effects of CAM treatments are nothing more than a placebo response. Recent research has shown that placebo analgesia is mediated by both opioid and non-opioid mechanisms and this may make it difficult to carry out critical analysis of the effects of treatment (Benedetti, 2006b). There is without doubt a placebo element in all treatments, whether orthodox or complementary, and much of this is based on the relationship between the practitioner and the patient, the way in which the drug or treatment is presented to the patient and the general psychological state of the relationship. Nonetheless the results of this research show that reflexology has an effect over and above that of a placebo response and in so doing encompasses real effects of treatment.

Mechanism of action of reflexology

It is difficult to speculate on the mechanisms involved in reflexology stimulation and the mechanisms involved in pain modulation are complicated. Whilst the gate control theory has been implicated as a possible mechanism for acupuncture and TENS through the interruption of the pain pathway and the release of endogenous neurochemicals (Carlsson, 2002, Han and Terenius, 1982, Knardahl et al., 1998, Melzack, 1975b) there is still no convincing evidence that this system alone is involved in the attenuation of pain following reflexology. Indeed, when the large Aβ neurons from low-threshold traffic interrupt the pain signal of the smaller nociceptive Aδ and C-fibres, pain is attenuated, but in the case of reflexology stimulation, the tactile afferents may be overridden by a more powerful nociceptive stimulus if the perceived effect of reflexology is that of pain or discomfort.

The experimental results have shown both nociceptive and anti-nociceptive responses occur and it is likely therefore that there are a number of systems involved, including, the descending inhibitory system at a supraspinal level. Pain from the hand and foot are known to ascend the spinal cord at different levels and speeds, but simultaneously encode the tactile information within the cortex (Nicolelis *et al.*,

1998) which may suggest that ice pain can be overridden at a cortical level through conscious evaluation.

The nociceptive response does not occur in all subjects which shows that any effects of reflexology are real and not placebo. In fact it is possible that the reflexology technique causes the initial pain and may therefore be the result of a purely mechanistic function as shown through the diffuse noxious inhibitory control system. The 'pain inhibiting pain' effect is triggered from any body area outside the field of pain, in this case the hand. Depending on the magnitude of the stimulus, the type of stimulus and the nerves involved, one can alter the descending inhibitory pain mechanisms by counter-irritation, thus the reflexology may be producing such an effect.

There are marked similarities between the effects of acupuncture and reflexology as this research has established and any future investigations should consider biochemical markers, cardiovascular activity and electrophysiological measurements in its proposal.

8.3 CONCLUSION

The results of this research show that reflexology produces decreases in certain aspects of autonomic function and on its own does not induce a stress response but that it may do so under stressful conditions. There was a general trend showing that reflexology increased both pain threshold and tolerance in healthy human subjects exposed to acute pain through immersion of the non-dominant hand in ice. There were however many variables to take into consideration, not least of which were the individuality of the subject results and the small group sizes. These experiments have shown that reflexology produces a significant anti-nociceptive effect and in some cases may produce a small nociceptive effect. The results of these experiments also showed that reflexology produces a biphasic effect on pain threshold and tolerance which seem to be independent of any changes in autonomic function. The biphasic responses of the treatment were indicative of both a nociceptive and anti-nociceptive affect. The minimum and maximum method of analysis used in this thesis has shown that it is possible to extrapolate a level of detail in responses to

reflexology stimulation that would otherwise have been lost in the mean ± SEM relative to time. This is a significant and exciting result, since it provides a method of analysis that may be of value in future CAM research.

In the Miscellaneous Chapter a method of measuring the value of pressures applied during reflexology stimulation has been identified and this has highlighted the fact that analgesic responses may be induced and it may not be reliant on the strength of the stimulus applied but rather on the foot type and texture.

Whilst this study has provided some general insights into the efficacy of reflexology for managing acute pain, it is limited by the uncertainty of such contributory effects as the general effect of skin and tissue stimulation, the social interactions and the effectiveness of other therapists to elicit similar results. Of importance however, is that there was a general trend toward an analgesic effect which may be useful on its own and alongside analgesic medications to treat pain conditions.

MISCELLANEOUS CHAPTER

1. APPLIED PRESSURE AND REFLEXOLOGY STIMULATION

1.1 Fundamentals of Pressure

Elastic and plastic deformation of materials relate to stresses and deformations in solid bodies under pressure (loading forces). An elastic material is defined as one that will return to its original shape and size upon removal of the applied load, whereas if the material does not restore to its original state, *i.e.* before the load was applied, the material is said to be behaving plastically (Lee *et al.*, 2007).

When a force or pressure, P, is applied in a direction perpendicular to a surface of a body the stress produced in that body, is given by Equation 9.1,

$$P = \frac{F}{A} \tag{9.1}$$

where, F is the force, N, and A is the area, m^2.

The subsequent deformation of a body by the produced stress is defined as a ratio called strain, ε, Equation 9.2,

$$\varepsilon = \frac{\Delta l}{l_0} \tag{9.2}$$

where, Δl = change in length (m), l_0 = original length (m), the strain ε is unitless.

Application of pressure to a viscoelastic material *i.e*. one that has both elastic and viscous properties will result in a deformation, the degree of which is determined by both the pressure and the viscolelastic properties of the material.

The deformability of such materials is given by the Young's modulus (*E)* which relates the stress to the strain applied, Equation 9.3,

$$E = \frac{\sigma}{\varepsilon} = \frac{(F/A)}{(\Delta l / l_0)} = \frac{F l_0}{A \Delta l}. \qquad (9.3)$$

The greater the modulus *E,* the stiffer the material. Isotropic materials obey Hooke's Law which states that the extension or indentation of the material is proportional to the force applied. An idealised stress-strain curve of a material is shown in Figure 1.1. The proportionality is limited to the region O-P, the material is said to exhibit Hookean behaviour and the gradient of this region is equal to the Young's Modulus (*E*). Beyond the elastic limit, point EL, the material deforms plastically and eventually fracture occurs.

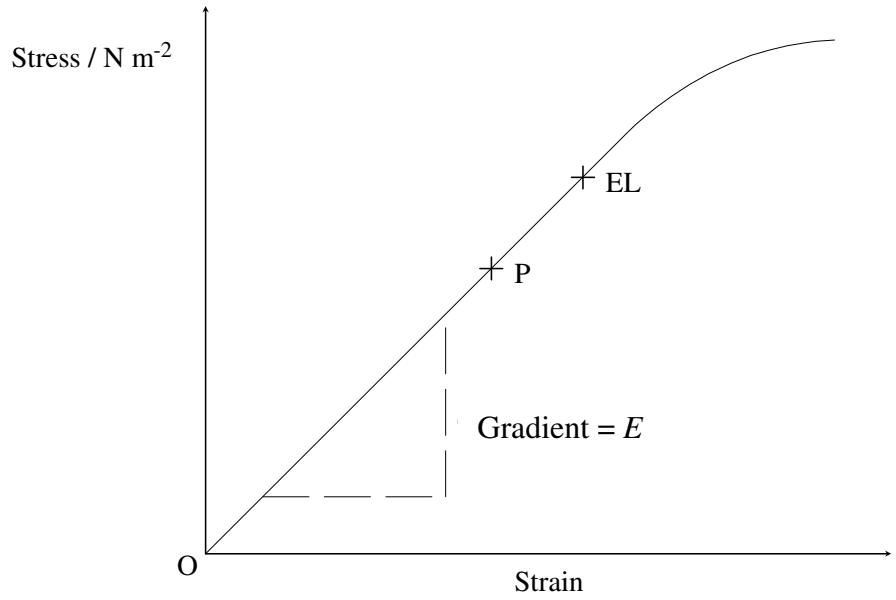


Figure 1.1: Idealised stress-strain curve

The Young's Modulus of a material can be obtained from force-indentation curves using models of Hertzian or Sneddon mechanics to describe the elastic deformation of two surfaces in contact under load (Hertz, 1881, Sneddon, 1965).

The Hertz model calculates the different relationships between the loading forces needed to create a given indentation depending upon the tips geometry, either (i) a sphere of radius *R*, or (ii) a cylindrical cone of opening angle α. When an infinitely

hard sphere of radius r, touches a soft flat surface, the Hertz model relationship between the loading force F and the indentation δ is given by Equation 9.4,

$$F_{\text{sphere}} = \frac{4}{3}\frac{E}{(1-\upsilon)}\sqrt{r}\delta^{3/2} \tag{9.4}$$

where E is the Young's Modulus and υ is the Poisson ratio of the soft material.

Where a spherical indenter is employed, as in Equation 9.4, the Young's modulus may be calculated from the gradient a plot of loading force *versus* $\delta^{2/3}$ as shown in Equations 9.5 and 9.6,

$$gradient = \frac{4}{3}\frac{E}{(1-\upsilon)}\sqrt{r} \tag{9.5}$$

$$\Rightarrow E = gradient \text{ x } \frac{3}{4}(1-\upsilon)\frac{1}{\sqrt{r}} \tag{9.6}$$

The Poisson ratio υ is related to the compressibility of a material. It describes how a materials expansion perpendicular to the applied force changes due to indentation of the material by the applied force. For an isotropic material, υ cannot be larger than 0.5. Whereas, the lower limit for υ is usually 0, increasing to 0.5 for materials like rubber and soft gels.

Sneddon, some 60 years after Hertz, solved the deformation problem for systems of common geometry (Sneddon, 1965). He showed that the dependence of load on the deformation of a surface, where $d \leq r$, for a flat-ended punch indenting a flat surface was given by d, for a spherical or parabolic indenter by $d^{3/2}$, and for a conical indenter by d^2.

1.2 Normal tissue construction and elasticity

The skin constitutes the largest organ of the body and comprises the epidermis, dermis, and subcutaneous tissue. Skin thicknesses can vary between 1.5 and 4 mm

depending on the area of the body (Smalls *et al.*, 2006). Dermal tissue is a strong, flexible connective tissue containing an arrangement of cells including fibroblasts, macrophages, mast cells and white blood cells embedded together with collagen, elastin and reticular fibre, to make up the extra cellular matrix (ECM) (Kline, 2006). The dermis is richly supplied with nerve fibres, many of which are equipped with sensory receptors, blood vessels and lymphatic vessels (Marieb, 1998).

Skin is a viscoelastic material possessing varying levels of stiffness and flexibility: for example, areas covering bone are less compliant than those over soft tissue. The skin has two protein fibres which form the reticular layer. The first is a yellow elastic tissue containing 80% elastin which allows movement and is often found in the walls of the arteries and lungs. The second is a white fibrous dense connective tissue (60%), found in cartilage, bone, tendons and ligaments and helps to bind and support the body. The epidermis, collagen, elastin and hypodermis contribute to the biomechanical properties of skin (Lokshin and Lanir, 2009). Distinct differences in its composition relate to the location on the body and the age of the tissue (Smalls *et al.*, 2006). This extracellular matrix (ECM) is a vast network that covers and infiltrates all parts of the body *via* interstitial fluid, blood plasma and cerebrospinal fluids (Marieb, 1998). It acts as an intermediary providing communication throughout the body both electrically, *via* the autonomic nervous system and biochemically, *via* the blood capillary system and specific organ cells (Lett, 2000). In soft tissue, large molecules such a proteoglycans become trapped in the ECM generating high osmotic pressures to counter-balance externally applied pressure (Lu *et al.*, 2006, Silver *et al.*, 2001). Collagen prevents tissue from excess swelling by forming a network that is resistant to stretch, hence helping to maintain tissue integrity. Soft tissue is said to be composed of two phases (a) a solid state which is largely composed of the ECM and (b) an aqueous state containing dissolved ionic species. The frictional force between the two phases is said to explain the viscoelastic properties of skin (Lu *et al.*, 2006)

1.3 Tissue and pressure

Collagen is the structural protein responsible for tissues such as bone, cartilage, tendons and ligaments (Gautieri *et al.*, 2009, Kassolik *et al.*, 2009) and, under

pressure, changes its geometric shape to accommodate deformation (Edsberg *et al.*, 1999). However, it is the elastin within the ECM that provides stretch and ensures that the shape of the tissue is recovered following such deformation (Silver *et al.*, 2001). Collagen fibres are rippled but when they are forced to stretch they flatten and become stiffer, whilst elastin fibres are straight and do not succumb to stress. Collagen and elastin work together to accommodate high strains from external forces but under low strain the elastin fibres dominate (Lokshin and Lanir, 2009). All body movement involves the transfer of forces between different segments of the kinetic chain and increased tension in one area must be balanced by increased tension in another in order to maintain shape and support the various structures (Kassolik *et al.*, 2009). Tissue that is subjected to pressure deforms by displacing fluid, however when the pressure is withdrawn the tissue soon returns to its original shape due to elastin in the fibres as shown in Figure 1.2.

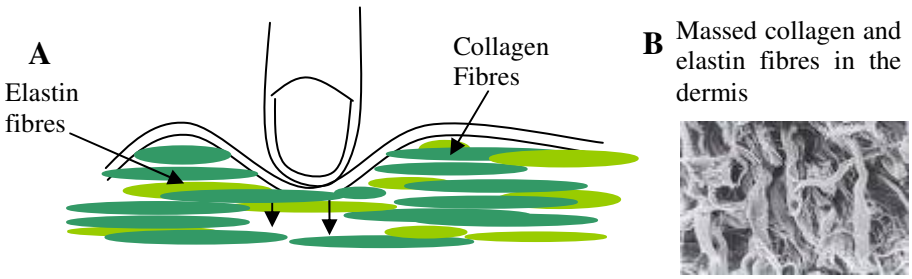


Figure 1.2: The effects of pressure on collagen and elastin fibres. (A) Schematic diagram to illustrate the effect of applied pressure on skin showing elongation and parallel alignment of collagen fibres and stretching of elastin fibres and (B) a scanning electron microscopy image of collagen and elastin fibres within the dermis (Gray, 2009)

An example of the effects of applied pressure in tissue is exhibited by blood vessels which constrict under pressures of 4 kPa (Edsberg *et al.*, 1999), fluid being displaced into neighbouring tissues until the pressure is released. The return to normal shape *i.e.* the compliance (Section 1.1) is most important in the vascular system where there is a need for constant expansion and contraction in response to changes of pressures for blood flow. In impaired venous systems, oedematous tissue is observed. In this condition, hydrostatic pressures results in water becoming filtered out in the tissue space and a reduction in osmotic pressure, which pulls fluid into the capillaries and creates swelling in the surrounding tissue. This results in unusually

compliant tissue and the loss in elasticity characteristic of this condition is attributed to a damping effect which makes the tissue more pliable.

1.4 The anatomy of the foot

The foot is a mobile, weight-bearing structure composed of twenty six bones with various muscle fibres that insert into the bone through tendons that store and recover elastic energy (Cui *et al.*, 2009). Tendons are composed mostly of collagen fibres water and other proteinaceous material; they are strong white flexible cords of inelastic fibrous connective tissue that join muscle to bone. The large Achilles tendon found at the back of the lower leg joins the calf muscles to the heel bone (Calcaneus). The muscles in the plantar surface of the foot are layered from superficial to deep and assist movement by contracting so that they shorten and pull on the bone through the tendon. The ankle joint is formed by the tibia, fibula and talus and make up a hinge joint allowing movement up (dosiflexion) and down (plantar flexion) and from side to side (inversion – inward /eversion - outward). The tibia and fibula join the foot through the short bones of the tarsals of which there are seven in total - talus, calcaneus, cuboid, navicular and three cuneiform bones. The tarsals attach to the five metatarsal bones of the foot which attach to the fourteen phalanges, three in each of the toes except the big toe which has two. The normal anatomy of the foot has fatty deposits in the area of the heel and the metatarsal heads (Kogler and Shorten, 2001), see Figure 1.3.

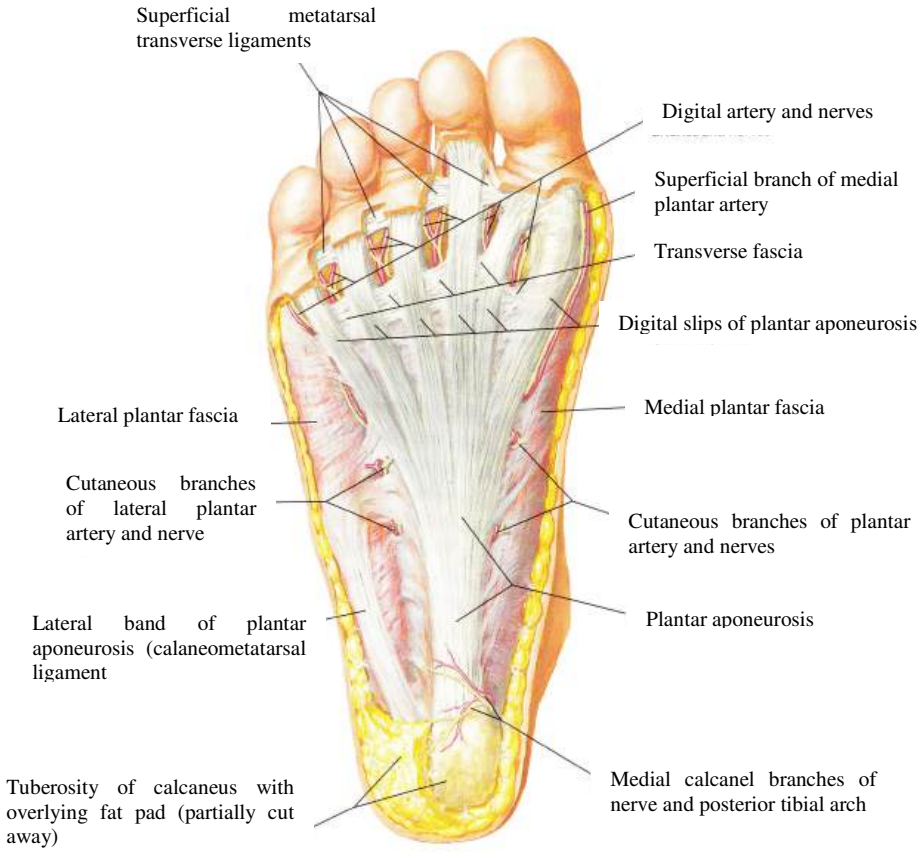


Figure 1.3: A superficial view of the anatomy of the sole of the foot (Netter, 2003).

1.5 Pressure and physiological responses

Killewich *et al.* (1995) and White *el al.* (1996) demonstrated the presence of a physiologic venous pumping mechanism in the plantar surface of the foot arch and impulses of pressure ranging from 10 – 26 kPa were shown to increase venous velocities within the popliteal and femoral veins (Killewich *et al.*, 1995). Abu-Own *et al.* (1993) demonstrated that pressure on the foot sole can stimulate the circulatory system and Rogers (1993) postulated that circulation of both lymph and blood was promoted simply by walking, suggesting that stimulation of the sensory nervous system occurred each time feet made contact with the ground. Fromy *et al.* (2000) and Meinders *et al.* (1996) indicated that when pressure was applied to the skin, blood flow was interrupted. In a condition known as filarial lymphoedema there is massive pooling of fluid in the limbs and genitalia, which is made worse by poor foot hygiene and non-compliance of patients in applying compression dressings. Manjula *et al.* (2002) discovered that sequential intermittent pneumatic compression, which

utilises a series of inflation/deflation pressures with loads between 13 - 23 kPa, can reduce the oedema volume by as much as 26% and White *et al.* (1996) have indicated that stretching of the foot arch may be sufficient to forcefully empty the veins.

Figure 1.4 shows the position of the various receptors in the skin layers. Further information on the types of receptors is detailed in Chapter 1, (Section 1.3.2).

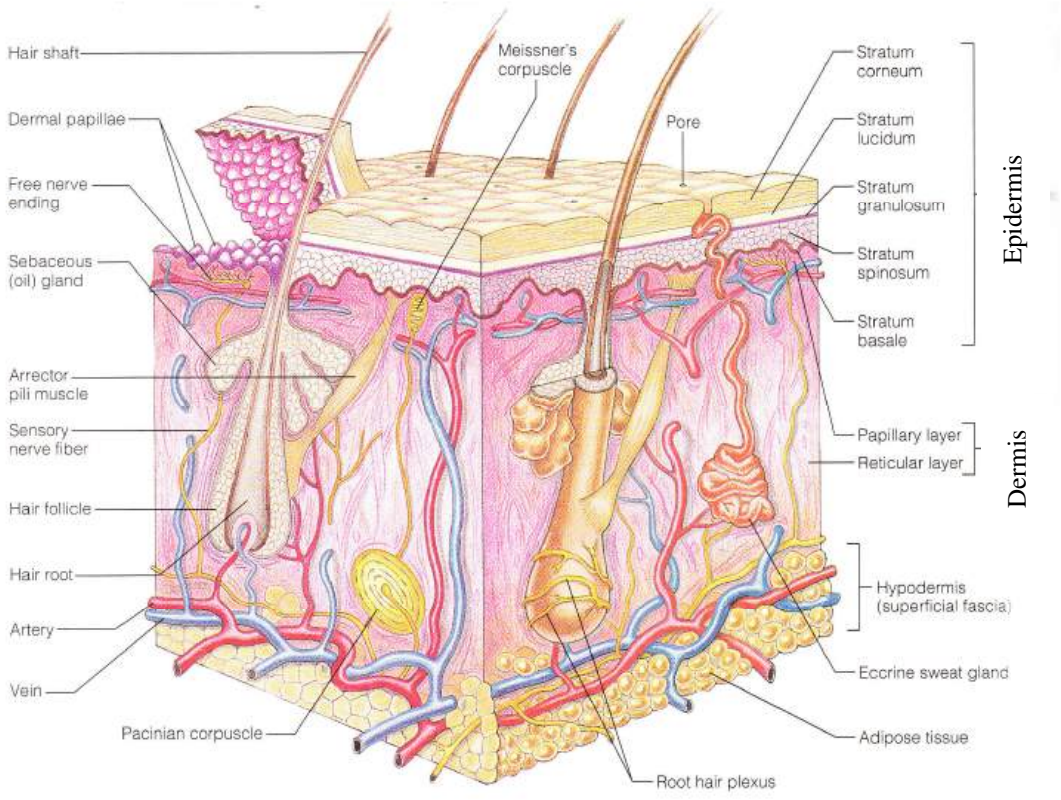


Figure 1.4: Illustration of the epidermal, dermal layers and the position of the various sensory receptors (Marieb, 1998).

The slowly adapting C-fibres of the nervous system have been identified as being the chief responders in vasodilatory mechanisms during moderate external pressures of 4 -8 kPa (Abraham *et al.*, 2001) whereas Fromy *et al.* (2000) have described slowly adapting receptors such as the Merkels disks and Ruffini corpuscles as the receptor units most likely to respond to forces of pressure between 6 - 24 kPa. However an increase in standing or static pressure can increase the number of callouses in the heel and metatarsal areas. Callouses or keratinisation as it is sometimes known,

increases the dermal thickness and makes it more difficult to stimulate the underlying mechanoreceptors effectively (Neziri *et al.*, 2009).

Kennedy and Inglis (2002) were able to locate 104 cutaneous mechanoreceptors in the foot sole responsive to a variety of environmental and sensory stimuli, composed mostly (70%) of the rapidly adapting type I Meissner corpuscles, with large randomly distributed receptive fields around the metatarsal-tarsal regions (Kennedy and Inglis, 2002). The rapidly adapting receptors are phasic touch receptors that detect change in texture and respond to light touch and slow vibration with an ability to adapt to constant or static stimuli at a fast rate but are insensitive to static skin deformation and low-frequency vibration (Johnson, 2001). Mechanoreceptors are activated by mechanical stimuli and have the ability to deform and change the position of the receptor so that it generates an action potential or nerve impulse. Pressure activation thresholds for both rapidly and slowly adapting mechanoreceptors on the sole of the foot were evaluated by Kennedy and Inglis (2002). They found that the median activation thresholds for rapidly adapting type I and II units were in the region of 11 and 4 mN respectively, whilst the slowly adapting type I were activated at 35 mN and the type II at 115 mN.

1.6 Mechanosensitisation of the foot and adaptive responses in the brain

The relationship between mechanosensitisation on the foot sole and adaptive responses is not fully understood. However, recent fMRI experiments have for the first time demonstrated some correlation between the reflex points in the feet and somatotopical regions of the brain (Nakamaru *et al.*, 2008). Reflex points for the eye, shoulder and small intestine were stimulated by use of a wooden stick (typically used in Eastern reflexology treatments) and mapped for their cortical activity. The experiment demonstrated somatotopical relationships between eye, shoulder and small intestine reflexes of the foot sole and regions within the somatosensory post central gyrus other than those usually related to touch.

1.7 Pressure Relationships in Reflexology

Reflexology is said to utilise an applied pressure to initiate a reflex response from mechanosensitive receptors in the skin. Claims have been made that the effectiveness of reflexology to affect an organ, or physiological response, is reliant on the intensity of a stimulus (Porter, 1997, Tay and Eu Hooi, 1988). However, to date no data exists on the actual pressures applied during reflexology treatment. Generally these are described as light, standard, static, knuckling *etc*, the pressure applied being purely subjective.

Tiran and Chummum (2005) have suggested that the pressure sensitive receptors in the feet, as described in Section 1.5, are triggered when pressure is applied to them during a reflexology stimulus. They proposed that this induces physiological change through peripheral vasodilation but concluded that the exact force of stimulus applied was very difficult to measure objectively. Sudmeier *et al.* (1999) were able to demonstrate that typical pressures applied during a reflexology treatment improved circulation but they did not quantify such pressures.

The Morrell reflexology (Evans *et al.*, 1998) technique utilises a so called "light" pressure, and proponents of the technique state that "the stimulus should be light and have the ability to reach the patient on a subtle level in order to evoke relaxation and restore homeostasis". "Standard" reflexology is attributed to the method defined by Ingham (1984) in which the pressure was described as being firm, whilst the Rwo Shur Health Method (Tay and Eu Hooi, 1988) proffered that the most beneficial use of reflexology is found with a much deeper pressure, utilising a knuckling technique and sometimes a rolling dowel (wooden stick). Marquardt (1984) suggested that there are no fixed rules for determining the intensity of the stimulus and recommended that the treatment carried out should fall within the pain thresholds of the patient being treated.

Research carried out by Poole (2001) and Evans (1998) has shown that using a "light" touch in reflexology can have an effect on pain levels and subjectively appears to reduce stress and anxiety. Veldhuizen and Pauly (2001) used a system of reflexology referred to as Nerve Reflex Point (NRP) therapy which uses the thumb in a static hold over the periosteum. The results of NRP techniques used to evaluate

relief in thoracic paraspinal muscles have shown that the stimulus can reduce tension in the treated muscles. Research carried out by others, using the Ingham (Byers, 1990) method of "standard" reflexology pressure have attributed their results to this technique (Hodgson and Andersen, 2008, Stephenson *et al.*, 2003), but as with so many other reflexology experiments they do not quantify the force of the applied pressures used in the experiments.

In a clinical environment however, the amount of pressure exerted during any given reflexology session varies according to the general health, age and size of the patient. The skin surface may also affect the pressure needed to effectively gain a physiological response. For example, a foot that is calloused requires a much greater pressure than a softer foot (Neziri *et al.*, 2009). The most commonly utilised reflexology technique is that of Ingham (Byers, 1990) which exerts an intermittent on/off caterpillar-like dynamic motion, generally applied using the medial aspect of the thumb. This type of stimulus appears to mimic the phasic activity of rapidly adapting mechanoreceptors with their small receptive fields, producing transient responses to the onset and offset of the stimulus. There is however no available data recommending the level of force that must be applied and most practitioners report that they work within the bounds of the feet presented before them, *i.e.* they adapt the treatment according to the physiology, sex, age and general demeanour of their patient.

1.2 COBBLESTONE MAT WALKING

In many parts of the Far East there are pathways laid with cobblestones, see Figure H5, that are used for exercising (Wright, 2005) and promoting physical well-being. In parts of Asia people walk on these pathways to improve their general health, circulation and balance (Walker, 2003). This cobblestone pathway system is said to be based on the ancient Samurai tradition of walking on split bamboo; pressure on the sole of the foot is said to increase when different areas of the pathway are walked, due to a change in the arrangement and size of the cobblestones (Walker, 2003).

Figure 1.5: An example of one of the reflexology stroll paths in the public gardens of Bangkok, Thailand (Lon, 2004). The direction and size of the pebbles varies across the pathways.

In 2005 Fuzhong (2005) carried out a randomised controlled trial to evaluate the effects of cobblestone mat walking on blood pressure and other physical performances such as walking, rising from a chair and general movement. The trial involved 108 participants with a mean age of 77.5 yrs, who were free of neurological and mobility-limiting orthopaedic conditions. Participants were randomised to cobblestone mat walking, n=54, whilst the remaining were randomised to normal walking sessions on a flat surface, n=54. The sessions were given for one hour, three times a week for 16 weeks. The team postulated that the cobblestones would provide stimulation to acupuncture tsubo points in the feet, see Chapter 1 (Section 1.2.4). The results obtained indicated that participants in the cobblestone mat walking group showed a significant improvement in their physical performance and a reduction in blood pressure compared to the conventional walking group. This study appears to support the hypothesis that a pressure stimulus in the feet can improve circulation to blood and lymph (Fromy *et al.*, 1998, Tiran and Chummun, 2005) .

1.2.1 Acupressure

Acupressure is a system of Traditional Chinese Medicine (TCM) similar to acupuncture and proponents of this therapy suggest that it uses the application of

pressure to sensitive skin areas known as acupoints or tsubo points, discussed previously in Chapter 1, (Section 1.2.4). The practitioner is said to use a rotating thumb, finger or elbow pressure to elicit a physiological response *via* the meridian system (Hsieh *et al.*, 2006). Blate (1982) has suggested that in order to locate a tsubo point pressures of up to 138 kPa must be employed. Similarly Tedeschi (2000) has suggested that a pressure of 103 kPa is the maximum one should apply for acupressure techniques. In Japan a similar therapy known as shiatsu which is described as a stimulus that promotes a nerve reflex action, also uses the application of pressure on tsubo points (Palanjian, 2004). It has been reported that shiatsu uses the relaxed weight of the practitioner rather than pure muscle strength on the patient, in a relaxed leaning posture (Liechti, 1998) and that it produces its effect through a static pressure at a medium-to-light depth applied through the clothing (Ingram *et al.*, 2005). Serizawa (1972) reported that a pressure of between 48 – 69 kPa should be used and suggests that one should judge the application of pressure by the response received from the patient. Furthermore he comments that the pressure should stimulate a pleasurable sensation of mild pain and not sharp pain or discomfort, which seems to correlate with the main teachings of reflexology (Ingham, 1984, Marquardt, 1984).

The hypotheses surrounding acupressure, acupuncture, shiatsu and reflexology are similar and promotes the idea that internal organs can be affected by stimulation of reflex areas or points distant from the organs themselves (Head, 1893, Washington *et al.*, 2003). All of these practices are deemed part of the Eastern philosophy of pressure point stimulation linked with TCM that are used to propagate physiological responses in the body. However no literature determining the actual forces of pressure applied is available. Whilst shiatsu practitioners utilise a slow sustained holding pressure (Liechti, 1998), most reflexology techniques employ an intermittent on/off dynamic pressure (Lett, 2000, Byers, 1990) and acupressure a vibrating, rotating pressure (Tedeschi, 2000).

Trigger points are a further area in which pressure applied to a sensitive area of muscle tissue and/or its associated fascia can invoke relief from pain in a muscle or tissue far removed from it (Melzack *et al.*, 1977, Davies and Davies, 2004, Dommerholt *et al.*, 2006, Bron *et al.*, 2007). Melzack (1977) discussed the

similarities between tsubo points and myofascial trigger points in terms of their distribution and associated pain patterns and found that 71% of tsubo points corresponded with trigger points found in the fascia. Acupuncture tsubo points and trigger points were discovered independently of one another and are derived from very different medicine concepts, yet it has been postulated they work *via* the same neural mechanisms (Melzack *et al.*, 1977). It may be reasonable therefore to suggest that acupressure, shiatsu and reflexology, which use similar pressure sensitive areas, may operate via the same neural mechanisms.

1.2.2 Pressure measurements in foot physiology

The Young's Modulus of Elasticity is used in the measurement of soft materials that demonstrate an elastic behaviour. However, few data on the dynamic properties of soft tissue exist in the literature (Saraf *et al.*, 2007). Measurement of elastin content using biochemical methods is extremely difficult (Jabareen *et al.*, 2009) and techniques for measuring the dynamic loading of soft tissue have mostly been carried out at the nanoscale (Beech *et al.*, 2002, Boukallel *et al.*, 2009). In biological systems such as the skin, the Young's modulus varies according to the location in the body and the amount of strain applied (Edsberg *et al.*, 1999). For example Silver *et al.* (2001) reported that the stress-strain curve on elastic fibres of skin was 4 MPa compared to the nuchal ligament of the neck where the stress-strain curve of the elastic fibres was 4 GPa. In collagen fibres the Young's Modulus has been reported to lie between 2 and 9 GPa but is largely dependent on the tissue sample used (Gautieri *et al.*, 2009) and the elastic modulus of bone has been recorded as 15 – 25 GPa (Ritchie *et al.*, 2009).

In cellular tissue, osmotic pressure provides the reference for the hydration state of the cell and is the difference in concentration between solutions on either side of a semi-permeable membrane. Blood cells can be used to illustrate this phenomenon. For example a blood cell in a hypotonic state contains more water and less solute, allowing the cell to expand, whilst a blood cell in a hypertonic state holds more solute than water which causes the cell to shrink as shown in Figure 1.6. Since cells are labelled soft materials measurement of the Young's modulus is carried out by

applying the Hertz Model for elastic behaviour, taking into account the viscoelastic properties of the cells.

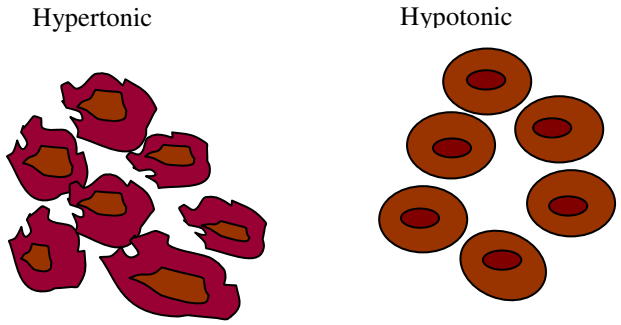


Figure 1.6: Osmotic pressure on blood cells. Graphic shows the differences in concentration between solutions either side of a semi-permeable membrane. In the hypotonic state there is an increase in water in the cell and in the hypertonic state the water content is lost.

1.3 AIMS

Although the study of pressure on plantar tissue has been evaluated for conditions such as foot ulcers in diabetes and blood circulation and muscle atrophy in space astronauts under non-gravitational conditions, the relationship between applied pressure and reflexology has not been quantified. Reflexology stimulations have involved the application of different pressures to either, the foot, hands, ears or back. In the case of the foot, a variety of pressures are employed. Such pressures have been described as “static” where the thumb is held in a relaxed position against the periost next to bone, “standard” where the treatment is much firmer and “light” where a very soft force is utilised. To evaluate the effects of mechanoreceptor stimulation in the foot sole by an applied pressure, knowledge of the actual values employed in the different treatment regimes is a key requirement. To date, no values exist on the true pressures employed during reflexology. The aim of this work was therefore to quantify the forces of pressure during a reflexology treatment. The specific objectives were to use three different pressure applications including a static pressure, a standard on/off dynamic pressure, and a light on/off dynamic pressure. Reflexology stimuli were applied to various foot types:

i) normal adult (healthy tone and texture),

ii) calloused,

iii) moist,

iv) ethnic (soft and spongy),
v) child,
vi) oedematous, and
vii) hard (dry).

Two pressure measuring systems, the *Tactilus® Freeform Sensor System V2.0.150 (2005)* and *Tactilus® Freeform Sensor System V3.1.27 (2007)* were used to determine pressure applied during reflexology treatments. Measurements were recorded at:

a) the medial aspect of the foot along the longitudinal arch,
b) the arch of the foot along the area of the first cuneiform bone,
c) the calcaneus (heel) and
d) the area of the right lateral malleolus (ankle).

The relationship between skin tone, texture and age and the strength of the reflexology stimulus were evaluated from data obtained. The study focused on the pressure application to normal and calloused feet.

1.4 MATERIALS AND EQUIPMENT

1.4.1 General Equipment

Latex rubber gloves (Semper guard), disposable nitrile powder free, non-sterile and a Lafuma Chair were used in the experiments.

Tactilus Systems

Two models of the Tactilus® Freeform Sensor System were employed leased from Sensor Products LLC, USA, http://www.sensorprod.com. The first system V2.0.150 (2005) consisted of a hub with a mechanism enabling the pressure to be switched between high and low pressure modes. The low pressure mode operated between 0 - 79 kPa whilst the high pressure mode operated between 0 – 492 kPa. Selection of

the pressure range was effected *via* the hardware and software on the Device Menu. The sensor system was equipped with eight flat sensor heads as shown in Figure 1.7 and was operated by collecting pressure data and sending an analog signal back to the intermediary hub. The analog signal was then converted into a digital signal, which was relayed to the Windows based software programme *via* a USB cable.

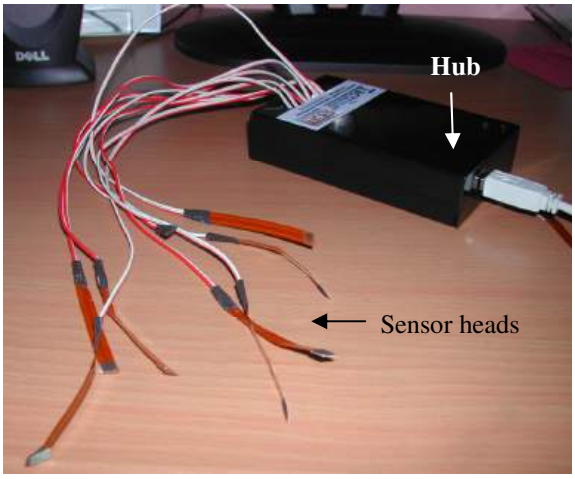
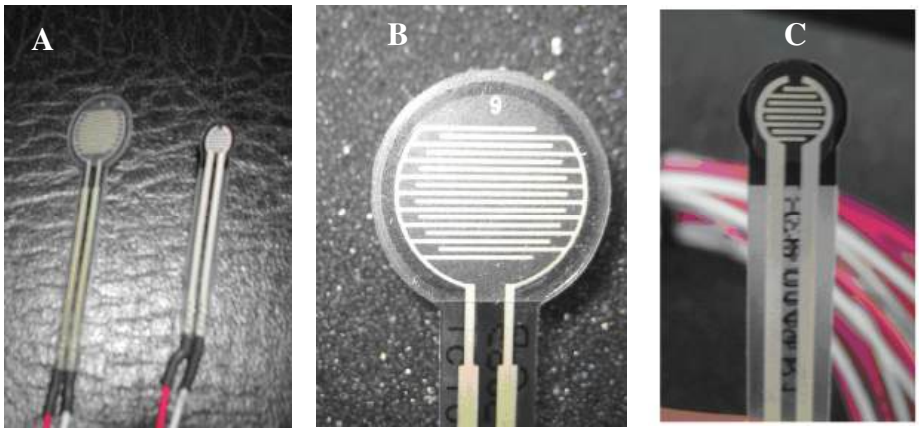


Figure 1.7: The Tactilus® Freeform Sensor System V2.0.150 (2005) showing the hub and the flat sensor heads.

The second Tactilus® Freeform Sensor System V3.1.27 (2007) was an updated and modified version of the original system. In this, the pressure sensors were pre-calibrated and highly resistant to electromagnetic noise, temperature and humidity fluctuations. There was no switching mechanism on the hub, Figure 1.8 and the sensor heads were spherical. Four with diameters of 0.8 cm and surface areas of 0.5 cm^2 and four larger sensors with diameters of 1.5 cm and surface areas of 1.8 cm^2, see Figures 1.9 a-c. All sensors were of equal thickness and contained an adhesive backing.

Figure 1.8: The Tactilus® Freeform Sensor System V3.1.27 (2007) shown with the hub connected *via* the USB cable to the Windows based software programme.



Figures 1.9: Images of the sensor heads with their electronic circuitry on the sensor surface. A) Large and small sensors together, B) enlarged image of large sensor head (1.5 cm) and C) small sensor head (0.8 cm).

The recorded pressure range of the sensor heads was between 4 - 412 kPa. Data obtained from the sensors during pressure measurements was displayed as a series of graphical plots, as shown in Figure 1.10.

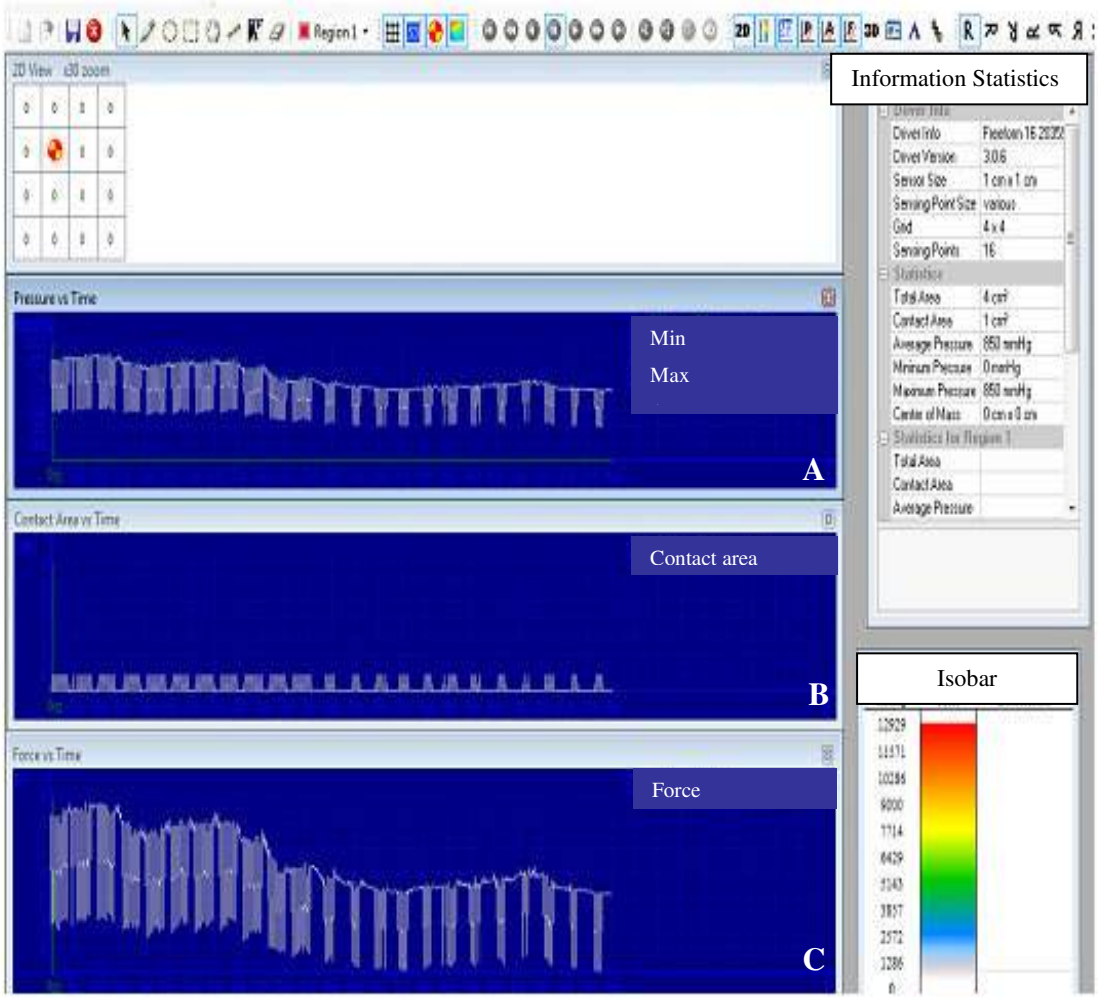


Figure 1.10: Tactilus® Freeform Sensor System V3.1.27 (2007) data presentation:
A) pressure *vs* time in ms, B) contact area *vs* time in ms and C) force *vs* time in ms.

The software also provided a series of information bars, shown more clearly in Figure 1.11, indicating the number of sensors and size of sensor in use together with respective pressure values. An isobar provided a visual image of the pressure scale applied during the recording, each level of pressure represented by a colour. Data on pressure as a function of time, contact area as a function of time and force applied were obtained. The pressure *vs* time trace recorded the minimum, maximum and average pressures applied over time (shown in mm Hg). All pressure values quoted have been converted to kPa in accordance with the Standard International System. The contact area *vs* time plot identified the area of the sensor in cm^2 and the force *vs* time plot displayed force in Newtons (N), see Figure 1.10.

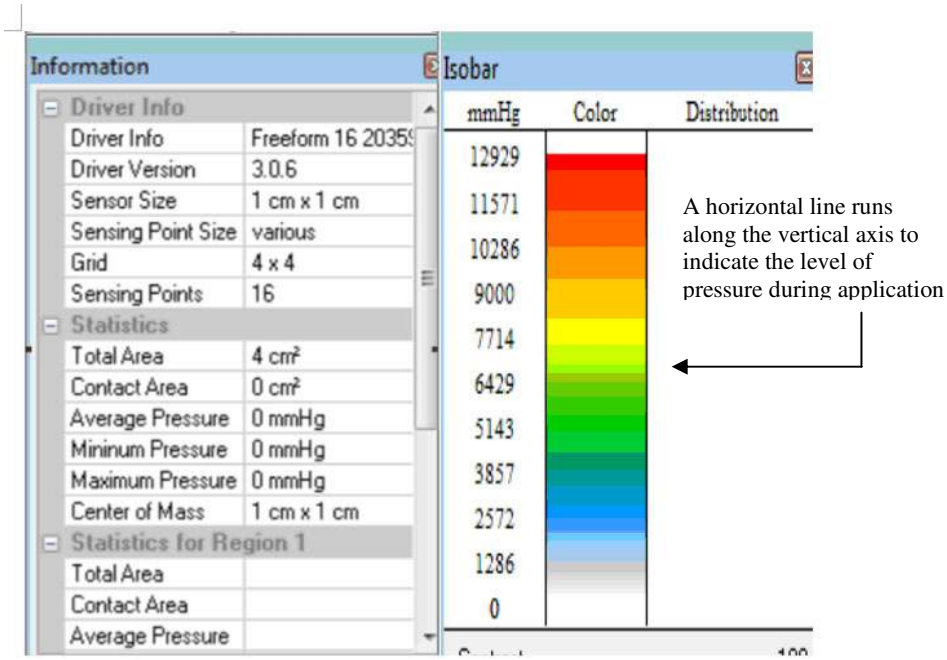


Figure 1.11: An enlarged image of the information bar and isobar.

1.5 METHODS

1.5.1 Tactilus® Freeform Sensor System V2.0.150 (2005)

The initial protocol for the pressure testing was developed using the 2005 version of the Tactilus system. This involved the application of a standard reflexology technique to various foot types. A number of sensor heads from the Sensor System were attached to the thumb and held in place with a latex glove to avoid movement during pressure measurements. The sensor leads were very short and the sensor hub was placed in close proximity to avoid overstretching the attachment points as shown in Figure 1.12. The stimulation entailed an intermittent on/off pressure in a caterpillar-like movement at two pressure levels. However, several problems were experienced with this system details of which were relayed to the company, leading to the development of a modified and improved system.

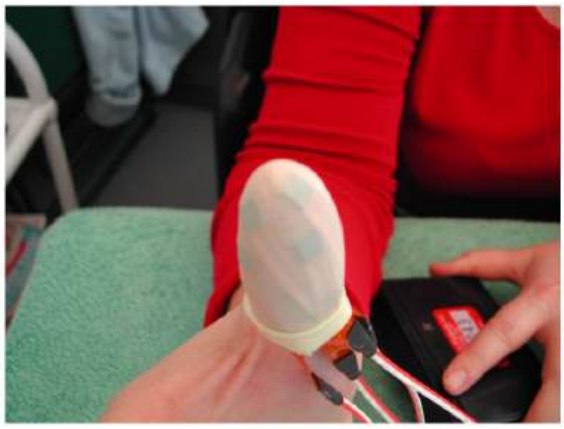


Figure 1.12: Image showing the arrangement of sensors during an experiment. The sensors were held in place by a cut-off thumb section of a latex glove.

1.5.2 Tactilus® Freeform Sensor System V3.1.27 (2007)

An updated and improved version of the Tactilus® equipment was provided in 2007 for all further experiments. In the new system, the sensor was composed of a thin flexible sheet densely packed with sensing points. These were spaced 1 mm apart and were able to collect data at the rate of 1000 readings per second (Sensor Products Inc, 2008). The construction of the sensor heads comprised of two polymer sheets sandwiched together, one of the sheets being coated with electrodes and the other with semi-conductive ink. Pressure applied to the sensors produced a shunting of electrodes which was measured as an electrical resistance (LuSense, 2007). The higher the pressure the greater the decrease in resistance (resistance values were between 5 – 500 kΩ). The data capture from the Tactilus® system produced an output in milliseconds and raw data from the individual plots were exported into Excel as a text file. From these data average pressure values across all recorded data frames were obtained

1.5.3 Subject selection

A total of nine subjects were recruited for the experimental procedure, differing in terms of their age (3-79 years), gender, and ethnicity. Foot types included:

i) normal adult (healthy tone and texture),

ii) calloused,

iii) moist,

iv) ethnic (soft and spongy),

v) child,

vi) oedematous, and

vii) hard (dry).

Images of these different foot types are shown in Figure H13.

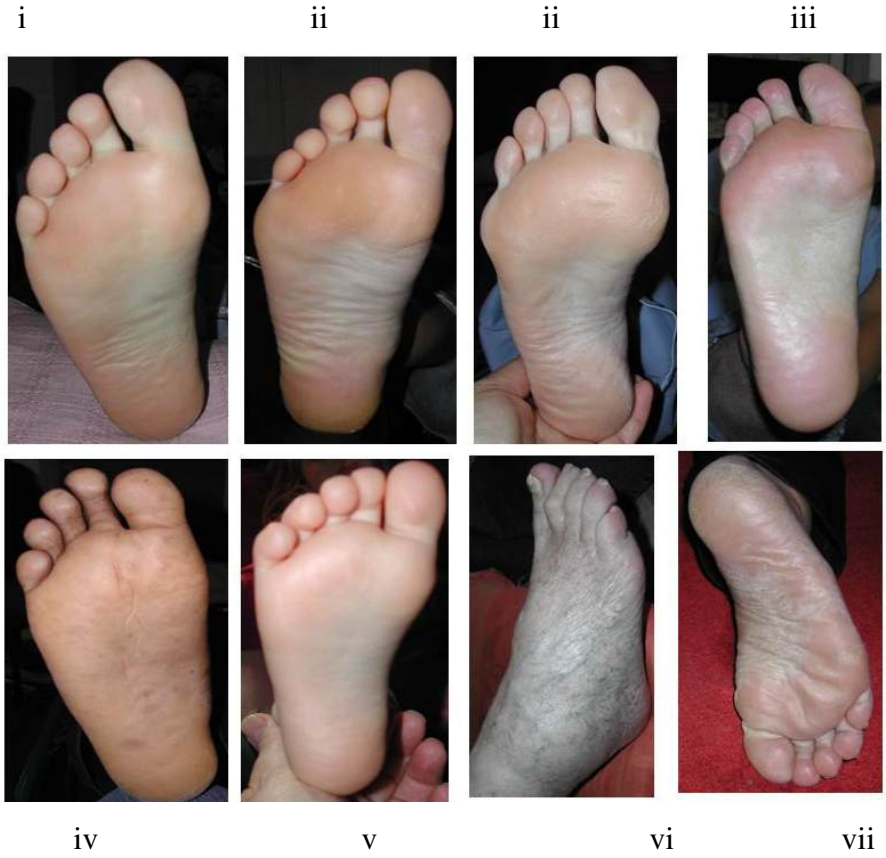


Figure 1.13: Images of foot types used in the pressure measurement experiments: i) normal healthy foot texture, ii) calloused areas in the ball and heel areas x2, iii) moist and full, iv) ethnic foot, soft and spongy texture, v) enlarged image of child's foot, vi) elderly foot with oedematous tissue and thin skin, showing lots of veins and surface capillaries vii) dry and hard.

1.5.4 Foot types

For each foot type, four areas were selected for the application of pressure:

a) the medial edge of the foot along the longitudinal arch,

b) the arch of the foot along the area of the first cuneiform bone,

c) the calcaneus (heel) and

d) the area of the lateral malleolus (ankle).

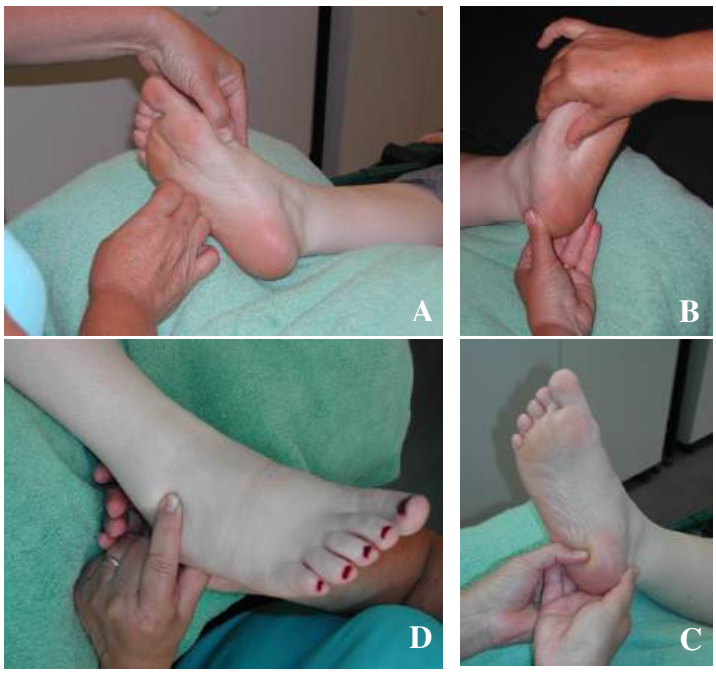


Figure 1.14: Images illustrating the four areas of stimulation during the experimental procedure, a) medial edge, b) arch, c) heel and d) ankle

The anatomical relationship of these areas according to current reflexology theory is as follows:

i) the spinal reflexes, Figure 1.14 A, are located on the medial aspect of the foot along the longitudinal arch. This region consists of a thin layer of skin over bony prominences with little subcutaneous tissue;

ii) the digestive reflexes, Figure 1.14 B, in the foot arch. This area consists of softer tissue with underlying tendon-like structures;

iii) the lower back and pelvic girdle reflexes, Figure 1.14 C, are represented by the heel. A greater density of subcutaneous tissue (fat pad) to cushion the pressures of walking is present in this location; and

iv) the reproductive and pelvic lymphatic reflexes, Figure H14 D are represented by the ankles which have strong ligamental structures but little subcutaneous tissue exists in this region.

1.5.5 Pressure application

Three different pressures were exerted for a maximum of 10 seconds on each foot type in the areas detailed above. These were:

a) a static holding pressure,

b) a standard caterpillar on/off dynamic pressure, and

c) a light caterpillar on/off dynamic pressure

During the experimental procedure a sensor head was attached to the medial aspect of the thumb using a latex glove, as shown in Figure 1.15.

Figure 1.15: Image of large sensor head secured to the medial aspect of the thumb using the thumb section of a latex glove.

Pressure application times were regulated by a technical assistant, thus minimising distraction and movement during pressure application. Subjects were relaxed into the semi-recumbent position of the Lafuma chair, described previously in Chapter 2. Data on variation of pressure, contact area and force with time were obtained.

1.6 RESULTS

1.6.1 Pressure measurements using the Tactilus® Freeform Sensor System

A novel method of pressure measurement was utilised in this investigation. This technique involved the use of sensors which measured changes in the electrical resistance of a conductive organic material on application of an external pressure. Two different versions of this system, known as the *Tactilus®,* were employed. The first experiments utilised the Tactilus® Freeform Sensor System V2.0.150 (2005). However, several problems arose when using this equipment. Firstly, the sensor heads were extremely fragile and flexible which resulted in their breaking away from the leads during pressure measurements. Furthermore, the short length of the leads attaching the sensors to the hardware did not allow reflexology to be performed in the correct manner and this hindered correct pressure application methods. As a consequence, the equipment was specifically modified by the manufacturers and the

updated pressure measuring system was employed for all further experimental studies.

1.6.2 Application of static pressure

In the first experiments, static pressures were applied to different regions of the feet on two foot types specifically selected to exhibit differences in foot tone and texture. Measurements were recorded on application of pressure by the medial aspect of the therapists thumb using a sensor with an area of 3.7 cm^2. The sensor was held against the foot as illustrated in Figure 1.16. Although pressure measurements were made on many different foot types, only those of a normal and calloused foot are reported here. Other data are included in Appendix I.

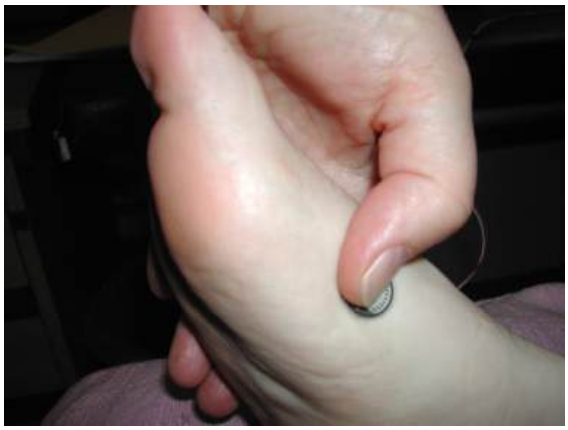


Figure 1.16: Illustration showing the position of the sensor along the medial edge of the foot (spinal reflexes) on a normal healthy foot. Contact is *via* the medial edge of the thumb.

The data in Figure 1.17 shows the variation of pressure with time during the application of static pressures to the medial edge, the arch, the heel and the ankle regions of a normal healthy foot. For clarity, Figure 1.18 shows an enlarged image of the pressure data for the medial edge. Similar measurements of a calloused foot are shown in Figure 1.19.

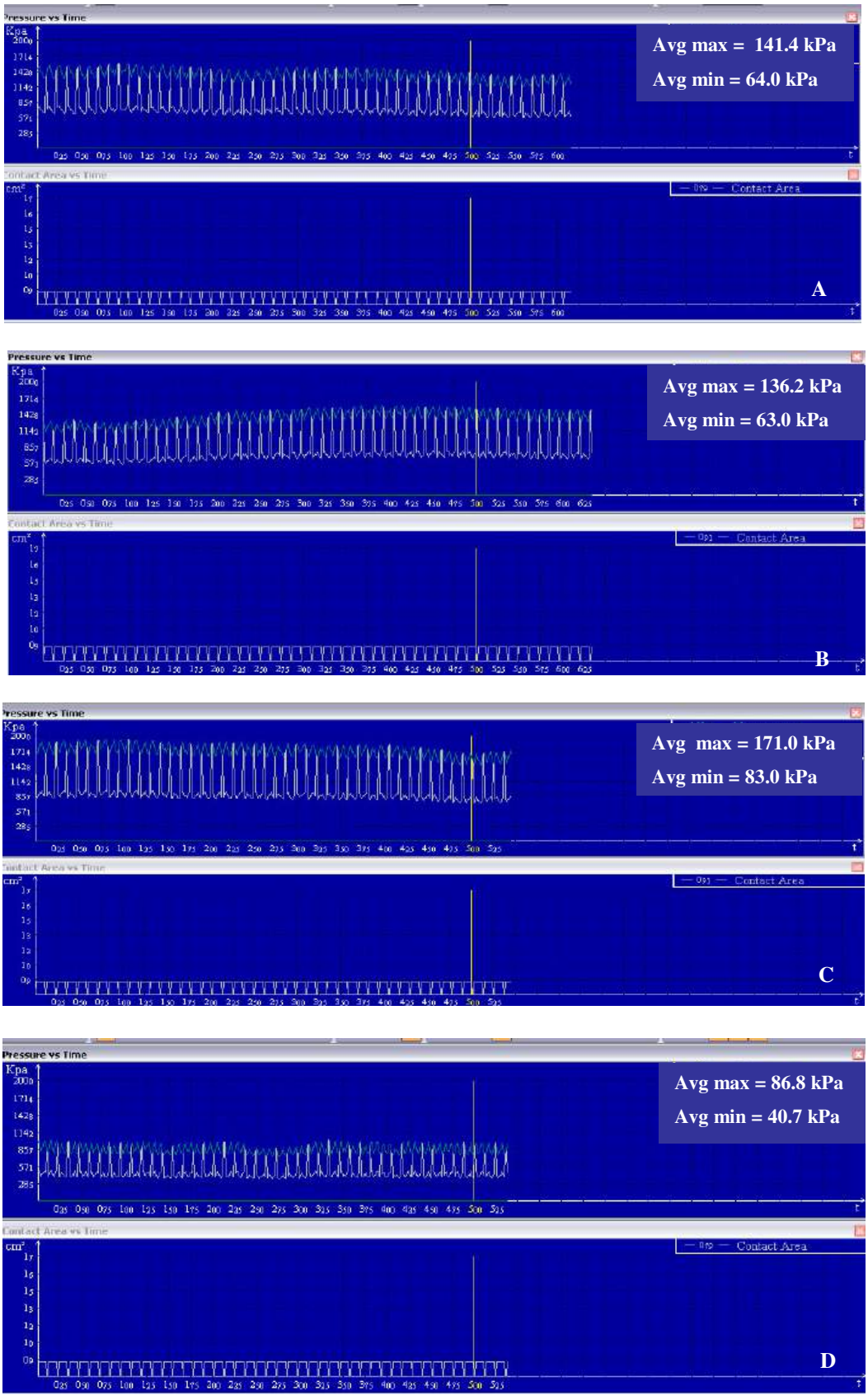


Figure 1.17: Data showing the variation in the average minimum and maximum applied pressure for a normal healthy foot on the, a) medial edge, b) arch, c) heel and d) ankle. Ghosting on the images is an instrumental artefact. The average minimum, P_{min} was measured at 5 ms prior to the average maximum, P_{max}.

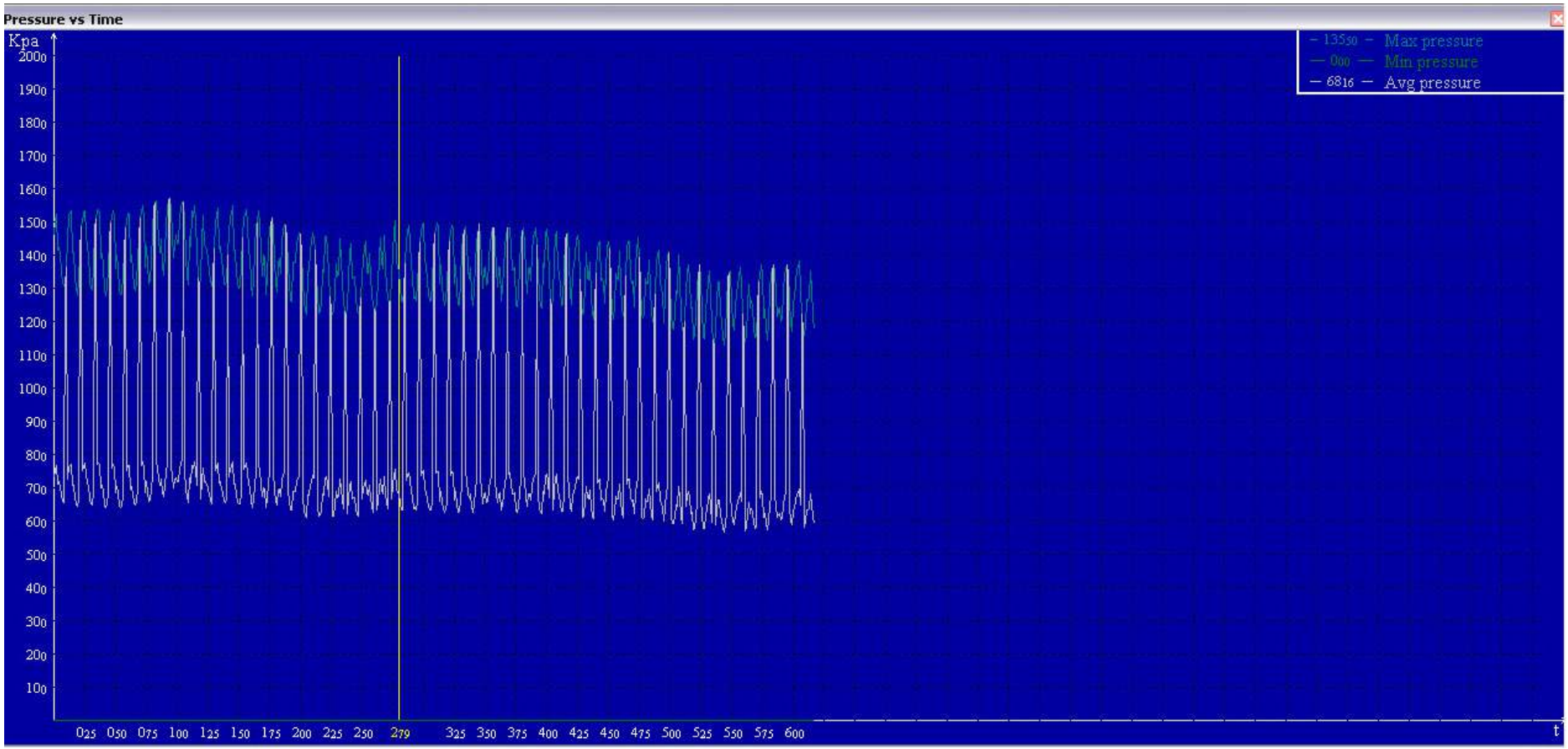


Figure 1.18: An enlarged image of the variation in pressure with time during the application of static pressure along the medial edge of a normal healthy foot. Ghosting on the images is an instrumental artefact.

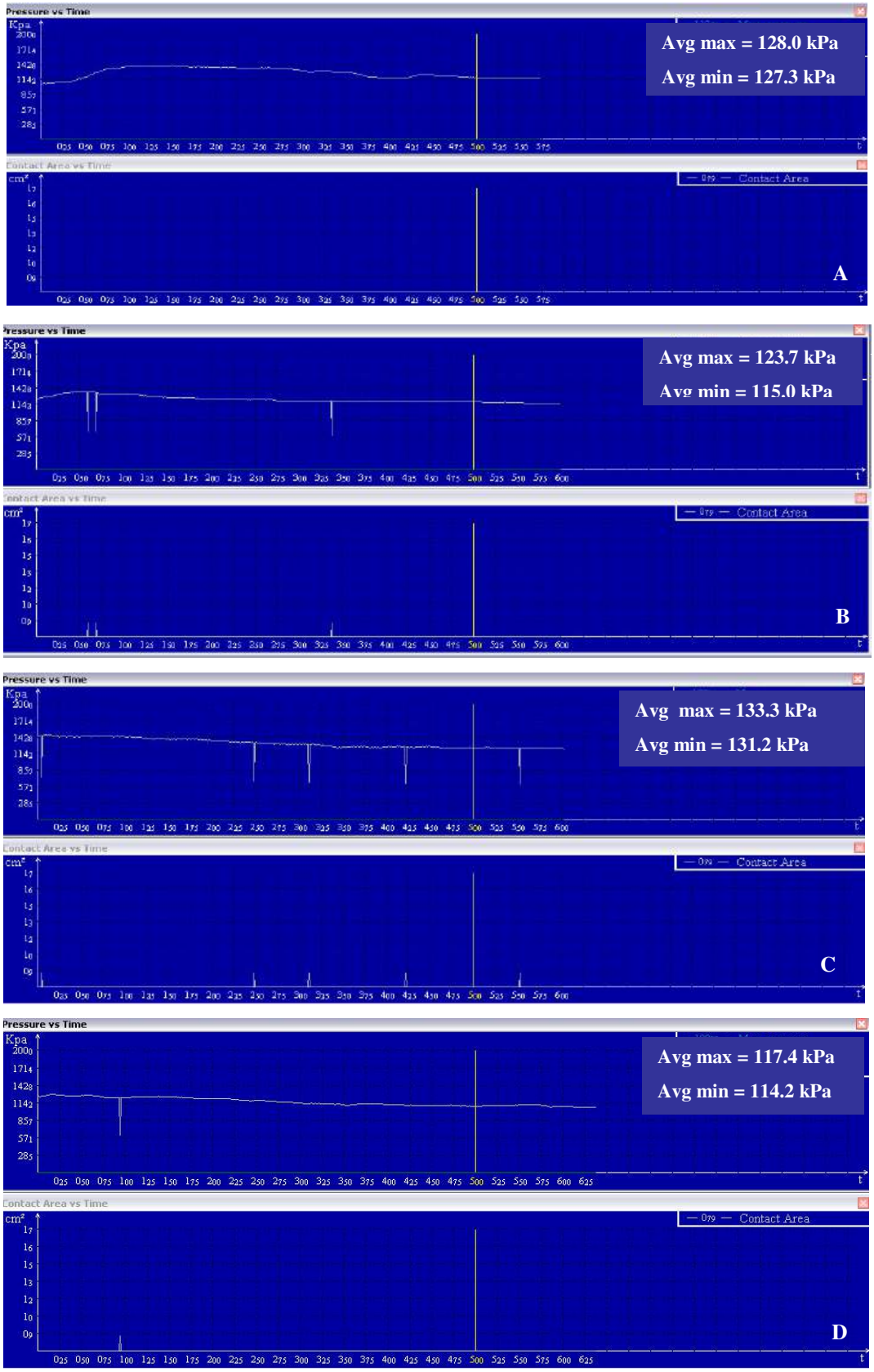


Figure 1.19: Data showing the variation in minimum and maximum applied pressure with time for a calloused foot on the, a) the medial edge, b) arch, c) heel and d) ankle. P_{min} was measured at 5 ms prior to P_{max}.

These data, including details of the contact area of the sensor during measurement and the average maximum and minimum pressures applied over an experimental period of 500 ms are summarised in Table 1.1.

Table 1.1: Average minima and maxima static pressures. Applied to a) normal healthy foot and b) calloused foot. Contact area and forces applied are shown for t=500 ms. Minimum and maximum measurement period is 500 ms.

A

Foot region	Contact area / cm^2	Force / N	Average minimum applied pressure / kPa	Average maximum applied pressure / kPa
Medial edge	0.8	10.4	64.0	141.4
Arch	0.9	6.9	63.0	136.2
Heel	0.9	7.5	83.0	171.0
Ankle	0.9	3.5	40.7	86.8

B

Foot region	Contact area / cm^2	Force / N	Average minimum applied pressure / kPa	Average maximum applied pressure / kPa
Medial edge	0.8	9.2	127.3	128.0
Arch	0.8	9.3	115.0	123.7
Heel	0.8	9.7	131.2	133.3
Ankle	0.8	8.5	114.2	117.4

The data in Table 1.1 are represented graphically in Figure 1.20

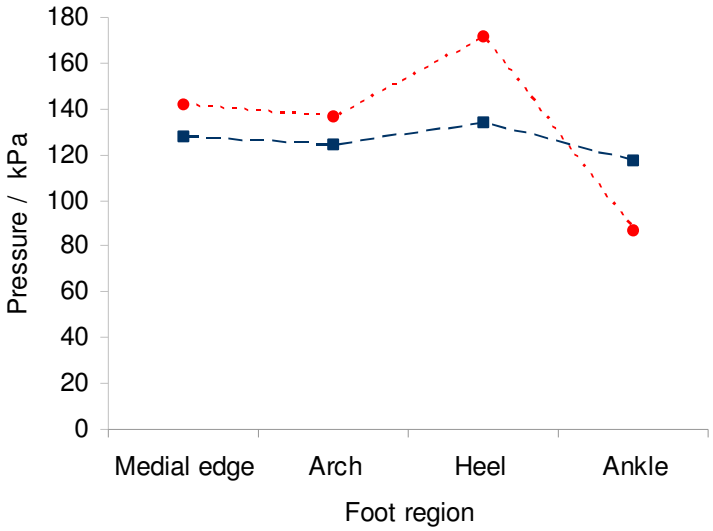


Figure 1.20: Illustration of the variation in static pressure, shown as maximum values applied to the medial edge, arch, heel and ankle reflexes of the two foot types, ● = normal healthy foot ■ = calloused foot.

1.6.3 Discussion of results for static pressures

The first experiments examined the application of a static pressure to two foot types namely a normal healthy foot and a calloused foot. The data showed clear differences in the pattern and pressure relative to the foot type and tissue tonus. Similar trends in pressure variations were observed across each region of the foot treated, irrespective of the physical properties, *e.g.* hard or soft tissue.

Normal healthy foot type

The data for the normal healthy foot which are summarised in Table 1.1, showed average maximum pressures of 141.4, 136.2, 171.0, and 86.6 kPa for the medial edge, arch, heel and ankle regions respectively. Observation of the pressure *vs* time transient shown in Figure 1.18c showed a cyclic variation in the maximum applied pressure as a function of time. A typical pattern can be illustrated by the variations in pressure recorded at t=275 ms where P_{max} was 164 kPa. This increased to 173 and 183 kPa at t=286 and t=299 ms respectively before falling to 180 and 162 kPa at t=309 and t=322 ms. This pattern was observed throughout the pressure recording period. One possibility for these variations in pressure over the experimental period might be the indiscriminative movement between two contacting surfaces, *i.e.* the foot and thumb, even though contact was not lost between the two surfaces. Indeed, the cyclical pattern observed in Figure 1.18c appears to be similar across all transients for this foot type and must reflect normal physiological activity such as venous flow, natural tissue recoil and responses of tactile indentation.

Calloused foot type

Pressure values applied to the calloused foot, Table 1.1 were of a similar order of magnitude to those of the normal foot: average maximum applied pressures of 128.0 kPa at the medial edge, 123.7 kPa at the arch, 133.3 kPa at the heel and 117.4 kPa on the ankle were measured. However, unlike the data for the normal foot the differences in the minimum and maximum applied pressures were marginal. Indeed irrespective of the foot region, a rather flat pressure response was obtained.

In summary, a comparison of the two foot types showed that the trends in the variation of the average maximum applied pressures were similar for both foot types. The average minimum and maximum values on a normal healthy foot varied for the

different regions. In the calloused foot however, the average minimum and maximum pressure values remained relatively constant throughout, irrespective of the foot region treated. The static nature of the pressure exhibited on the latter foot type may be synonymous with the stiffness expressed in the tissue which may become stiff to the touch due to keratinization and dehydration of the outer layers, resulting in loss of compliance of the underlying structure (Edsberg *et al.*, 1999). The heel region received a higher pressure loading in both the normal healthy foot and the calloused foot; this observation may be related to the development of subcutaneous tissue which has adapted to withstand sudden impacts and prolonged pressure (Kuhns, 1949, Miller-Young *et al.*, 2002, Ledoux and Blevins, 2007). In general, the pressure values obtained are consistent with data from Tedeschi (2000) and Blate (1982) who quote pressures of 103 and 137 kPa for acupressure and foot acupressure respectively.

1.7 APPLICATION OF DYNAMIC PRESSURES

The next set of pressure measurements were carried out on the same two foot types but in these the thumb and the associated sensor were moved across the area in a phasic manner providing an on/off stimulus. Two levels of pressure, 'standard' and 'light' were employed as these are used in normal clinical treatments (see Chapter 5a).

1.7.1 Results

Standard dynamic pressure in reflexology treatment

The data in Figure 1.21 shows the variation of pressure with time during the application of standard dynamic pressures to a normal healthy foot. The average maximum pressures applied are highlighted on the respective pressure transients and represent 7 cycles. This experiment was repeated with a calloused foot and the data are shown in Figure 1.22.

A summary of the results for each of the two foot types and treated foot regions is given in Table 1.2.

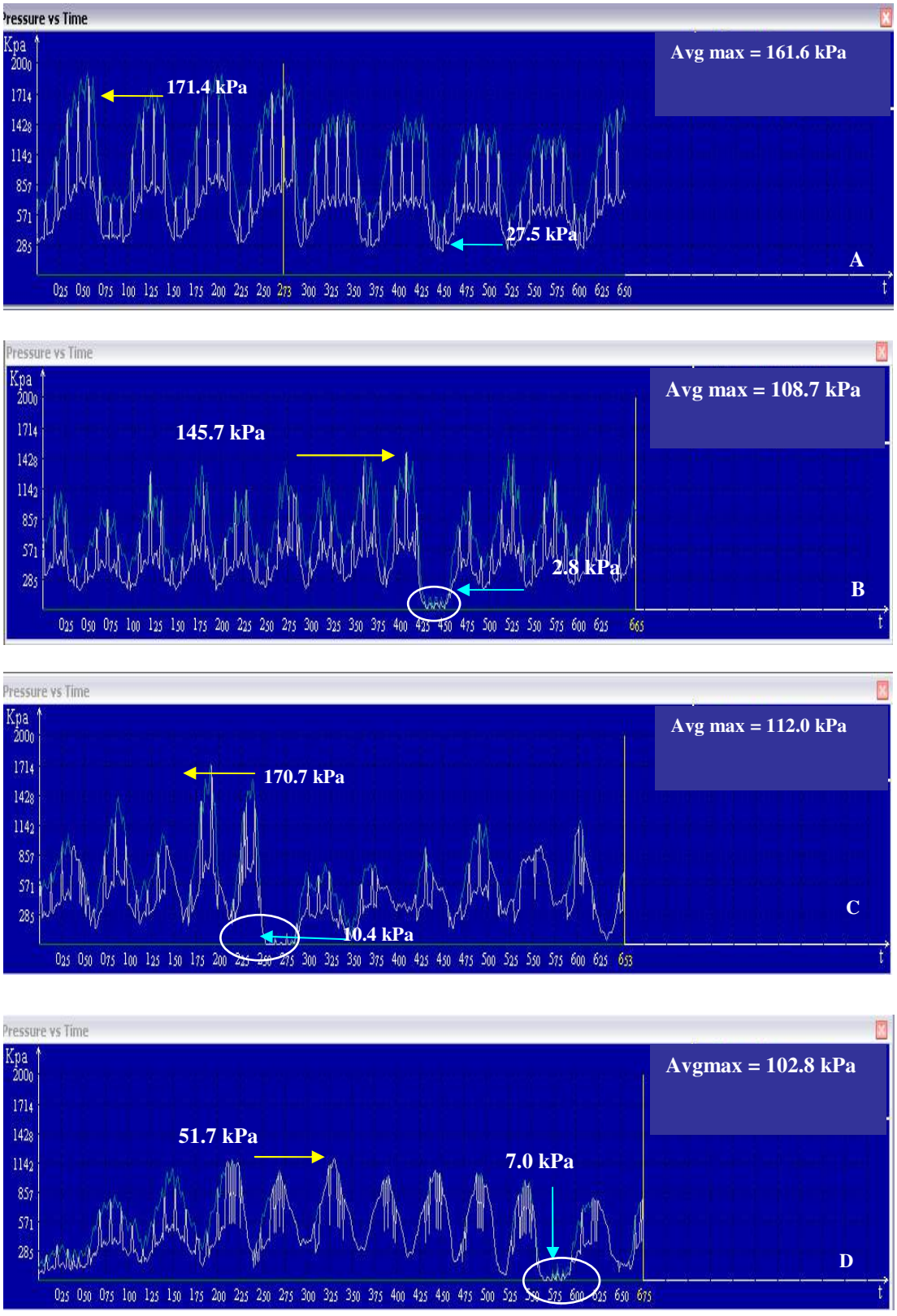


Figure 1.21: Data showing the standard dynamic pressure applied to a normal healthy foot at a) the medial edge, b) arch, c) heel and d) ankle. Blue and yellow arrows represent troughs and peaks of the pressure values at random time intervals. Ringed areas highlight regions where contact was static or minimal. Data were averaged for 7 'cycles'.

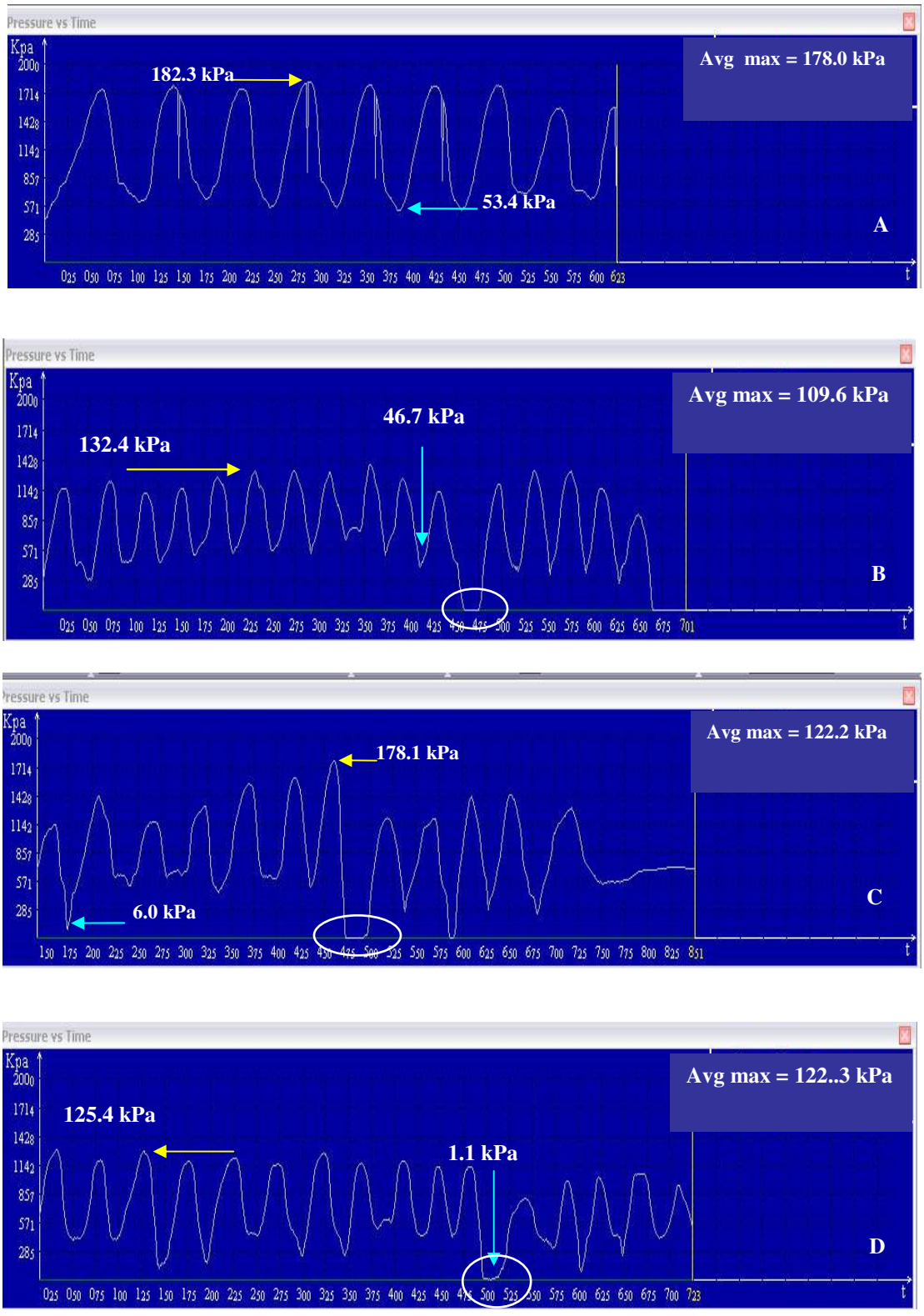


Figure 1.22: Data showing the standard dynamic pressure applied to a calloused foot at a) the medial edge, b) arch, c) heel and d) ankle on a calloused foot. Blue and yellow arrows represent troughs and peaks of the pressure values at random time intervals. Ringed areas highlight regions where contact was static or minimal. Data were averaged for 7 'cycles'.

.

Table 1.2: Average minima and maxima pressure values of standard dynamic pressure. Applied to a) normal healthy foot, and b) calloused foot. Data were averaged over 7 cycles. Contact area and force applied are shown at t=500 ms.

A

Foot region	Contact area / cm^2	Force / N	Minimum pressure per cycle / kPa	Maximum pressure per cycle / kPa
Medial edge	0.8	10.1	29.8	161.6
Arch	0.9	2.3	25.2	108.7
Heel	0.9	4.5	18.8	112.0
Ankle	0.8	7.3	20.0	102.8

B

Foot region	Contact area / cm^2	Force / N	Minimum pressure per cycle / kPa	Maximum pressure per cycle / kPa
Medial edge	0.8	13.3	55.1	178.0
Arch	0.8	8.9	48.6	109.6
Heel	0.8	2.4	44.8	122.2
Ankle	0.8	0.1	25.7	122.3

A summary in the pressure application for the two foot types together with the different foot regions is shown in Figure 1.23.

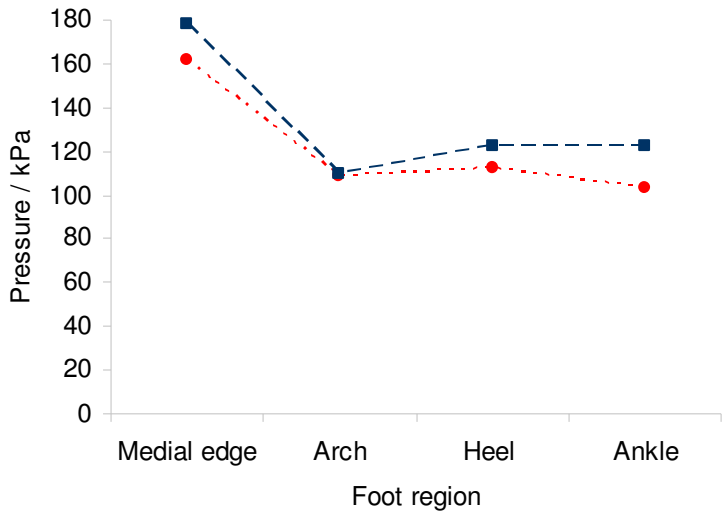


Figure 1.23: Illustration of the variation in standard dynamic pressure applied to the spinal, arch, heel and ankle reflexes of the two foot types, ● = normal healthy foot, ■ = calloused foot.

1.7.2 Discussion of results for standard dynamic pressure

The variations in pressure application for the two foot types using the standard dynamic method is shown in Figure 1.23. Although the pressure maxima are of the

same order of magnitude, there are significant differences in the pressure vs time transients as would be expected given that the pressure was applied in a periodic manner.

Standard dynamic pressure in the normal healthy foot

The application of dynamic pressure on the normal healthy foot has shown average maximum pressures (7 cycles) of 161.6 kPa on the medial edge, 108.7 kPa on the arch, 112.0 kPa on the heel and 102.8 kPa on the ankle. The cyclic pattern of the pressure response, see Figure 1.21, shows similarities across all transients and represents the on/off nature of the stimulus, the 'on' pressure representing the peak value, and the 'off' times by troughs. Transient A, Figure 1.21 that of pressure applied to the medial edge of the foot shows a similar pattern across the entire cycle but a slight decrease in the applied pressure is apparent with an increase in time. Transients B and D (arch, and ankle) however, are much 'noisier' with the periodicity of the response closer and somewhat smaller in magnitude. These transients also exhibited times where the dynamic pressure application became static: these regions are circled on the appropriate transients. The changes in the mode of pressure application and sequence can be explained by consideration of the factors involved in these measurements such as:

i) the compliance of the tissue, which varies within the foot regions and so the periodicity in the response changes as the tissue compliance fluctuates,

ii) dryness present in the tissue, which can result in slippage between the contacting surfaces. This requires a renewed contact and a need to restart the movement. This is particularly relevant to the heel region, (Transient C) and is certainly not unusual as tissue here is often dehydrated,

iii) sticking from the latex glove which impedes the flow of movement across the skin surface.

In normal clinical practice a small amount of lubricant is used to assist in movement across the surface areas of the foot. Nonetheless, the pattern of movement reveals a very precise on/off phasic response.

Comparison of these data with those of the static pressure, Figure 1.20, showed higher values for the average maximum pressures applied to the medial edge, and marginally lower values for the arch, heel and ankle. These data are consistent with

reflexology in clinical practice where a greater pressure is often applied along the boney medial edge of the foot. Tissue in the arch and ankle regions is more compliant, hence the application of such high pressures is not normally required, whilst pressures applied to the heel region is dependent on the tissue tonus of the foot treated.

Standard dynamic pressure in the calloused foot

The data in Figure 1.23 show that the pressure values for the calloused foot are very similar to those shown for the normal healthy foot. The values ranged from 178.0 kPa at the medial edge, 109.6 kPa on the foot arch, 122.2 kPa on the heel to 122.3 kPa on the ankle. The big difference between the normal healthy foot and the calloused foot is seen in the periodicity of the cycle as shown by Figure 1.22. For example, the transients show much less 'noise' in the responses and thus, there is a much smoother pattern in the periodicity of the peaks and troughs. The movement generally appears much less chaotic and this is likely due to the precision of the movement on the stiffer tissue.

A comparison of the normal healthy foot and the calloused foot under standard dynamic pressure application has shown similarities in the loading of pressures applied across the foot regions. The highest pressure was applied to the medial edge of the foot. The reason for this is not known for sure, but may be due to the underlying tissue structure in this region, where there is much less subcutaneous tissue and thus, less elasticity. The data in Table 1.2 show the difference between the applied average minima and maxima (P_{min} and P_{max}) in both foot types. As expected the difference between the values is much less in the calloused foot, reflecting the lack of compliance of the stiffer, dryer tissue.

1.7.3 Application of Light pressure in reflexology treatments

The equivalent measurements for light dynamic pressures are shown in Figure 1.24 for a normal healthy foot and Figure 1.25 for a calloused foot. Relative comparisons have been made for the medial edge, the arch, the heel and the ankle regions.

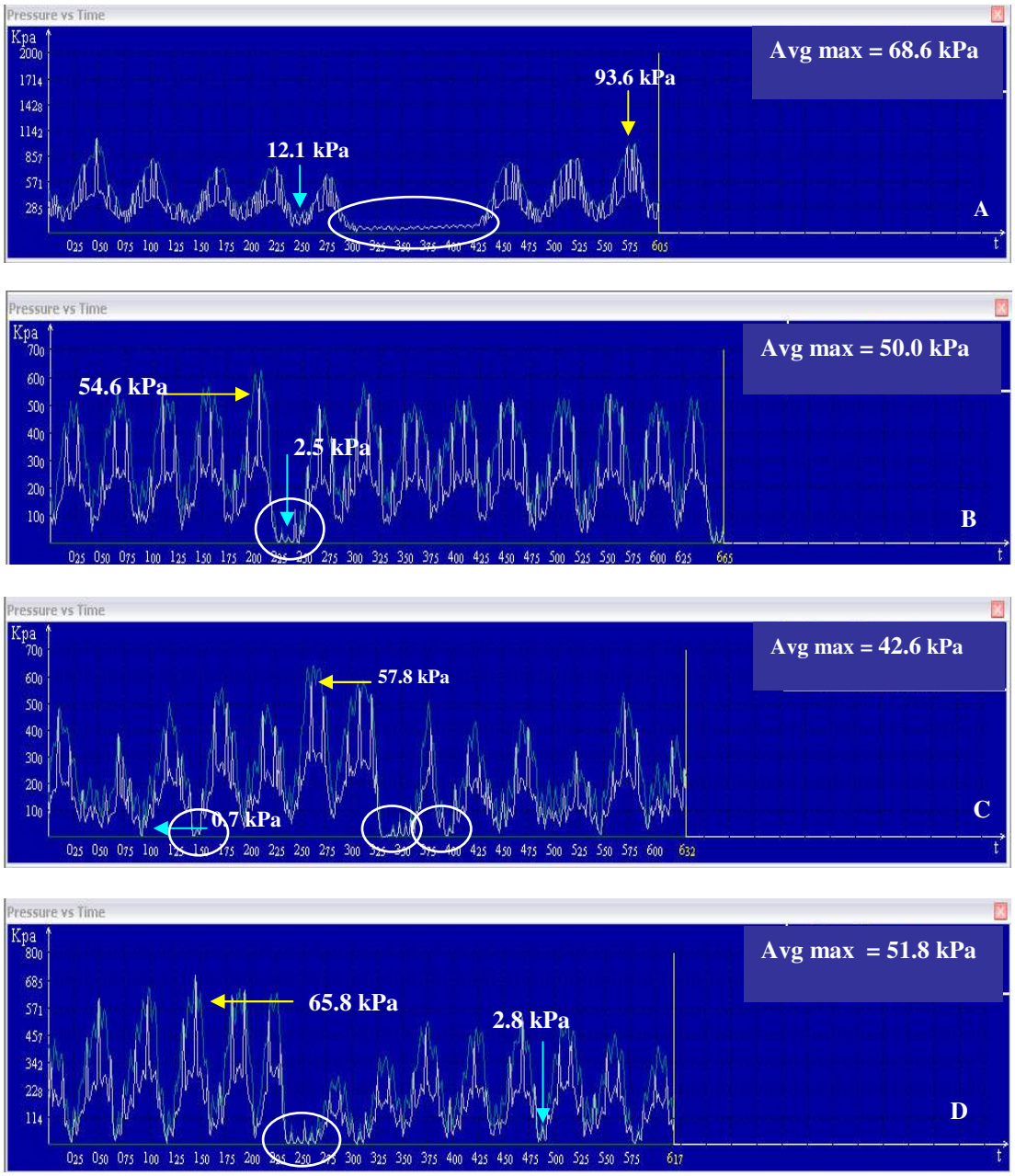


Figure 1.24: Data showing the light dynamic pressure applied to a normal healthy foot on the a) medial edge, b) arch, c) heel and d) ankle. Blue and yellow arrows represent troughs and peaks in the pressure values at the various time intervals. Ringed areas highlight regions where contact was static or minimal. Data were averaged for 7 'cycles'.

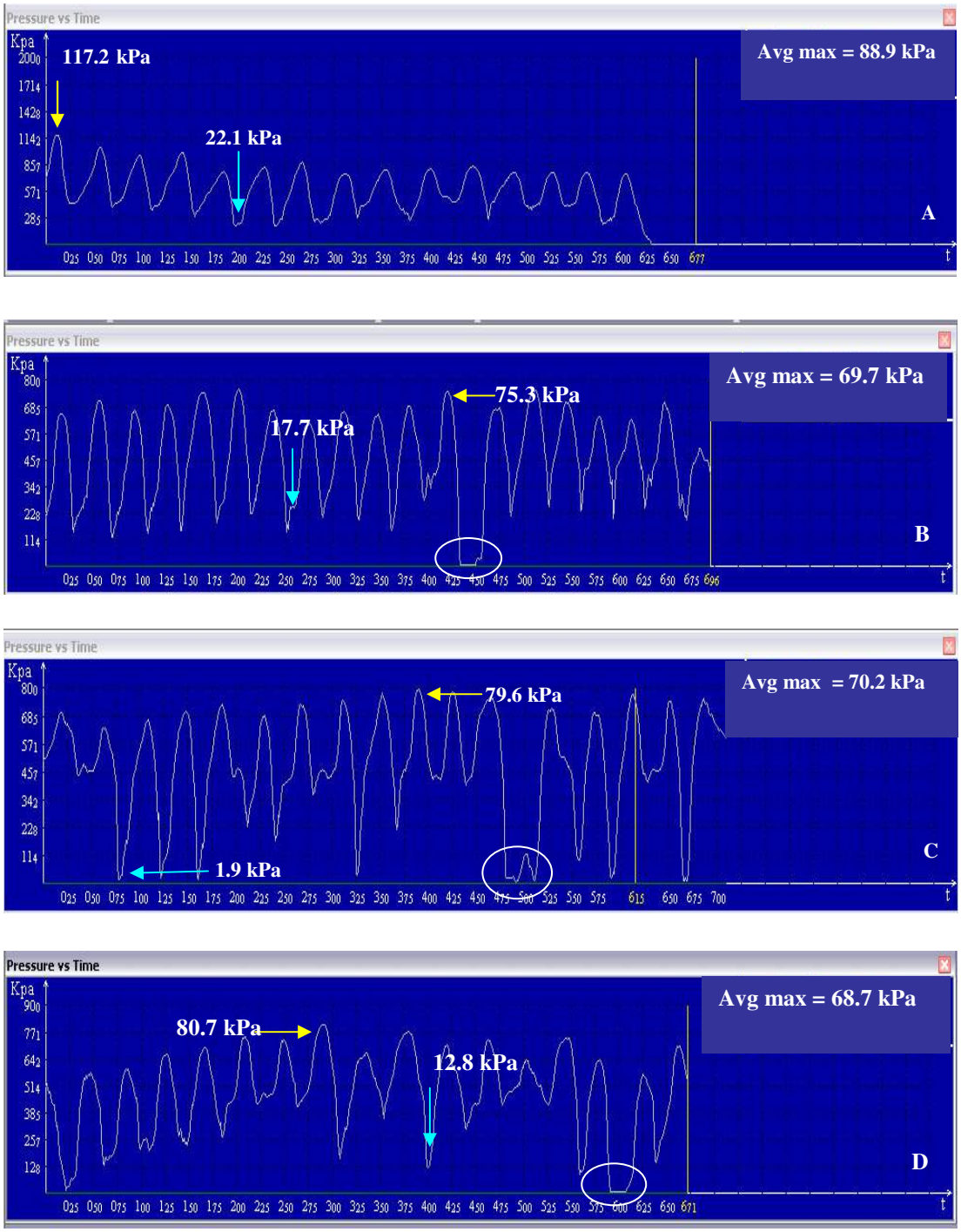


Figure 1.25: Data showing the light dynamic pressure applied to a) the medial longitudinal edge, b) arch, c) heel and d) ankle on a calloused foot. Blue and yellow arrows represent troughs and peaks of the on/off pressure values at the various time intervals. Ringed areas highlight regions where contact was static or minimal. Data were averaged for 7 'cycles'

Table 1.3 and Figure 1.26 provide a summary of the data for the two foot types and four foot regions using the light dynamic pressure application together with details of the contact area and the force applied at t=500 ms.

Table 1.3: Average minima and maxima pressure of light dynamic pressure. Applied to a) normal healthy foot and b) calloused foot. Data represent 7 'cycles'. Contact area and force applied are shown at t=500 ms.

A

Foot region	Contact area / cm^2	Force / N	Minimum pressure per cycle / kPa	Maximum pressure per cycle / kPa
Medial edge	0.9	2.3	11.9	68.6
Arch	0.9	2.2	5.8	50.0
Heel	0.8	0.6	4.4	42.6
Ankle	0.9	1.7	2.2	51.8

B

Foot region	Contact area / cm^2	Force / N	Minimum pressure per cycle / kPa	Maximum pressure per cycle / kPa
Medial edge	0.8	3.3	32.4	88.9
Arch	0.8	4.3	16.3	69.7
Heel	0.8	0.9	12.5	70.2
Ankle	0.8	4.7	24.6	68.7

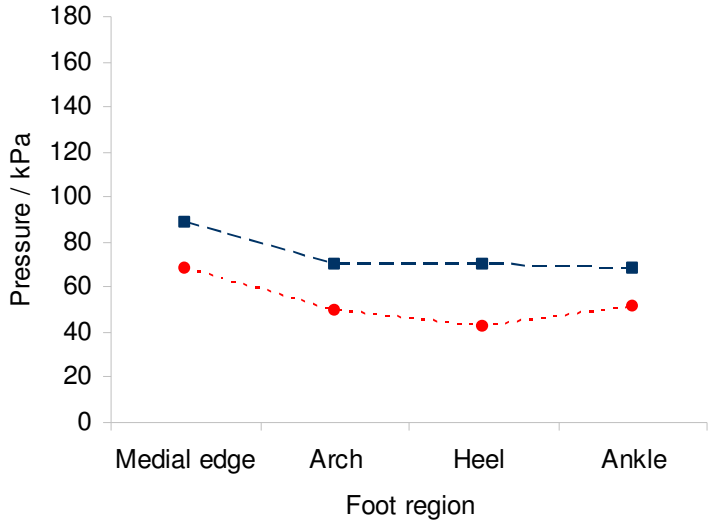


Figure 1.26: Variation in light dynamic pressure applied to the medial edge, arch, heel and ankle regions of the two foot types, ● = normal healthy foot, ■ = calloused foot.

1.7.4 Discussion of results for light dynamic pressures

Light pressure application on a normal healthy foot

The maximum average light dynamic pressure values applied to the normal healthy foot were recorded as 68.6 kPa on the medial edge, 50.0 kPa on the foot arch, 42.6 kPa on the heel and 51.8 kPa on the ankle, see Table 1.3. In terms of the pressure *vs* time transients, the two modalities: 'standard' and 'light', were very similar. Both exhibited cyclic responses with several peaks however, in the case of the light dynamic pressure the cycle times are much reduced. The periodicity of the cyclic pattern (Figure 1.24) was similar to that observed during standard dynamic application with a clear indication of the on/off response. However, the pressure maxima and minima are much smaller as shown in Table 1.3. The ringed areas on the transients show breaks in the flow of the movement and this can be attributed to the latex from the gloved thumb.

Light pressure application on a calloused foot

The maximum average pressures applied to the calloused foot using the light dynamic application were 88.9 kPa at the medial edge, 69.7 kPa on the arch, 70.2 kPa on the heel and 68.7 kPa on the ankle, see Table 1.3. The response pattern of the pressures applied to the four foot regions was similar for both standard and light dynamic pressure. However, the cycles were much more erratic when compared to the standard dynamic pressure. Figure 1.25, transient C, shows the heel area, for the light dynamic pressure and when compared to the standard dynamic pressure, Figure 1.22, transient C the periodicity of response is both shorter and closer. The heel on the calloused foot however, has much more keratinized tissue formation and the lighter pressure is more difficult to apply on this type of tissue. The transients for the other foot areas are much less erratic and demonstrate that it is possible to apply lighter pressure to calloused, stiff tissue.

As shown by the standard dynamic pressure values, the average variation between P_{min} and P_{max} was greatest in the normal healthy tissue, see Table 1.3, thus reflecting a greater level of compliance and ability to deform under pressure.

Summary of differences between static, standard dynamic and light dynamic

The highest average maximum pressure values (P_{max}) were shown in static mode as shown in Table 1.4 and Figure 1.27. The data show that the medial edge of the foot received the highest pressures over all modes of application. The boney skeleton at the medial edge is closer to the foot surface and is built to withstand huge mechanical loads that are able to dissipate energy (Ritchie *et al.*, 2009) without deformation. The pressure values therefore reflect the ability of the skeletal system to perform according to normal physiological load. P_{max} in the heel region of the normal healthy tissue was 171 kPa and this region of the foot with its elastic compliance is built to display greater recoil (Silver *et al.*, 2001) and thus withstand large pressure values, therefore the pressure values observed for static loading in the normal healthy tissue are to be expected.

Table 1.4: Average pressures applied to the two foot types across the four foot regions using the static, standard and light dynamic pressure applications.

Normal healthy foot	**Average pressure P_{max}**	**Average pressure P_{max}**	**Average pressure P_{max}**	**Average pressure P_{max}**
Foot region ⇨	Medial edge	Arch	Heel	Ankle
Static pressure	141.4	136.2	171.0	86.0
Standard dynamic	161.6	108.7	112.0	102.8
Light dynamic	68.6	50.0	42.6	51.8
Calloused foot				
Static pressure	128.0	123.7	133.3	117.4
Standard dynamic	178.0	109.6	122.2	122.3
Light dynamic	88.9	69.7	70.2	68.7

In summary, static pressures showed the highest values overall. There was an approximate difference of ≥ 50% between standard and light dynamic pressure but in general the pressures varied according to the mode of application, the foot type and the foot region treated.

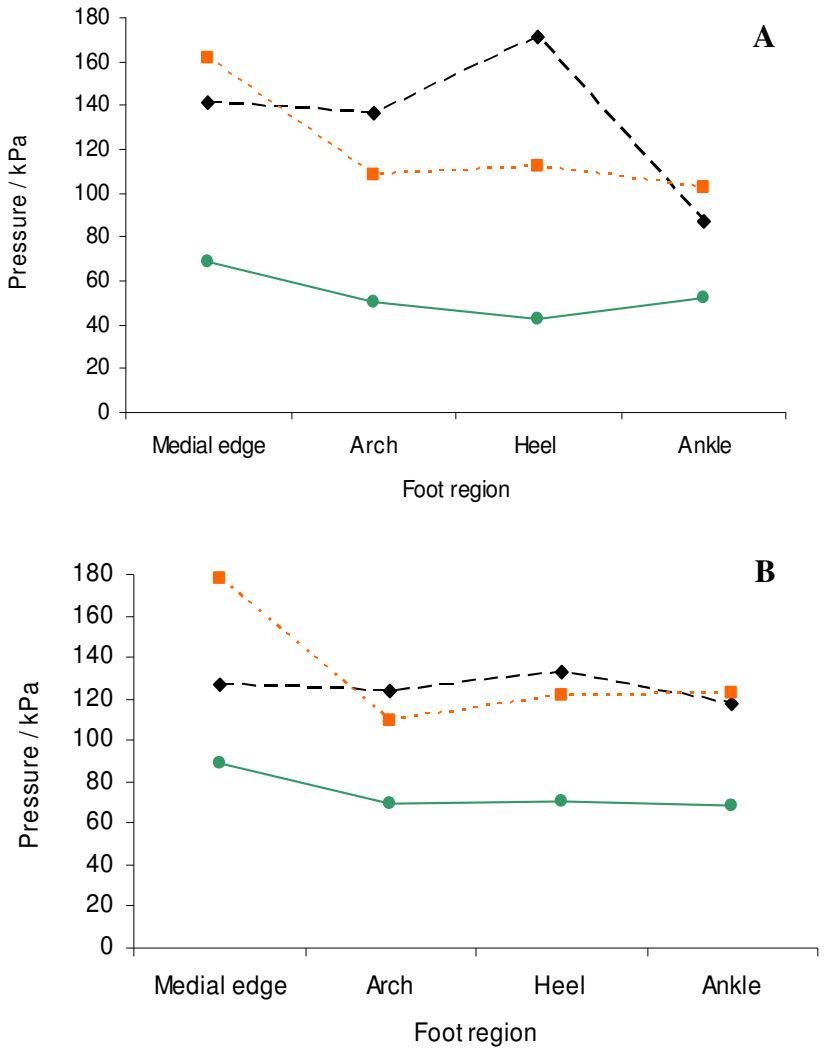


Figure 1.27: Maximum average pressure (kPa) for static, standard dynamic pressure and light dynamic pressure on a) normal healthy foot and b) calloused foot. The four treated regions were the medial edge, arch, heel and ankle.
◆ Static pressure ■ Standard dynamic pressure ● Light dynamic pressure.

1.8 DISCUSSION

These investigations aimed to measure the effects of pressure during static and dynamic loading of the foot sole. A number of difficulties were associated with the equipment during both experimental procedures and these have been highlighted in Section 1.5.1.

When evaluating these issues, the relationship between the sensitivity of the fingers of the reflexologist to the tissue type must be considered. The palms of the hands have a vast number of Meissner corpuscles in the dermal papillae that provide two-point sensory discrimination (Johnson, 2001). The reflexologist relies upon this ability to provide feedback on the condition of the tissue in the foot and hence the level of response to be applied. Although the use of a latex immobilising layer caused some contact problems, it did not appear to have hindered this sensitivity to the applied pressures as the data obtained compared well with the literature for shiatsu (Serizawa, 1972) and acupressure (Tedeschi, 2000).

Whilst there is an abundance of literature available on the measurement of pressures responsible for bed sores (Edsberg *et al.*, 1999), pressure in the diabetic foot (Jacob Thomas *et al.*, 2003) and pressure on blood flow (Santos *et al.*, 2003b, a, Fromy *et al.*, 2000) none is available on the pressures applied during reflexology treatments.

Comparison of the static and dynamic pressure applications in the normal healthy foot and the calloused foot showed that the static pressure was greater than either the standard or light dynamic pressure across all foot regions, with the exception of the heel.

The dynamic pressure images seen in Figures 1.17–26 have illustrated the fluctuations created by shear stress during movement. The pressures applied to a normal healthy foot (Figures 1.17, 1.21 and 1.25) showed a very precise load/unload pattern with small intermittent steps, reflecting the precision of the movement. These results indicate that on application of pressure, the shape of the tissue responds to the progress of the movement of the thumb, which in turn leads to a greater spread of impact. In comparison, the pressures applied to the calloused foot, Figures 1.19,

1.22 and 1.26 were similar with none of the sharp peaks as seen for the normal response evident: as discussed earlier this has been attributed to the stiffness of the tissue in the calloused foot. It is likely that the differences in response to the applied pressures for the two foot types are largely related to the elasticity and compliance of the tissue (Andersen *et al.*, 2001).

A number of physiological responses are required to maintain a homeostatic environment. Many of these relate to pressure and forces within the circulatory systems (Lu *et al.*, 2006). Indeed, Abraham *et al.* (2001) has reported that pressure of between 4 - 8 kPa impairs cutaneous blood flow and Odman (1989) has reported that an exchange of ions or electrical activity in the cell membrane is generated by tissue deformation that is directly related to the degree of compression. Although Neziri (2009) has shown that a stronger stimulus, with a high frequency offers a greater chance of initiating an action potential. However, experiments described in Chapter 5a indicate that irrespective of the amount of pressure applied, a response is initiated.

Lim *et al.* (2006) have shown that mechanical loads induced within or outside the body could increase or decrease the properties of living cells. Loading exerted at tissue level is transmitted to individual cells to affect physiological function and Fromy *et al.* (1998) have indicated that Aδ and C-fibres respond to pressures between 6 - 24 kPa. Such pressure values have been surpassed during these experiments, indicating that pressures applied during reflexology stimulation, are sufficient to initiate change in the homeostatic environment of the cell.

The conversion of a mechanical force into a cellular response is an essential part of cellular processing and an increase in mechanical stimuli can trigger the release of Ca^{++} entry in excitable cells (Heppenstall and Lewin, 2006, Lim *et al.*, 2006). The rapidly adapting type I and II Meissner and Pacinian corpuscles account for 70% of the receptors found in the sole of the foot (Kennedy and Inglis, 2002). Rapidly adapting receptors are thought to respond better to an on/off stimulus (Toma and Nakajima, 1995, Kolosova *et al.*, 2000, Kennedy and Inglis, 2002) and this type of on/off dynamic pressure is typically applied during a reflexology treatment. There is

at the present time however, very little evidence available to detect how sensory cells adjust to mechanical stimuli (Lewin, 2008).

A limited number of receptor units are found in the foot arch (Kennedy and Inglis, 2002), with most receptors located in the lateral borders, the heel and the anterior aspects of the foot, which is typical of the proprioceptive responses required in walking and balance. In weight-bearing the foot constantly adjusts to the stimulation of receptors in these areas and the on/off rapidly adapting mechanoreceptors are thought to be responsible for this process. It is therefore possible that the dynamic stimulus applied in reflexology simulates this constant physiological adjustment.

As the skin is the largest organ system in the body its receptors of sensation respond to a variety of tactile stimuli (Mackey, 2001). The receptive fields of mechanoreceptors found in the foot sole are three times greater than in the hand (Kennedy and Inglis, 2002) and provide a much more responsive surface. Most reflexology techniques incorporate the use of a two handed application, with one hand holding the foot whilst the other hand stimulates the mechanoreceptors of the feet. Whether it is the tactile sensation acting singly or in combination with the stimuli that provoke a reaction in the cell is unclear at present. However, experience indicates that if the comparisons of reflexology stimulation are matched to the literature on impact of pressures on blood circulation, cellular change and the mechanisms involved in pain, it would be reasonable to assume that reflexology can initiate physiological change, regardless of the pressure applied.

Conclusion

This investigation has evaluated the effects of the application of static and dynamic forces applied during typical reflexology stimulation to two foot types, a normal healthy foot and a calloused foot. The following conclusions may be made from these experiments:

a) It is now possible to obtain a pressure measurement for reflexology using the Tactilus ® Freeform Sensory system.
b) The data obtained confirm that it is possible to differentiate pressures applied between the foot regions, *e.g.* medial edge, arch, heel and ankle.

c) The data for static, standard and light dynamic show a general trend that reflects the physiological make up of the tissue and region under pressure.

d) There was a ≥ 50% difference in the data for the standard and light dynamic pressures

e) P_{min} and P_{max} differences were greatest in the normal healthy tissue, reflecting the elasticity and compliance of the tissue.

Appendix A

PRESENTATIONS AND PAPERS

- C A Samuel, S A Campbell, I Ebenezer 'Reflexology in the Management of Pain'. Research Conference on Pain Management: Is there a role for Complementary Medicine? Royal College of Nursing, 2003.

- C A Samuel, S A Campbell, I Ebenezer 'Reflexology in the Management of Pain'. NHS Biennial Conference Portsmouth and Isle of Wight PCT, 2005.

- C A Samuel, I Ebenezer. 'Effects of Reflexology on pain threshold and tolerance in an ice-pain experiment'. Developing Research Strategies Conference, Northampton University, 2007.

- C A Samuel 'Complementary and Alternative Medicine: benefits and uses in health and illness'. Nurses Forum Rowans Hospice. 2007

- C A Samuel 'The effects of reflexology on pain threshold and tolerance in an ice-pain experiment in healthy human subjects'. International Complementary Medicine Research Congress, Munich 2007.

- C A Samuel, S A Campbell, I Ebenezer 'Reflexology in the Management of Pain'. Prince of Wales Foundation for Integrated Health: *Searching for Evidence: complementary therapies research* 2006. 5

- C A Samuel, I S Ebenezer 'The effects of reflexology on pain threshold and tolerance in an ice-pain experiment in healthy human subjects'. *Forschende Komplementarmedizin* Band 14, Supplement 1, 2007, **15**

- C A Samuel, I S Ebenezer 'The effects of reflexology on pain threshold and tolerance in an ice-pain experiment in healthy human subjects'. *Complementary Therapies in Medicine* (2008) **16** 233-237

- C A Samuel 'Reflexology and Pain Management' *Reflexions* 2008 91, 22

Appendix B

DATA COLLECTION FORMS

Subject Information Sheet

You are asked to read this form carefully. If you consent to take part, as a subject, in the trial being undertaken by *Mrs Carol Samuel,* then you should sign the consent form. If you have any query, or are unsure or uncertain about anything, then you should not sign until your problem has been resolved and you are completely happy to volunteer.

The study for which you are being asked to volunteer for is being carried out in order to *review scientifically the effects reflexology has on the management of pain.*

Subjects are requested not to partake of alcoholic beverages or take non-prescription medication such as analgesics, aspirin-like drugs, cough mixtures or nasal inhalers, nor should they smoke prior to each experimental trial

You may at any time withdraw from the experiment. You do not have to give any reason, and no-one can attempt to dissuade you. If you ever require any further explanation, please do not hesitate to ask.

Any information obtained during this trial will remain confidential as to your identity: If it can specifically be identified with you, your permission will be sought in writing before it will be published. Other material, which cannot be identified with you, will be published or presented at meetings with the aim of benefiting others. All information will be subject to the conditions of the Data Protection Act 1998, Part II, S7 'Rights of Data Subjects & Others' and S33 'Research history & Statistics' and subsequent statutory instruments.

REFLEXOLOGY RESEARCH PROGRAMME

CONSENT FORM

1. I have read the information sheet, which provides full details of this study, and have had the opportunity to raise and discuss my questions with the Project Officer, with regard to the general nature, object, potential risks and duration of the study, and understand what is expected of me.

2. I understand that in the event of my sustaining injury, illness or death as a result of participating as a volunteer in this research I, or my dependents, may enter a claim with the University of Portsmouth for compensation under the provisions of the University Compensation scheme. I also understand that should such injury, illness or death have been caused by the negligence of the University of Portsmouth or its employees either I, or my dependents, may have a claim in law.

3. I understand that the aim of the study is to prove scientifically that reflexology has a positive benefit to the management of pain.

4. I agree to volunteer as a subject for the study described in the information sheet. I give my full consent to my participation in this study.

5. This consent is specific to the particular test described in the information sheet attached, and shall not be taken to imply my consent to participate in any subsequent experiment or deviation from that detailed here.

6. I reserve the right to withdraw from this experiment at any time; I also understand that I may be withdrawn at any time, and will suffer no penalty as a result.

Project Officer: ***Carol Samuel***

Signed: _____

Name: _____ Date: _____

Witnessed: _____

Name: _____ Date _____

PATIENT RECORD FORM

REFLEXOLOGY RESEARCH PROGRAMME

All information contained in these sheets is held in the strictest confidence and will be used for the purposes of assessing your suitability for treatment only.

Date of initial consultation:	Client reference:
Name: ……	DOB: .....
Address:	Occupation: .....
.....	Tel. No: (H)….....
Post Code:	Tel. No: (W)
Doctors details: …….....	
.....Tel. No:	

MEDICAL DETAILS

Condition	✓	**Please give specific details**
Do you have any kind of heart condition?		
Do you have any circulatory disorders, *e.g*. Thrombosis, Raynauds syndrome, varicose veins		
Muscular/ skeletal problems (arthritis, osteoporosis etc)		
Respiratory problems, *e.g*. asthma, bronchitis		
Do you have any hereditary condition or genetic defects		
Are you suffering from any ongoing pain condition?		
Do you have any disorder of the nervous system, *e.g*. Multiple Sclerosis, Carpal Tunnel Syndrome?		
Are you pregnant?		
Do you suffer from Epilepsy?		
Are you Diabetic? If so, diet controlled or insulin?		

Are you currently undergoing medical care, including homeopathic, herbal or other? (Please give specific details)_____

Name of medication	Dosage taken	Reason prescribed

CLIENT DECLARATION

I have read the details contained in this form and declare that everything described in it; to the best of my knowledge, is correct. I have not knowingly given false information and take full responsibility for the treatment offered and am willing to take part in the experiment.

Client Signature: _____ Date:_____

Data collection sheet (Chapter 4)

NOTES:

_____

_____

_____

_____

TREATMENT:

T.E.N.S (Low Voltage) ❑ Reflexology ❑

ICE/PAIN TEST RESULTS:

	Time	Threshold Time	Tolerance Time	H.R – Start	H.R. - Finish
1	Baseline = 15mins prior to treatment				
2	Immediately following treatment	**NO ICE PLUNGE**			
3	+ 30 mins post treat				
4	+ 60 mins post treat				
5	+ 90 mins post treat				
6	+ 120 mins post treat				

	Time	Threshold Time	Tolerance Time	H.R – Start	H.R. - Finish
1	Baseline = 15mins prior to treatment				
2	Immediately following treatment	**NO ICE PLUNGE**			
3	+ 30 mins post treat				
4	+ 60 mins post treat				
5	+ 90 mins post treat				
6	+ 120 mins post treat				

COMMENTS:

_____

_____

_____

_____

Basic Subjective Rating Questionnaire – (Adapted for each experiment)

Reflexology Research Programme

Subject Name/Number:	Date:
Treatment:	Time:

To be completed BEFORE first trial (Ice plunge)

1

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mildly Anxious		Relaxed (not at all anxious)	

Q3. Have you drunk any of the following beverages in the past 60 minutes?

Tea		Coffee		Canned or bottle drinks	

Complete AFTER the first ice plunge PRIOR to treatment (baseline)

2

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mildly Anxious		Relaxed (not at all anxious)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

To be completed immediately after treatment (Reflexology/TENS) **No ice plunge**

3

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mildly Anxious		Relaxed (not at all anxious)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

To be completed after 1st trial (ice plunge) post treatment (+ 30minutes)

4

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mildly Anxious		Relaxed (not at all anxious)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

To be completed after 3rd trial (+60 minutes post treatment)

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

5

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mildly Anxious		Relaxed (not at all anxious)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

To be completed after 4th trial (+90 minutes post treatment)

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

6

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mildly Anxious		Relaxed (not at all anxious)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

To be completed after 5th trial (+120 minutes post treatment)

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

7

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mildly Anxious		Relaxed (not at all anxious)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

Q4. Do you think that the treatment had any overall effects on your responses to the two parameters that were measured during each trial?

Yes ☐ No ☐

Thank you for taking part in these trials and for completing the subjective ratings questionnaire

POST TREATMENT FEEDBACK DIARY

Thank you for taking part in the experiment today. As part of the ongoing monitoring process may I ask you please to complete the following questionnaire over the next two of days and return it to: -

Carol Samuel, Reflexology Research, School of Pharmacy & Biomedical Science, St Michael's Building, White Swan Road, Portsmouth PO1 2DT

What treatment were you given today?

Reflexology ❑ Standard ❑ Light ❑

Low-frequency T.E.N.S ❑

Mechanical Reflexology ❑

Have you experienced any of the following reactions?

Dark colour/strong odour to urination	Yes ❑	No ❑
Increase in bowel movements and/or flatulence	Yes ❑	No ❑
Increase in nasal secretions and/or coughing	Yes ❑	No ❑
Vaginal discharge	Yes ❑	No ❑
Extra energy or depleted energy levels	Yes ❑	No ❑
Spots and/or minor skin blemishes	Yes ❑	No ❑
Muscular/skeletal aches and pains (not usual for you)	Yes ❑	No ❑
Headaches at the front of the forehead	Yes ❑	No ❑
Improved sleep	Yes ❑	No ❑

Have you experienced anything not mentioned above, that may be unusual for you? (Please specify)

On a scale of 1 – 5 please rate your overall experience of the treatment (i.e. T.E.N.S/Reflexology/mechanical reflexology) you were given by ticking ✓ one box.

Enjoyed very much	Enjoyed a little	No comment	Disliked	Disliked a lot
5	4	3	2	1

ADAPTED VERSION OF EYSENCK PERSONALITY QUESTIONNAIRE

E.P.Q. (ADULT)

Occupation**:** _____

Age: _____ Sex: _____

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

PLEASE REMEMBER TO ANSWER EACH QUESTION

1.	Do you have many different hobbies?	YES	NO
4.	Have you ever taken the praise for something you knew someone else had really done?	YES	NO
5.	Are you a talkative person?	YES	NO
8.	Were you ever greedy bu helping yourself to more than your share of anything?	YES	NO
10.	Are you rather lively?	YES	NO
13.	If you say you will do something, do you always keep your promise no matter how inconvenient it might be?	YES	NO
14.	Can you usually let yourself go and enjoy yourself at a lively party?	YES	NO
16.	Have you ever blamed someone for doing something you knew was really your fault?	YES	NO
17.	Do you enjoy meeting new people?	YES	NO
20.	Are *all* your habits good and desirable ones?	YES	NO
21.	Do you tend to keep in the background on social occasions?	YES	NO
24.	Have you ever taken anything (eve a pin or button) that belonged to someone else?	YES	NO
25.	Do you like going out a lot?	YES	NO
28.	Do you sometimes talk about things you know nothing about?	YES	NO
29.	Do you prefer reading to meeting people?	YES	NO
32.	Do you have many friends?	YES	NO
35.	As a child did you do as you were told immediately and without grumbling?	YES	NO
39.	Have you ever broken or lost something belonging to someone else?	YES	NO
40.	Do you usually take the initiative in making new friends?	YES	NO

42.	Are you mostly quiet when you are with other people?	YES	NO
44.	Do you sometimes boast a little?	YES	NO
45.	Can you easily get some life into a rather dull party?	YES	NO
48.	Have you ever said anything bad or nasty about anyone?	YES	NO
49.	Do you like telling joes and funny stories to your friends?	YES	NO
51.	As a child were you every cheeky to your parents?	YES	NO
52.	Do you like mixing with people?	YES	NO
55.	Do you always wash before a meal?	YES	NO
59.	Have you ever cheated at a game?	YES	NO
60.	Do you like doing things in which you have to act quickly?	YES	NO
63.	Have you ever taken advantage of someone?	YES	NO
64.	Do you often take on more activities than you have time for?	YES	NO
69.	Would you dodge paying taxes if you were sure you could never be found out?	YES	NO
70.	Can you get a party going?	YES	NO
73.	Have you ever insisted on having your own way?	YES	NO
77.	Do you often feel lonely?	YES	NO
78.	Do you always practice what you preach?	YES	NO
81.	Have you ever been late for an appointment or work?	YES	NO
82.	Do you like plenty of bustle and excitement around you?	YES	NO
85.	Do you sometimes put off until tomorrow what you ought to do today?	YES	NO
86.	Do other people think of you as being very lively?	YES	NO
89.	Are you always willing to admit it when you have made a mistake?	YES	NO

PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS

DATA COLLECTION SHEET (Chapter 3) Physiological Experiments

Date of last menstrual period: _____

TREATMENT:

T.E.N.S ❒ **Reflexology ❒**

WEEK ONE TREATMENT: Date: _____ Time: _____

Baseline Readings

	Time	Heart Rate	Temperature	Blood Pressure
1	Baseline			
2	+10mins			NO READING
3	+10mins			
TREATMENT – DURING READINGS				
4	+ 10minutes (through treatment)			NO READING
5	+ 20minutes (through treatment)			
6	+ 30 minutes (end of treatment)			NO READING
END OF TREATMENT – POST TREATMENT READINGS				
7	+ 10 minutes			
8	+ 20 minutes			NO READING
9	+ 30 minutes			
10	+ 40 minutes			NO READING
11	+ 50 minutes			
12	+ 60 minutes			NO READING

WEEK TWO TREATMENT: Date: _____ Time: _____

Baseline Readings

	Time	Heart Rate	Temperature	Blood Pressure
1	Baseline			
2	+10mins			NO READING
3	+10mins			
TREATMENT – DURING READINGS				
4	+ 10minutes (through treatment)			NO READING
5	+ 20minutes (through treatment)			
6	+ 30 minutes (end of treatment)			NO READING
END OF TREATMENT – POST TREATMENT READINGS				
7	+ 10 minutes			
8	+ 20 minutes			NO READING
9	+ 30 minutes			
10	+ 40 minutes			NO READING
11	+ 50 minutes			
12	+ 60 minutes			NO READING

Comments:

_____

_____

SUBJECTIVE RATING QUESTIONNAIRE

REFLEXOLOGY RESEARCH TRIALS – Physiological Experiments

First/Second Visit

Instructions: For each question tick ☑ the answer which best applies to you.

1. **How often have you been bothered by any illness, bodily disorder, aches or pains during the past month/week?**

Every day	❑
Almost every day	❑
About half of the time	❑
Now and then, but less than half the time	❑
Rarely	❑
None of the time	❑

2. **Have you been bothered by nervousness during the past month/week?**

Extremely so, to the point where I could not work or take care of things	❑
Very much so	❑
Quite a bit	❑
Some, enough to bother me	❑
A little	❑
Not at all	❑

3. **Were you generally tense or did you feel any tension during the past month/week?**

Yes, extremely tense, most or all of the time	❑
Yes, very tense most of the time	❑
Not generally tense, but did feel fairly tense several times	❑
I felt a little tense a few times	❑
My general tension level was quite low	❑
I never felt tense or any tension at all	❑

4. **Did you feel healthy enough to carry out the things you like to do or had to do during the past month/week?**

Yes, definitely so	❑
For the most part	❑
Health problems limited me in some important ways	❑
I was only healthy enough to take care of myself	❑
I needed some help in taking care of myself	❑
I needed someone to help me with most or all of the things I had to do	❑

5. Have you been concerned, worried or had any fears about your health during the past month/week?

Extremely so	❑
Very much so	❑
Quite a bit	❑
Some, but not a lot	❑
Practically never	❑
Not at all	❑

6. Have you been anxious, worried, or upset during the past month/week?

Extremely so, to the point of being sick or almost sick	❑
Very much so	❑
Quite a bit	❑
Some, enough to bother me	❑
A little bit	❑
Not at all	❑

7. Did you feel relaxed, at ease or highly strung, tight or keyed up during the past month/week?

Relaxed and at ease all month	❑
Relaxed and at ease most of the time	❑
Generally felt relaxed by at times felt fairly highly strung	❑
Generally felt highly strung but at times felt fairly relaxed	❑
Highly strung, tight or keyed-up most of the time	❑
Felt highly strung, tight or keyed-up the whole month	❑

8. Have you been under, or felt you were under any strain, stress or pressure during the past month/week?

Yes, almost more than I could bear or stand	❑
Yes, quite a bit of pressure	❑
Yes some, more than usual	❑
Yes some, but about usual	❑
Yes, a little	❑
Not at all	❑

Thank you for completing this questionnaire.

SCORE SHEET – PHYSIOLOGICAL

1. How often have you been bothered by any illness, bodily disorder, aches or pains during the past month/week?

Every day	0
Almost every day	1
About half of the time	2
Now and then, but less than half the time	3
Rarely	4
None of the time	5

2. Have you been bothered by nervousness during the past month/week?

Extremely so, to the point where I could not work or take care of things	0
Very much so	1
Quite a bit	2
Some, enough to bother me	3
A little	4
Not at all	5

3. Were you generally tense or did you feel any tension during the past month/week?

Yes, extremely tense, most or all of the time	0
Yes, very tense most of the time	1
Not generally tense, but did feel fairly tense several times	2
I felt a little tense a few times	3
My general tension level was quite low	4
I never felt tense or any tension at all	5

4. Did you feel healthy enough to carry out the things you like to do or had to do during the past month/week?

Yes, definitely so	5
For the most part	4
Health problems limited me in some important ways	3
I was only healthy enough to take care of myself	2
I needed some help in taking care of myself	1
I needed someone to help me with most or all of the things I had to do	0

5. Have you been concerned, worried or had any fears about your health during the past month/week?

Extremely so	0
Very much so	1
Quite a bit	2
Some, but not a lot	3
Practically never	4
Not at all	5

6. Have you been anxious, worried, or upset during the past month/week?

Extremely so, to the point of being sick or almost sick	0
Very much so	1
Quite a bit	2
Some, enough to bother me	3
A little bit	4
Not at all	5

7. Did you feel relaxed, at ease or highly strung, tight or keyed up during the past month/week?

Relaxed and at ease all month	5
Relaxed and at ease most of the time	4
Generally felt relaxed by at times felt fairly highly strung	3
Generally felt highly strung but at times felt fairly relaxed	2
Highly strung, tight or keyed-up most of the time	1
Felt highly strung, tight or keyed-up the whole month	0

8. Have you been under, or felt you were under any strain, stress or pressure during the past month/week?

Yes, almost more than I could bear or stand	0
Yes, quite a bit of pressure	1
Yes some, more than usual	2
Yes some, but about usual	3
Yes, a little	4
Not at all	5

SCORING

	Questions	**Range of scores**	**High score**	**Low Score**
Anxiety	2,3,6,7,8,	0-25	Not bothered by nerves; low tension; not anxious; relaxed; little or no stress or strain	Extremely bothered by nervousness, very tens, anxious, worried, upset; felt under heavy pressure.
General Health	1,4,5	0-15	Rarely if every bothered by illness; healthy enough to do things; not fearful or worried about health	Often bothered by illness, bodily disorders; needed help in caring for self; worried or fearful about health.

DAILY ICE PLUNGE TESTS

Ice plunge will take place at 15-minute intervals throughout a one-hour session given daily over four consecutive days. Subjects are to plunge their non-dominant hand into crushed ice. The first sensation of pain will be recorded as pain threshold, at which point subjects will keep their hand in the ice until they reach a point where they are unable to withstand the pain any longer and will then remove the hand, this will be recorded as the pain tolerance level.

Subject Name:_____ **DOB:** _____

DAY ONE: Date:_____ Time: _____

	Time	**Heart Rate**			**Temperature**		**Threshold/Tolerance**		
		Before	*During*	*After*	*Before*	*After*		*Threshold*	*Tolerance*
1	**Baseline**						**Baseline**		
2	**+10 min**								
3	**+20 min**						**15 min**		
4	**+ 30 min**						**30 min**		
5	**+ 40 min**								
6	**+ 50 min**						**45 min**		
7	**+ 60 min**						**60 min**		

DAY TWO: Date:_____ Time: _____

	Time	**Heart Rate**			**Temperature**		**Threshold/Tolerance**		
		Before	*During*	*After*	*Before*	*After*		*Threshold*	*Tolerance*
1	**Baseline**						**Baseline**		
2	**+ 10 min**								
3	**+ 20 min**						**15 min**		
4	**+ 30 min**						**30 min**		
5	**+ 40 min**								
6	**+ 50 min**						**45 min**		
7	**+ 60 min**						**60 min**		

DAY THREE: Date:_____ Time: _____

	Time	**Heart Rate**			**Temperature**		**Threshold/Tolerance**		
		Before	*During*	*After*	*Before*	*After*		*Threshold*	*Tolerance*
1	**Baseline**						**Baseline**		
2	**+ 10 min**								
3	**+ 20 min**						**15 min**		
4	**+ 30 min**						**30 min**		
5	**+ 40 min**								
6	**+ 50 min**						**45 min**		
7	**+ 60 min**						**60 min**		

DAY FOUR: Date:_____ Time: _____

	Time	**Heart Rate**			**Temperature**		**Threshold/Tolerance**		
		Before	*During*	*After*	*Before*	*After*		*Threshold*	*Tolerance*
1	**Baseline**						**Baseline**		
2	**+ 10mins**								
3	**+ 20mins**						**15 min**		
4	**+ 30 min**						**30 min**		
5	**+ 40 min**								
6	**+ 50 min**						**45 min**		
7	**+ 60 min**						**60 min**		

DATA COLLECTION SHEET

Standard Reflexology, Light Reflexology and No Treatment (control) – Chapter 5

ICE/PAIN TEST RESULTS:

Session 1: _____Date: _____ Time: _____

	Time	Threshold	Tolerance	HR Start	HR Finish
1	Baseline = 15mins prior to treatment				
2	Immediately following treatment				
3	+ 30 mins post treat				
4	+ 60 mins post treat				
5	+ 90 mins post treat				
6	+ 120 mins post treat				

Session 2: _____Date: _____ Time: _____

	Time	Threshold	Tolerance	HR Start	HR Finish
1	Baseline = 15mins prior to treatment				
2	Immediately following treatment				
3	+ 30 mins post treat				
4	+ 60 mins post treat				
5	+ 90 mins post treat				
6	+ 120 mins post treat				

Session 3: _____Date: _____ Time: _____

	Time	Threshold	Tolerance	HR Start	HR Finish
1	Baseline = 15mins prior to treatment				
2	Immediately following treatment				
3	+ 30 mins post treat				
4	+ 60 mins post treat				
5	+ 90 mins post treat				
6	+ 120 mins post treat				

Comments:

_____

_____

_____

DATA COLLECTION SHEET – MECHANICAL REFLEXOLOGY

(Chapter 6)

ICE/PAIN TEST RESULTS:

Session 1: _____ Date: _____ Time:

	Time	HR B	HR D	HR A	Threshold	Tolerance
1	Baseline = 10mins prior to treatment					
	+ 10 heart rate **START TREATMENT**					
2	10 minutes into treatment (30 mins)					
	+10 heart rate					
3	+ 10 mins post treatment (50 mins)					
	+10 heart rate					
4	+ 30 mins post treatment (70 mins)					
	+10 heart rate					
5	+ 50 mins post treatment (90 mins)					
	+ 10 heart rate					
6	+ 70 mins post treatment (110 mins)					
	+ 10 heart rate					
7	+ 90 mins post treatment (130 mins)					

Session 2: _____ Date: _____ Time:

	Time	HR B	HR D	HR A	Threshold	Tolerance
1	Baseline = 10mins prior to treatment					
	+ 10 heart rate **START TREATMENT**					
2	10 minutes into treatment (30 mins)					
	+10 heart rate					
3	+ 10 mins post treatment (50 mins)					
	+10 heart rate					
4	+ 30 mins post treatment (70 mins)					
	+10 heart rate					
5	+ 50 mins post treatment (90 mins)					
	+ 10 heart rate					
6	+ 70 mins post treatment (110 mins)					
	+ 10 heart rate					
7	+ 90 mins post treatment (130 mins)					

Subjective Rating Questionnaire
Reflexology Research Programme – Mechanical Reflexology

Subject Name/Number:	Date:
Treatment:	Time:

Have you consumed any of the following beverages in the past 60 minutes?

Tea		Coffee		Canned or bottle drinks	

Baseline Ice Plunge on entry

1

Q1. **How would you rate your level of arousal?**

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mild anxiety		Relaxed (no anxiety)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

Ice Plunge during Mechanical Foot Reflexology/TENS) – 10 mins into treatment

2

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mild anxiety		Relaxed (no anxiety)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

10 Minutes post treatment. Actual timeline 40 minutes after start.

3

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mild anxiety		Relaxed (no anxiety)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

30 Minutes post treatment. Actual timeline 60 minutes after start.

4

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mild anxiety		Relaxed (no anxiety)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

50 Minutes post treatment. Actual timeline 80 minutes after start

5

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mild anxiety		Relaxed (no anxiety)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

70 Minutes post treatment. Actual timeline 100 minutes after start

6

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mild anxiety		Relaxed (no anxiety)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

90 Minutes post treatment – Actual timeline 120 minutes after start

7

Q1. How would you rate your level of arousal?

Very High		High		Normal		Below Normal	

Q2. How would you rate your level of anxiety?

Very Anxious		Anxious		Mild anxiety		Relaxed (no anxiety)	

Q3. How would you rate your level of discomfort during the trial?

Very High		High		Normal		Below Normal	

Q4. Do you think that the treatment had any overall effects on your responses to the two parameters that were measured during each trial?

Yes ☐ No ☐

Thank you for taking part in these trials and for completing the subjective ratings questionnaire.

DATA COLLECTION SHEET FOR 6 WEEK STUDY

NOTES:

ICE/PAIN TEST RESULTS: **Subject No:** _____ **Week:** _____ **Date:** _____ **Time:** _____

Time	HR- B	HR - D	HR - A	BP	PThrs	PTol
Baseline = on entering						
FIRST ICE PLUNGE – 10 mins. after entering				**Before recline**		
START TREATMENT						
+10						
+ 20						
+ 30						
+ 40						
IMMEDIATELY POST TREATMENT – 2ND ICE PLUNGE						
10 mins						
20 mins						
30 mins – **3RD ICE PLUNGE**						
40 mins						
50 mins						
60 mins – **4TH ICE PLUNGE**						
70 mins				**After plunge**		
80 mins						
90 mins – **5TH ICE PLUNGE**						

Appendix C

CHAPTER 4 INDIVUDUAL SUBJECT GRAPHS AND MIN/MAX GRAPHS

Individual Pain Threshold graphs

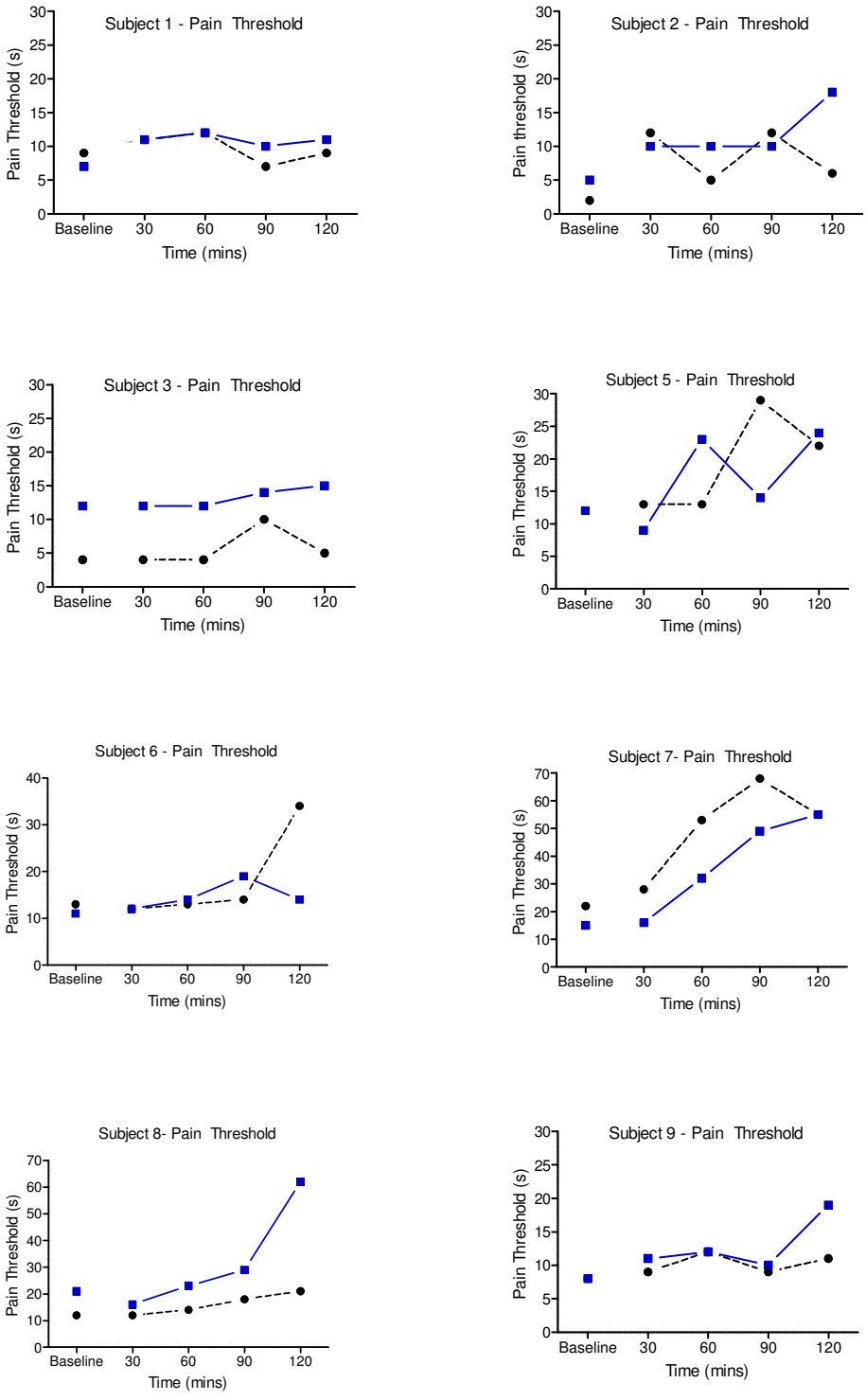


Figure C1: Individual pain threshold (s) graphs for subjects 1 – 9, *n=16*. *Subject 4 dropped out after first session -. Subjects 6, 7 & 8 show an extended Y Axis. ● Sham TENS (control) ■ Standard Reflexology

Individual Pain Threshold graphs

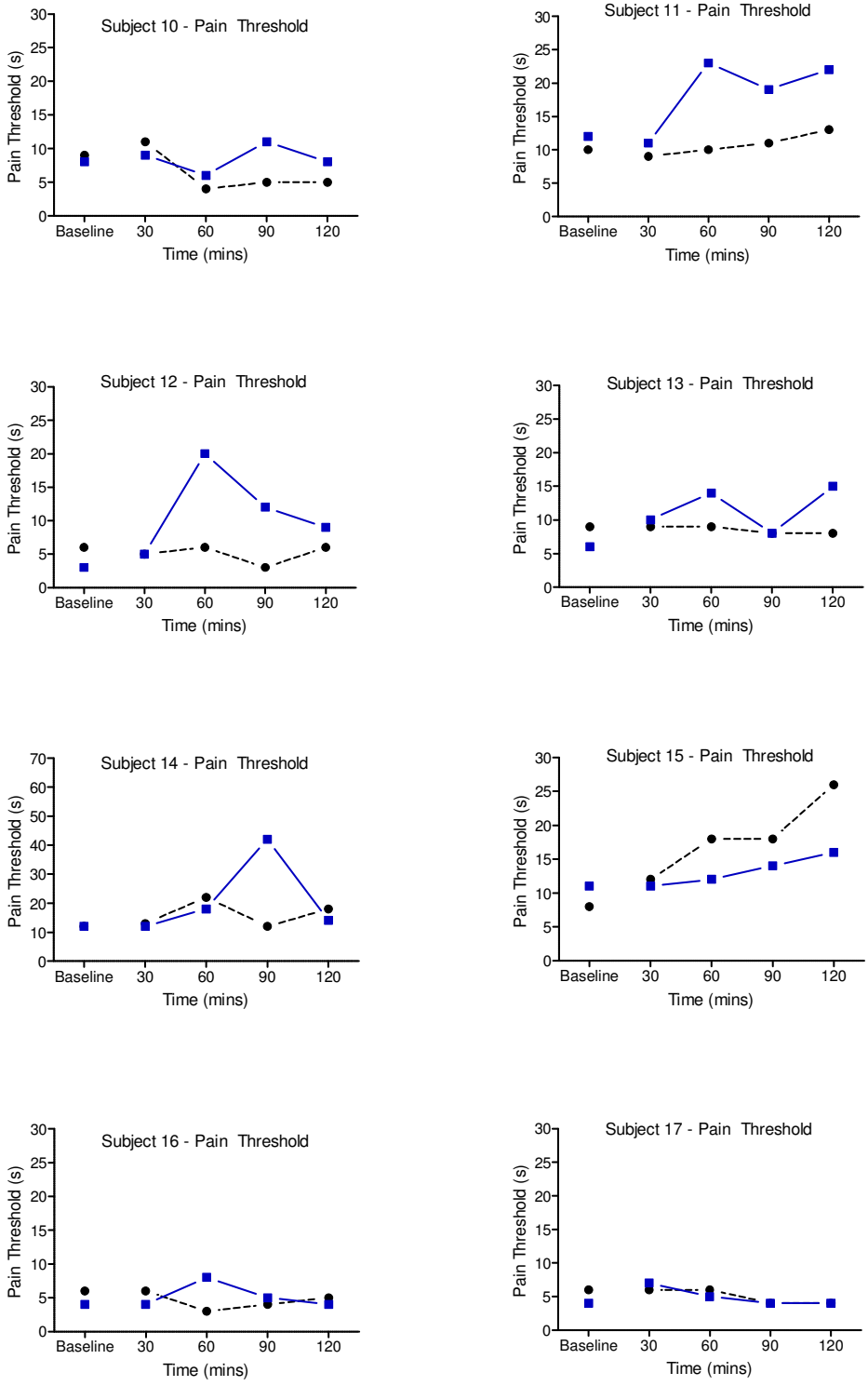


Figure C2: Individual pain threshold (s) graphs for subjects 10 – 17, *n=16*. *Subject 4 dropped out after first session -. Subject 14 shows an extended Y Axis. ● Sham TENS (control) ■ Standard Reflexology

Individual Pain Tolerance graphs

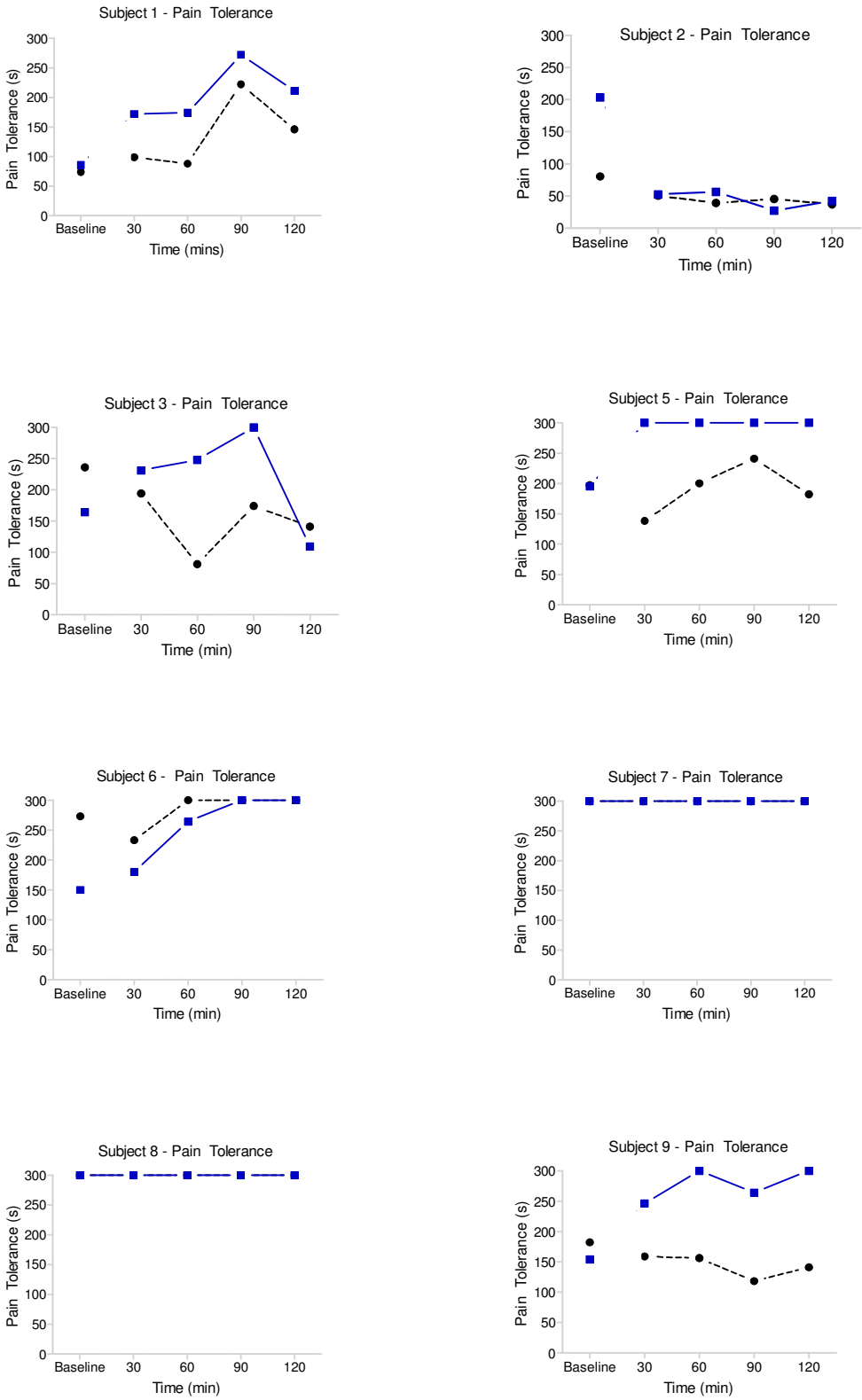
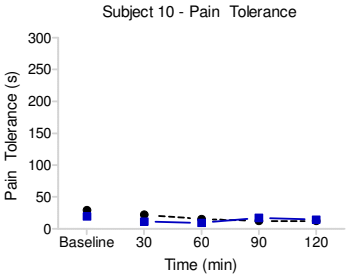
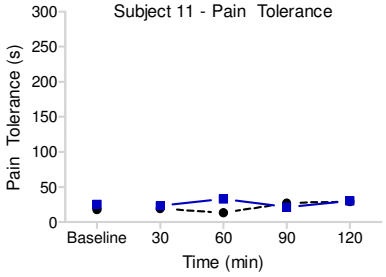
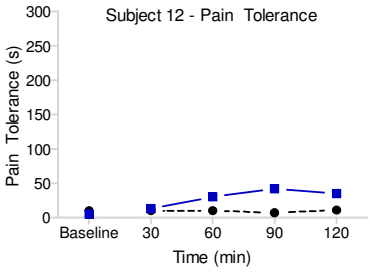


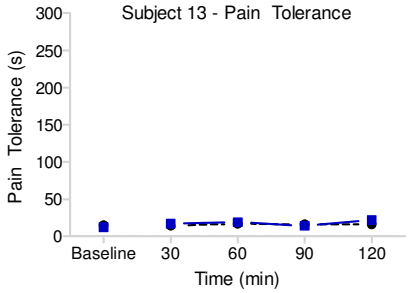
Figure C3: Individual pain tolerance (s) graphs for subjects 1-9, *n=16*. *Subject 4 dropped out after first session - ● Sham TENS (control) ■ Standard Reflexology

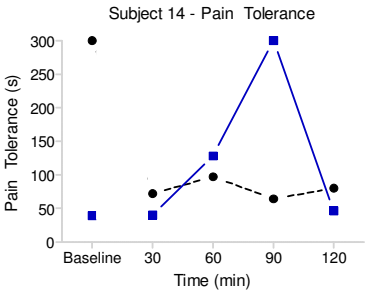
Individual Pain Tolerance graphs

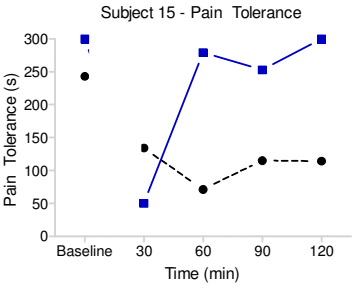


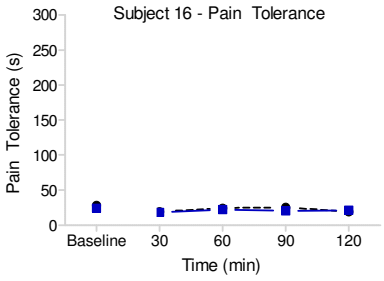












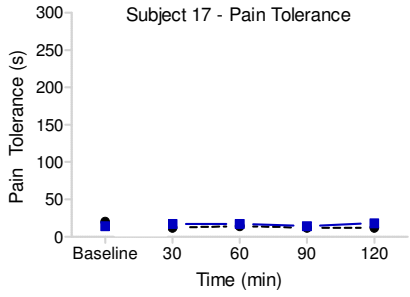
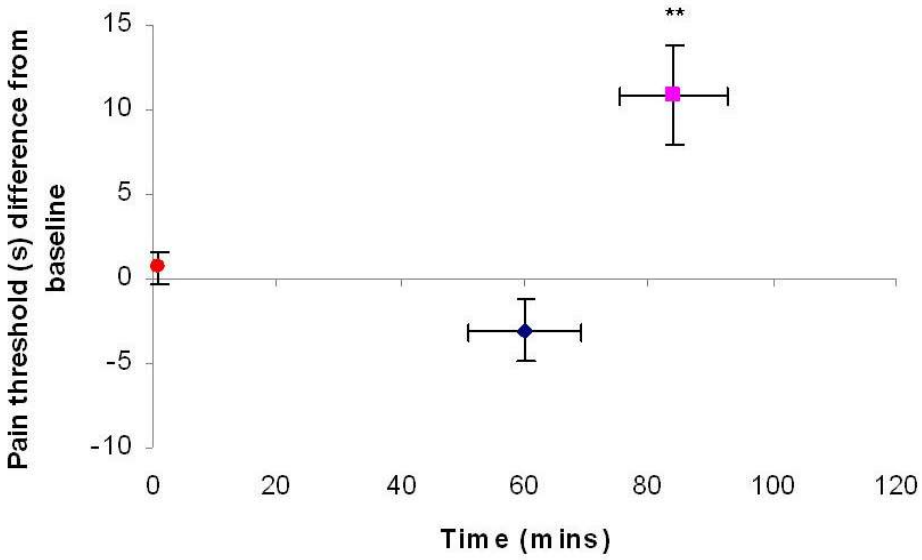


Figure C4: Individual pain tolerance (s) graphs for subjects 10-17, *n=16*. *Subject 4 dropped out after first session -. ● Sham TENS (control) ■ Standard Reflexology



C5: The mean ± SEM minimum and maximum pain threshold (s) relative to control. Shown as a change from the pre-treatment baseline. **p<0.01 for maximum pain threshold (s). Horizontal lines represent the ± SEM for time (min). Vertical lines represent ± SEM for pain threshold. ◆ = Baseline ● = Minimum, ■ = Maximum.

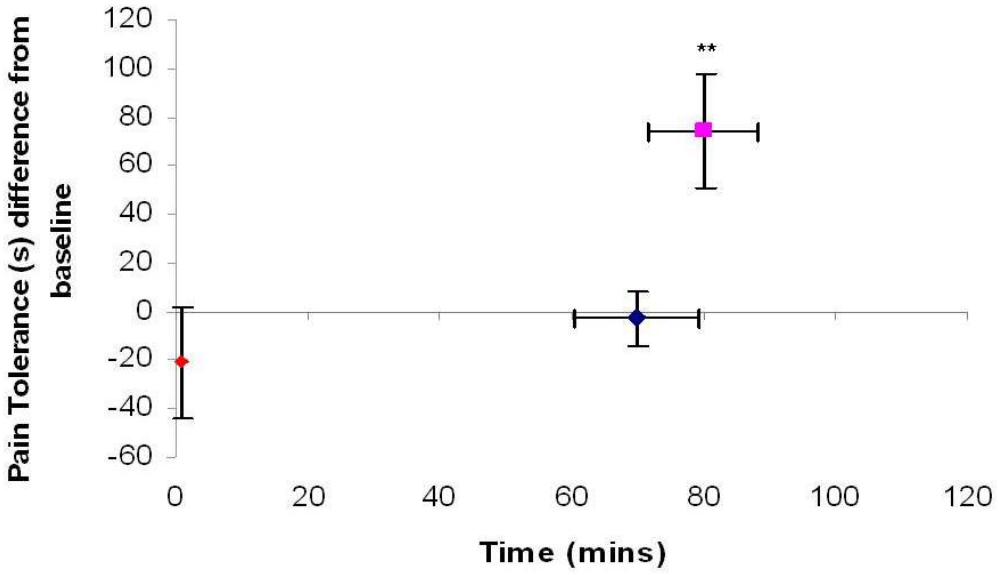
Table C1: The mean ± SEM minimum and maximum pain threshold (s) values relative to control. p<0.01 for mean maximum pain threshold compared to control.

PAIN THRESHOLD

Minimum Time	**Control**	**S.Reflex**	**T-test**
60.0 ± 9.1	14.2 ±2.4	11.1 ± 1.2	n.s
Maximum Time			
84.0 ± 8.7	9.2 ± 1.3	20.2 ± 3.8	p<0.01

Table C2: The mean ± SEM pre and post plunge heart rate (bpm) values in relation to mean minimum and maximum latency for pain threshold.

Minimum Time	**Control HR pre**	**SReflex HR pre**	**T-test**	**Control HR post**	**SReflex HR post**	**T-test**
60.0 ± 9.1	72.4 ± 3.4	69.3 ± 4.1	n.s	72.1 ± 3.5	69.8 ± 3.2	n.s
Maximum						
84.0 ± 8.7	74.5 ± 3..7	69.5± 4.3	n.s	72.7 ± 3.4	70.8 ± 3.7	n.s



C6: The mean ± SEM minimum and maximum pain tolerance (s) relative to control shown as a change from the pre-treatment baseline. **p<0.01 for mean maximum pain tolerance (s). Horizontal lines represent the ± SEM for time (min). Vertical lines represent ± SEM for pain threshold. ◆ = Baseline ● = Minimum ■ = Maximum.

C3: The mean ± SEM minimum and maximum pain tolerance (s) values relative to control. *p<0.01 for mean maximum pain tolerance compared to control.

PAIN TOLERANCE

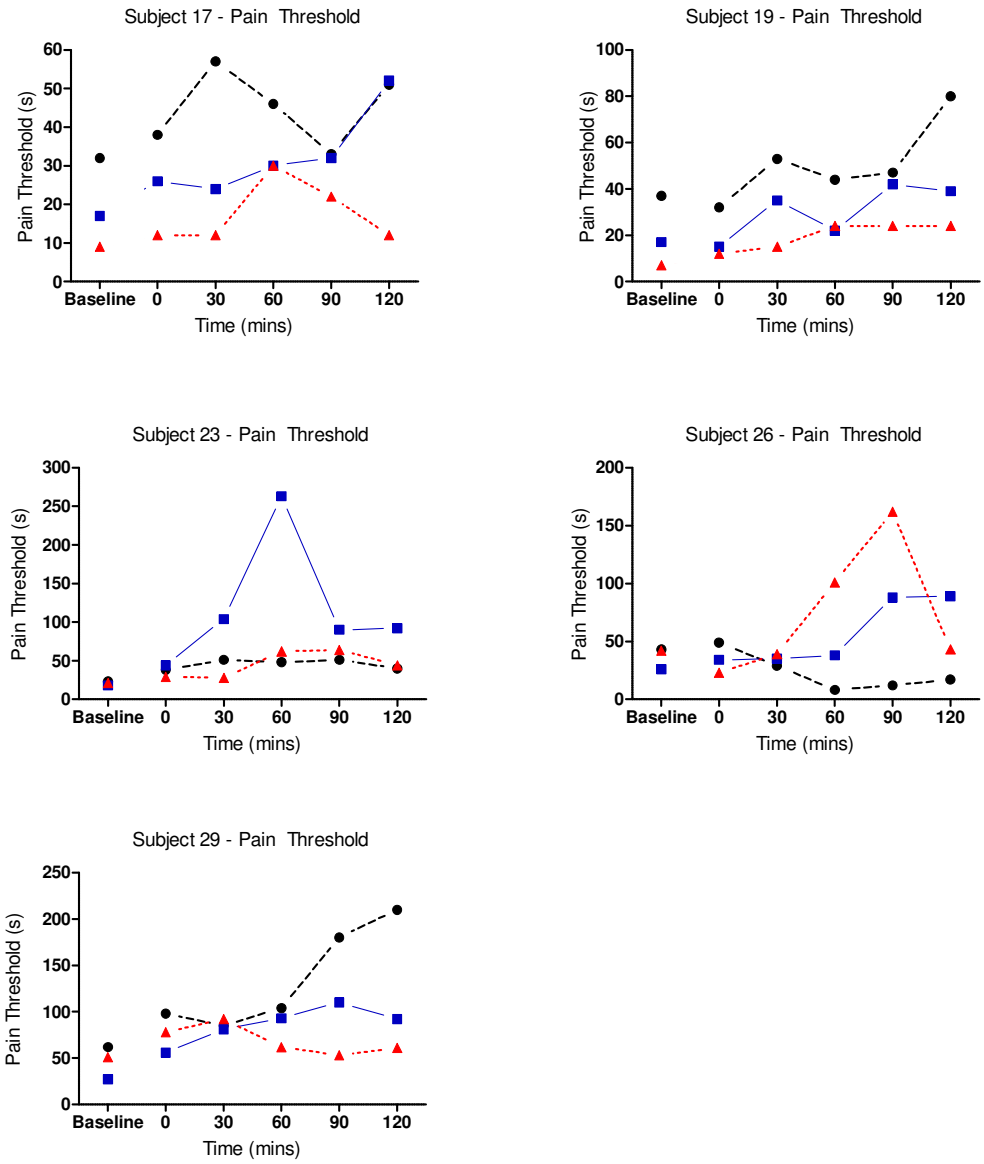
Minimum Time	Control	S.Reflex	T-test
70.0 ± 9.4	111.1 ± 26.8	108.2 ± 31.1	n.s
Maximum Time			
80.0 ± 8.4	86.7 ± 26.0	160.7 ± 35.0	p<0.01

C4: The mean ± SEM pre and post heart rate values in relation to mean minimum and maximum latency for reflexology relative to control. There was a significant correlation between minimum latency and pre plunge heart rate p<0.05.

Minimum Time	Control HR pre	SReflex HR pre	T-test	Control HR post	SReflex HR post	T-test
70.0 ± 9.4	73.9 ± 3.3	67.7 ± 3.7	p<0.05	73.3 ± 3.5	71.2 ± 3.0	n.s
Maximum Time						
80.0 ± 8.4	71.9 ± 3.3	71.0 ± 4.0	n.s	73.9 ± 2.9	71.9 ± 3.6	n.s

Appendix D

CHAPTER 5A - INDIVIDUAL SUBJECT GRAPHS OF ELIMINATED SUBJECTS



D1: Individual pain threshold graphs of the eliminated subjects for Chapter 5a.

Appendix E

THE EFFECTS OF REPEATED DAILY ICE IMMERSION OF THE NON-DOMINANT HAND IN ICE ON PAIN THRESHOLD, TOLERANCE AND BASAL PHYSIOLOGICAL FUNCTIONS

E1 HABITUATION TO ICE PAIN

There is a type of tolerance to drugs known as tachyphylaxis, which is an acute response to rapid and repeated doses of a drug, so that larger doses are required to achieve the same effect. In physiological terms this type of tolerance may be termed adaptation. Repeated exposure to cold pain can create a similar form of adaptive response (LeBlanc and Potvin, 1966, Agostinho *et al.*, 2008). Bingel *et al.* (2007) carried out a heat pain experiment in which 20 healthy male subjects received a repetitive 48°C thermode induced heat stimulus, over an 8 day cycle. The purpose was to investigate how repeated painful stimulation over several days is cognitively evaluated in the human brain. The result showed that habituation to pain was not a uniform process and that not everyone responded in the same way. Agonstinho *et al.* (2008) on the other hand tested habituation in both heat and cold in 39 healthy subjects and 36 sufferers of chronic neuropathic pain. The results of which indicated that whilst subjects habituated to heat pain, they did not habituate to cold pain. During the previous experiments standard reflexology was shown to improve pain threshold and tolerance to repeated exposure of ice. It is not known however, whether or not subjects were showing an adaptive response. To test this, a short experiment was undertaken to measure repeated daily ice pain exposures in healthy human subjects.

E2 AIMS

To evaluate the effects of repeated exposure to ice pain and to establish if a) repeated exposures affect basal physiological responses such as heart rate and core body temperature and b) subjects adapt to the ice over four days of repeated exposure every 15 minutes for 75 minutes.

E3 METHOD

Demographics

Four female subjects were recruited into the experimental procedures with a mean ± SEM age of 32 ± 5.6 years. All subjects were tested between the hours of 8 – 12a.m. each day. All of the subjects were Caucasian.

E4 PROCEDURE

The experimental protocol was discussed on entering the laboratory and subjects were seated in the Lafuma chair (Figure 2.1, Chapter 2) in an upright position. They were then fitted with the heart rate monitoring equipment and baseline measurements were recorded for heart rate and core body temperature. After 15 minutes rest subjects were asked to plunge their non-dominant hand into a container of crushed ice (-0°C ± 4°C). The procedure adopted for the ice plunge is mentioned earlier in Chapter 2, (sub-section 2.3.4). Heart rate was recorded immediately prior to each ice plunge (before reading), immediately following the point of pain threshold (during ice plunge), when the subject shouted 'now', and when the subject indicated that they could no longer tolerate the ice pain and shouted 'out' and subsequently removed their hand from the container. Core body temperature was recorded immediately prior to each ice plunge. The ice plunge was carried out at 15 minute intervals for a period of 60-minutes following the 15 minute initial rest period. Subjects were asked to attend daily for a period of four days consecutively when the above procedure was repeated.

E5 STATISTICAL ANALYSIS

A three-way analysis of variance with repeated measures with one between-subjects factor (i.e. period) and two within-subject factors (i.e. time and period) was used to analyse the results of data obtained during these experimental procedures.

E6 RESULTS

Pain Threshold

The results are illustrated in Figure E1 and although a slight increase on pain threshold is shown at t=30min on day four, the analysis of the data revealed that there were no significant period effects on pain threshold ($F_{(4,9)}$=3.4582,n.s.). Furthermore there were no significant effects of time ($F_{(4,12)}$=2.6890,n.s.) and there were no time x period interactions ($F_{(12,36)}$=0.7467,n.s.).

Pain Tolerance

The results for the analysis on pain tolerance are shown in Figure E2 and illustrate a pattern similar to that shown for pain threshold. However, the ANOVA indicated that there were no significant period effects for pain tolerance ($F_{(3,9)}$=1.2389,n.s.), there were no significant time effects ($F_{(4,12)}$=1.3292,n.s.) and no time x period interactions ($F_{(12,36)}$=1.4611,n.s.). Overall these results indicate there are no effects of adaptation and the trend seen for pain tolerance appears likely to suggest an effect of sensitisation. Nonetheless, the day to day differences were neglible for repeated expose to ice.

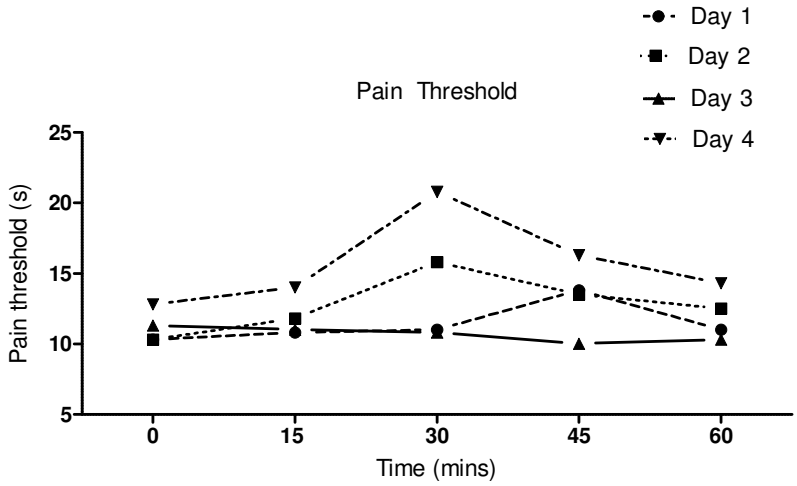


Figure E1: The effect of repeated exposure to ice pain on mean pain threshold (s) values observed over four days.

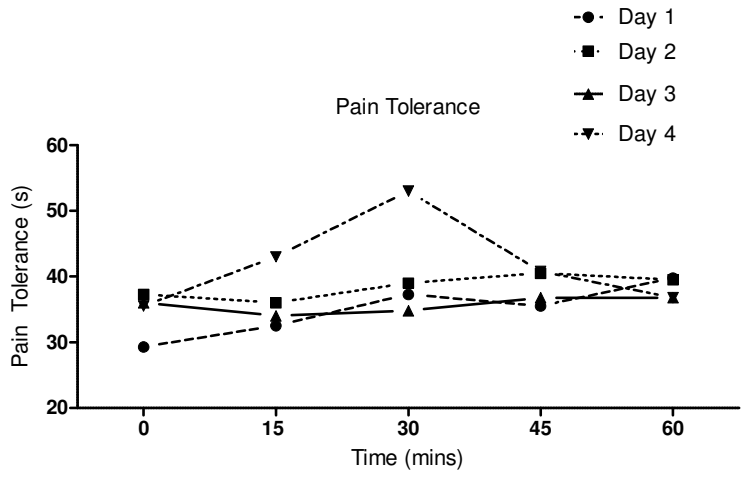


Figure E2: The effects of repeated daily ice immersions on mean pain tolerance (s) values observed over four days.

Heart Rate

Heart rate readings were taken before, during and after the ice immersion and results are demonstrated in Figure E3. There were no significant effects for either pre, during or post ice plunge heart rates. See text below for further details.

Pre ice plunge heart rate

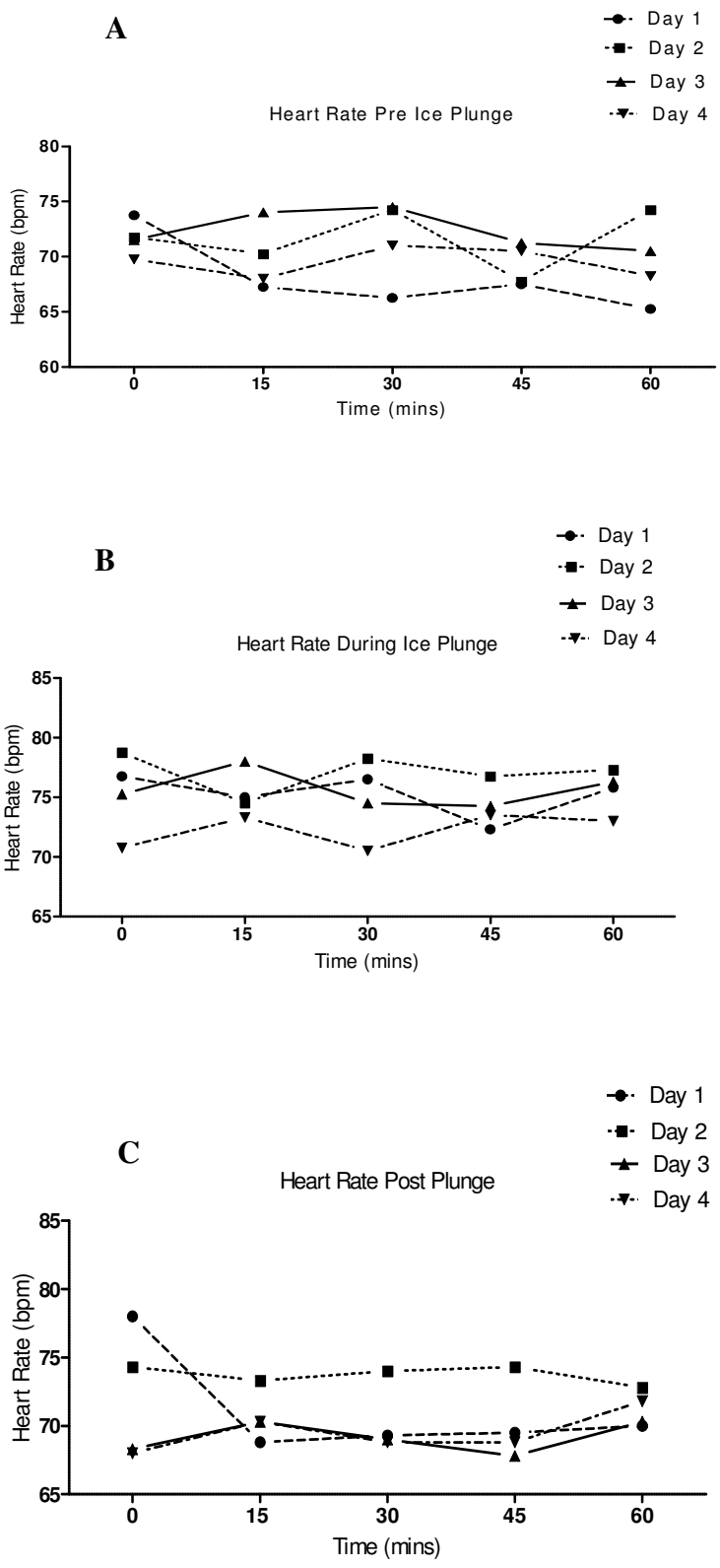
The effects of repeated ice plunge on mean heart rate values pre plunge are shown in Figure E3A. Baselines were similar across all four days (t=0min) and the pre plunge heart rate does not differ significantly across the four treatment periods ($F_{(3,9)}$=2.1652,n.s.). There were no significant effects of time ($F_{(4,12)}$=1.7670,n.s.) but there is a pattern for a slight increase on days two, three and four at t=30min. There were nonetheless no time x period interactions ($F_{(12,36)}$=1.2138,n.s).

During ice plunge heart rate

Figure E3B shows the effects of the repeated ice plunge on mean heart rates during the ice plunge. The baseline values on days 1 – 3 were higher than those for day four, but the ANOVA showed that there were no significant period effects ($F_{(3,9)}$=2.1173,n.s.). Overall, day four values are lower than those observed on days 1 -3 but in general there were no significant effects of time ($F_{(4,12)}$=0.2183,n.s.) and there were no timet x period interactions ($F_{(12,36)}$=1.1674,n.s). Heart rate values during the ice plunge however appear slightly more chaotic than either pre or post ice plunge, perhaps reflecting the intensity of the ice pain.

Post ice plunge heart rate

The mean heart rate observations for the post ice plunge appear in Figure E3C. The post plunge baselines on days 3 and 4 are much lower than those observed during the days 1 and 2 but the ANOVA showed there were no significant period effects ($F_{(3,9)}$=1.9020,n.s.). In addition the pattern of the heart rate post ice plunge is much less variable than either the pre or during ice plunge values even though there were no significant effects of time ($F_{(4,12)}$=0.8250,n.s.) and no time x period interactions ($F_{(12,36)}$=1.3537,n.s).



Figures E3 A-C: The effects of repeated exposure to ice pain on a) pre b) during and c) post ice plunge heart rate (bpm) values observed over four days.

Temperature

Results of the temperature observations recorded for each subject at 15 minutes intervals immediately prior to their ice plunge are illustrated in Figure E4. The ANOVA revealed that there were no significant period effects ($F_{(3,9)}$=0.80735,n.s.), there was however a significant effect of time ($F_{(4,12)}$=4.7929,p<0.01) but no time x period interactions ($F_{(12,36)}$=0.7616,n.s).

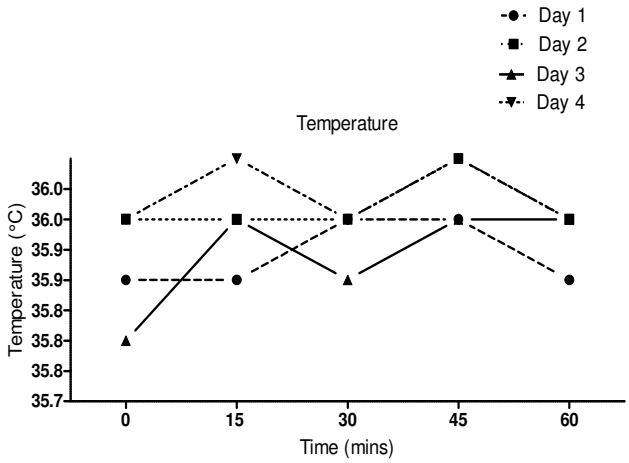


Figure E4: The effects of daily repeated exposure to ice pain on mean temperature (°) values observed over four days.

E7 DISCUSSION

Pain threshold and tolerance levels did not improve as a result of daily repeated ice pain exposure, nor were there any significant changes in heart rate either pre, during or post ice immersion. There was a significant effect of time on core body temperature which was to be expected following repeated skin cooling (Brinnel and Cabanac, 1989). These results are consistent with the literature suggesting that habituation is a central process and involves anti-nociceptive systems (Condes-Lara *et al.*, 1981, Tipton *et al.*, 1998, Bingel *et al.*, 2007) and confirms the general theory that habituation to cold pain does not occur (Ingersoll and Mangus, 1992, Smith *et al.*, 2008)

Conclusion

This experiment has looked at the effects of repeated ice pain exposure and concludes that there were no significant effects on daily repeated ice immersions neither within an experimental session nor between days.

APPENDIX F

MEAN MINIMUM AND MAXIMUM RESULTS OF CHAPTER 6

MINIMA AND MAXIMA RESULTS FOR MECHANICAL REFLEXOLOGY VS SHAM TENS (CONTROL)

The computations of tables and graphs for mechanical reflexology and sham TENS (control) are shown and reflect the data as a change from the normalised baseline.

Minimum and Maximum responses

In line with the analysis carried out in Chapter 5b (Section 5.1.1b) the minimum and maximum values for pain threshold and tolerance with associated latencies was investigated.

F1 Computation of tables and graphs

The rationale for the selection of the three points for analysis is discussed in Chapter 5b, (Section 5.1.1b) but identifies three values, i) baselines, ii) minimum values and, iii) maximum values along with the time at which these values occurred.

Analysis of data in terms of minimum and maximum

i) Baseline: Table F1 shows the mean ± SEM baseline threshold and tolerance scores (s) for control and mechanical reflexology recorded prior to treatment. As the results show, there were large differences in the pain threshold values but these were significantly different for pain tolerance ($p<0.05$). The data represented for baselines in the graphs, Figures F1 and F2 have therefore been normalised.

ii) Minimum: Table F2 shows the mean ± SEM minimum threshold and tolerance scores (s) recorded for the five eligible subjects as a percentage change from the normalised baseline for mechanical reflexology, relative to the control treatment. In addition it shows the mean ± SEM time (min) after mechanical reflexology when this occurred compared with the corresponding mean ± SEM threshold and tolerance scores (s) recorded under control conditions.

The data on the graphs, Figure F1 and F2 represent the mean ± SEM of the data shown in Table F2 for each subject given mechanical reflexology, from the corresponding control score, and the mean ± SEM time at which this occurred.

iii) Maximum: Table F3 shows the mean ± SEM percentage change in maximum pain threshold and tolerance scores (s) of the subjects and the mean ± SEM time after mechanical reflexology when this occurred. The data are represented graphically in Figures F1 (pain threshold) and F2 (pain tolerance) and were calculated as the mean ± SEM (s) difference from the control scores for the maximum threshold and tolerance and the time (min) at which this occurred.

Table F1: Mean ± SEM raw data baseline pain threshold and pain tolerance scores (s) for control and mechanical reflexology.

BASELINES	**Control**	**Mech. Reflex**	**T-test**
Pain Threshold	13.2 ± 4.2	6.2 ± 1.2	n.s

BASELINES	**Control**	**Mech. Reflex**	**T-test**
Pain Tolerance	96.2 ± 52..9	77.8 ± 48.7	p<0.05

Table F2: The mean ± SEM % change in minimum pain threshold and tolerance scores and mean ± SEM time (min) relative to control for mechanical reflexology after normalising the baselines.

MINIMUM PAIN THRESHOLD

Minimum Time	*Control*	*Mech .Reflex*	*T-test*
82.0 ± 16.7 min	15.6 ± 4.9	6.0 ± 1.7	ns

MINIMUM PAIN TOLERANCE

Minimum Time	*Control*	*Mech .Reflex*	*T-test*
74.0 ± 19.2	138.0 ± 59.0	73.2 ± 35.1	0.056

Table F3: The mean ± SEM % change in maximum pain threshold and tolerance (s) scores and mean ± SEM time (min) relative to control for mechanical reflexology after normalising the baselines.

MAXIMUM PAIN THRESHOLD

Maximum Time	*Control*	*Mech .Reflex*	*T-test*
54.0 ± 11.0 min	8.2 ± 1.0	13.8 ± 2.9	ns

MAXIMUM PAIN TOLERANCE

Maximum Time	*Control*	*Mech .Reflex*	*T-test*
62.0 ± 15.2 min	122.8 ± 57.2	116.6 ± 52.2	ns

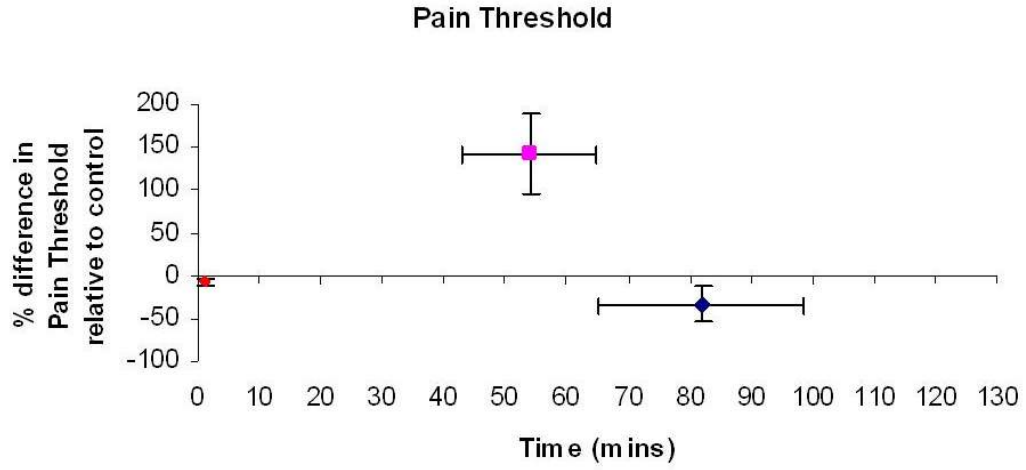


Figure F1: The mean ± SEM % change from normalised baseline showing the mean minimum and maximum pain threshold scores relative to control. Horizontal lines represent ± SEM for time (min) and vertical lines represent ± SEM for the difference in pain threshold from baseline, *n=5*. ●Minimum ■ Maximum ◆ Baseline

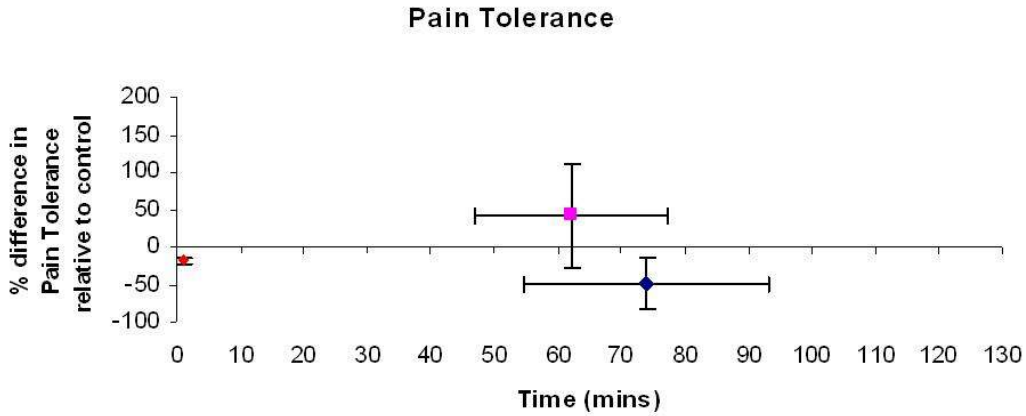


Figure F2: The mean ± SEM % change from normalised baseline showing the minimum and maximum pain tolerance scores relative to control. Horizontal lines represent ± SEM for time (min) and vertical lines represent ± SEM for the difference in pain threshold from baseline. ●Minimum ■ Maximum ◆ Baseline

F2 Results observed for pain threshold and tolerance responses

Analysis of the data using a paired t-test revealed there were no significant differences between the mean minimum pain threshold but minimum pain tolerance was just outside the level of significance (p=0.056) showing that mechanical reflexology was producing a small nociceptive effect. Whilst the data showed no significant effects on mean maximum pain threshold or tolerance, rather interestingly the mean ± SEM minimum pain threshold occurred at 82.0±16.7 min and the mean ± SEM maximum pain threshold at 54.0±11.0 min. This is also true for the mean maximum pain tolerance which was reached slightly earlier (62.0±15.2) than the mean minimum pain tolerance (74.0±19.2). Thus, reiterating the slight nociceptive effect of mechanical reflexology on the mean minimum and maximum pain tolerance when compared to the sham TENS (control).

F3 DISCUSSION

When the data were subjected to the minimum and maximum criteria as set out in Chapter 5b (Section 5.1.1b), there was a decrease on mean minimum pain threshold and tolerance following the mechanical stimulation. Interestingly, the mean maximum pain threshold, albeit non-significant, was reached before the mean minimum pain threshold (Figure F1). Furthermore the maximum pain tolerance was reached before the mean minimum pain tolerance (Figure F2) and there was an almost significant (p=0.056) increase in the effect of sham TENS (control) when compared with mechanical reflexology thus suggesting that mechanical reflexology may be increasing the nociceptive response.

Appendix G

CHAPTER 7 – TABLE OF MEAN ± SEM RESULTS ON RAW DATA FOR 3-WAY ANOVA

Table G1: Results of the 3-way ANOVA (Chapter 7). Results include 3 periods and 2 treatment groups – standard reflexology and sham TENS (control)

	BETWEEN SUBJECT		WITHIN SUBJECTS											
Parameter	**Group**	**Sig.**	**Period**	**Sig.**	**Group x period**	**Sig.**	**Time**	**Sig.**	**Group x time**	**Sig.**	**Time x Period**	**Sig.**	**Group x Time x Period**	**Sig.**
Pain Threshold	$F_{(1,12)}$ = 0.0336	n.s	$F_{(2,24)}$ = 0.3895	n.s	$F_{(2,24)}$ = 1.7933	n.s	$F_{(3,36)}$ = 1.8962	n.s	$F_{(3,36)}$ = 0.6728	n.s	$F_{(6,72)}$ = 1.3127	n.s	$F_{(6,72)}$ = 0.4151	n.s.
Pain Tolerance	$F_{(1,12)}$ = 0.7898	n.s	$F_{(2,24)}$ = 0.8274	n.s	$F_{(2,24)}$ = 0.3683	n.s	$F_{(3,36)}$ = 0.1928	n.s	$F_{(3,36)}$ = 0.3670	n.s	$F_{(6,72)}$ = 1.6274	n.s	$F_{(6,72)}$ = 0.6817	n.s
Heart Rate pre Plunge	$F_{(1,12)}$ = 0.0665	n.s	$F_{(2,24)}$ = 1.2203	n.s	$F_{(2,24)}$ = 0.9466	n.s	$F_{(3,36)}$ = 8.6070	**0.01**	$F_{(3,36)}$ = 1.0757	n.s	$F_{(6,72)}$ = 0.3433	n.s	$F_{(6,72)}$ = 1.1789	n.s
Heart Rate during Plunge	$F_{(1,12)}$ = 0.0189	n.s	$F_{(2,24)}$ = 0.2685	n.s	$F_{(2,24)}$ = 0.3664	n.s	$F_{(3,36)}$ = 0.7943	n.s	$F_{(3,36)}$ = 0.3051	n.s	$F_{(6,72)}$ = 0.5256	n.s	$F_{(6,72)}$ = 1.2296	n.s
Heart Rate post Plunge	$F_{(1,12)}$ = 0.0542	n.s	$F_{(2,24)}$ = 0.0845	n.s	$F_{(2,24)}$ = 0.1998	n.s	$F_{(3,36)}$ = 1.5002	n.s	$F_{(3,36)}$ = 1.2316	n.s	$F_{(6,72)}$ = 0.9922	n.s	$F_{(6,72)}$ = 1.0745	n.s
Diastolic BP	$F_{(1,12)}$ = 0.0006	n.s	$F_{(2,24)}$ = 1.2110	n.s	$F_{(2,24)}$ = 0.1205	n.s	$F_{(2,24)}$ = 9.1165	**0.01**	$F_{(2,24)}$ = 0.1738	n.s	$F_{(4,48)}$ = 1.6735	n.s	$F_{(4,48)}$ = 0.9068	n.s
Systolic BP	$F_{(1,12)}$ = 0.4094	n.s	$F_{(2,24)}$ = 0.0513	n.s	$F_{(2,24)}$ = 0.0868	n.s	$F_{(2,24)}$ = 3.6984	**0.05**	$F_{(2,24)}$ = 0.9029	n.s	$F_{(4,48)}$ = 0.5892	n.s	$F_{(4,48)}$ = 0.8516	n.s
Pulse Pressure	$F_{(1,12)}$ = 0.3400	n.s	$F_{(2,24)}$ = 0.8048	n.s	$F_{(2,24)}$ = 0.1752	n.s	$F_{(2,24)}$ = 0.0791	n.s	$F_{(2,24)}$ = 0.6688	n.s	$F_{(4,48)}$ = 1.7485	n.s	$F_{(4,48)}$ = 0.1313	n.s

Appendix H

MEAN MINIMA AND MAXIMA RESULTS FOR CHAPTER 7

H1 MINIMUM AND MAXIMUM DATA ANALYSIS CHRONIC ICE PAIN

The data analyses are presented using the minimum and maximum method adopted in Chapter 5b, (Section 5.1.1b). Minimum and maximum results were subjected to a 2-way ANOVA with repeated measures on treatment and time to compare the treatment effects of pain threshold and tolerance over the weeks and a 1-way ANOVA with Neuman- Keul post-hoc test was used to evaluate the effect of time.

H1.1 Minimum and Maximum pain threshold and tolerance

The minimum and maximum criteria of analysis, set out in Chapter 5b (section 5.1.1b), was adopted for these data. Figures H1A and H2A show the effect of treatment on minimum and maximum pain threshold and tolerance (s) scores respectively. Figures H1B and H2B show the time (min) at which minimum and maximum pain threshold (Figure H1B) and tolerance (Figure H2B) occurred relative to the control.

B) Data representation for minimum and maximum values

i) Baselines. Table H1 shows the mean ± SEM baseline threshold (s) and tolerance (s) scores for control and standard reflexology recorded prior to treatment at each of the three treatment periods.

Table H1: Mean ± SEM baseline pain threshold and tolerance scores (s) for control and standard reflexology.

Baselines A	**PAIN THRESHOLD**		
	Period 1	*Period 2*	*Period 3*
Control	12.4 ± 2.5	13.0 ± 3.9	15.6 ± 4.1
Standard Reflexology	12.1 ± 2.5	15.6 ± 4.1	12.3 ± 2.7

Baselines B	**PAIN TOLERANCE**		
	Period 1	*Period 2*	*Period 3*
Control	49.3 ± 16.7	66.0 ± 19.9	67.7 ± 18.4
Standard Reflexology	46.3 ± 12.9	53.0 ± 11.1	55.0 ± 12.0

Results for each of the three periods were subjected to a two-way ANOVA in order to recognize the value of the differences in the mean minimum and maximum pain threshold and tolerance values across the entire experimental period. A one way ANOVA with Neuman-Kuels post-hoc test was performed to show the latency at which this occurred. This method of analysis follows the rules adopted in the previous chapters for minimum and maximum values, but the ANOVA also takes into consideration the cumulative period effect and is a more accurate measure of effect than the t-test for this type of data.

ii) Minimum. The data on the graphs shown in Figure H1 illustrates the minimum mean +/- SEM as a change from the pre-treatment baseline for A) pain threshold (s) and B) the time (min) at which the minimum pain threshold occurred for each treatment period. A two-way ANOVA on the cumulative effects of treatment revealed a significant effect of treatment ($F_{(1,6)}$=15.9879,p<0.01) but no significant period effects ($F_{(2,12)}$=0.1837,n.s.) and no period x treatment interaction ($F_{(2,12)}$=0.6354,n.s.). Period 3 shows there is an increase in pain threshold for reflexology when compared to the decrease in effect for sham (TENS) control and a concurrent increase in the latency effect. A paired t-test on the individual treatment periods showed there was a significant effect of sham TENS (control) treatment during period 2 (Table H2). It was however, interesting to note that the mean minimum pain threshold values for the sham TENS (control) actually decreased in relation to time, whilst for reflexology the latency of the effect increased as the treatment effect increased.

iii) Figure H2 illustrates the mean minimum ± SEM as a change from the pre-treatment baseline for A) pain tolerance (s) and B) the time (min) at which the mean minimum pain tolerance occurred for each treatment period. A two-way ANOVA on the cumulative effects revealed that there were no significant treatment effects ($F_{(1,6)}$=0.0614,n.s.), no significant period effect ($F_{(2,12)}$=0.8218,n.s.) and no period x treatment interaction ($F_{(2,12)}$=0.7425,n.s.). Individual period analysis using a paired t-test showed there were no significant differences between the treatments on mean minimum pain tolerance (Table H2). However, of note is the inverse

relationship between the treatments and the time at which the mean minimum pain tolerance was reached.

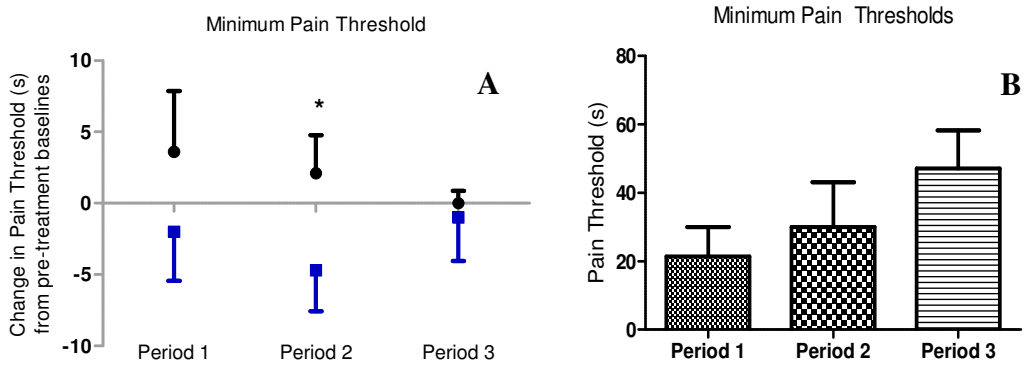


Figure H1: The cumulative effect of standard reflexology on A) mean minimum pain threshold (s) and B) time (min) at which the mean minimum pain threshold occurred. Period 2 shows *p<0.05 for sham TENS (control). Vertical lines represent +/- SEM. ● = Sham TENS (control) ■ = Standard reflexology.

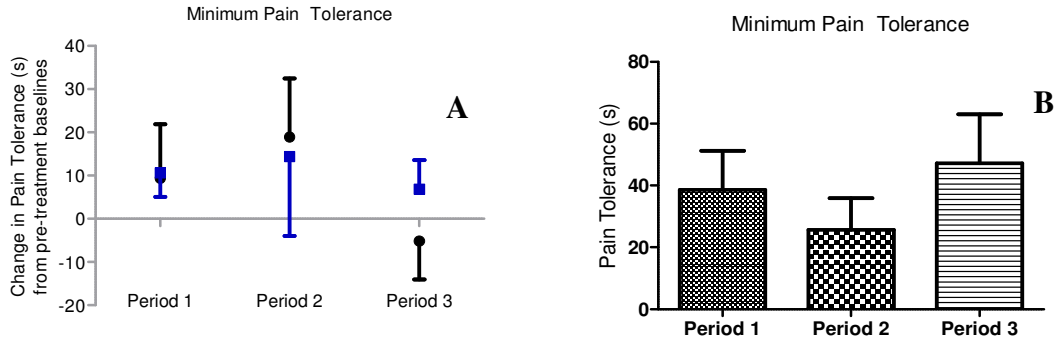


Figure H2: The cumulative effect of standard reflexology on A) mean minimum pain tolerance (s) and B) time (min) at which the mean minimum pain tolerance occurred. Vertical lines represent +/- SEM. ● = Sham TENS (control), ■ = Standard reflexology.

Table H2: Mean ± SEM change in the mean minimum pain threshold and tolerance scores (s) for standard reflexology and sham TENS (control) shown as a change from the pre-treatment baseline values.

PAIN THRESHOLD

	Period 1	*Period 2*	*Period 3*
Minimum Time (min)	21.4 ± 9.2	30.0 ± 14.1	47.1 ± 11.9
Sham TENS (control)	3.6 ± 4.2	2.1 ± 2.6	0.0 ± 0.85
Standard Reflexology	-2.0 ± 3.4	-4.7 ± 2.8	-1.0 ± 3.0
Paired t-test result	ns	**p<0.05**	ns

PAIN TOLERANCE

	Period 1	*Period 2*	*Period 3*
Minimum Time (min)	38.6 ± 13.6	25.7 ± 11.0	47.1 ± 17.1
Sham TENS (control)	9.4 ± 12.5	18.9 ± 13.6	-5.1 ± 8.9
Standard Reflexology	10.6 ± 5.5	14.4 ± 18.3	6.9 ± 6.6
Paired t-test results	ns	ns	Ns

iv) Maximum. The data on the graphs shown in Figure H3 illustrate the maximum mean ± SEM effect for A) pain threshold (s) and B) the time (min) at which maximum pain threshold occurred for each treatment period. A two-way ANOVA to evaluate the cumulative effect of treatment and time revealed there were no significant main effects of treatment ($F_{(1,6)}$=2.918, n.s), no significant period effects ($F_{(2,12)}$=0.0255,n.s.) and no period x treatment interaction ($F_{(2,12)}$=0.0051,n.s.) for maximum pain threshold. A paired t-test showed no significant differences in the mean maximum pain threshold see Table H3.

v) Figure H4 illustrates the maximum ± SEM effect for A) pain tolerance (s) and B) the time (min) at which maximum pain tolerance occurred for each treatment period. A two-way ANOVA on the cumulative effects of treatment revealed there were no significant main effects of treatment ($F_{(1,6)}$=5.2886,n.s.), no significant period effect ($F_{(2,12)}$=2.6287,n.s.) nor any period x treatment interaction ($F_{(2,12)}$=3.119,n.s.) for maximum pain tolerance. A paired t-test however showed a significant increase in mean maximum pain tolerance (s) for reflexology in period 1 ($p<0.05$), and in periods 2 and 3, there was an increase that was almost significant ($p=0.07$ and $p=0.06$, respectively) see Table H3.

A one-way ANOVA with post-hoc Newman Keuls test was performed to evaluate the latency at which the mean minimum and the mean maximum pain threshold and tolerance occurred. The tests revealed that there were no significant effects of time for mean minimum or mean maximum pain threshold and tolerance.

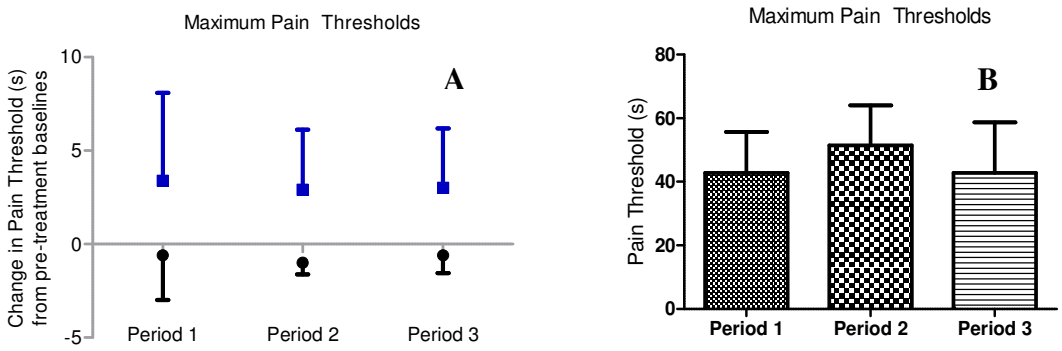


Figure H3: The cumulative effect of standard reflexology on A) mean maximum pain threshold (s) and B) time (min) at which the mean maximum pain threshold occurred Vertical lines represent +/- SEM. ● = Sham TENS (control) ■ = Standard reflexology

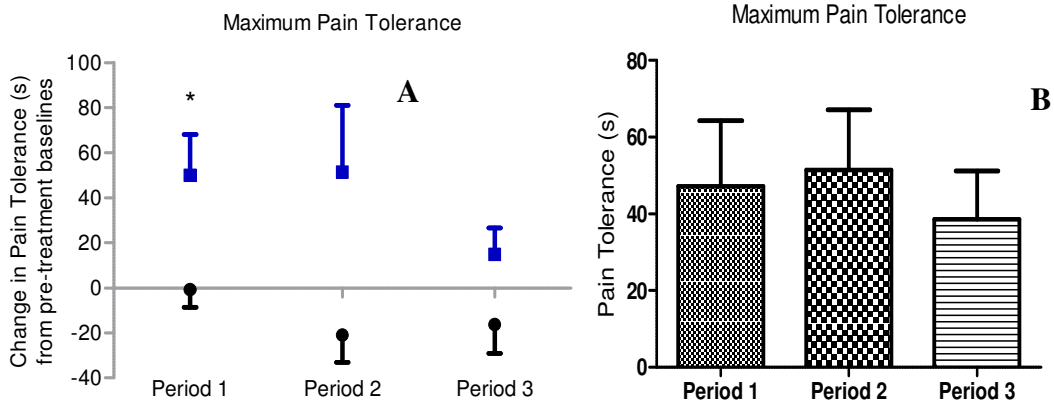


Figure H4: The cumulative effect of standard reflexology on A) mean maximum pain tolerance (s) and B) time (min) at which the mean maximum pain tolerance occurred. Period 1 shows *p<0.05 for standard reflexology. Vertical lines represent +/- SEM. ● = Sham TENS (control) ■ = Standard reflexology

Table H3: Mean ± SEM change in the mean maximum pain threshold and tolerance (s) for standard reflexology and sham TENS (control) shown as a change from the pre-treatment baselines.

PAIN THRESHOLD

	Period 1	*Period 2*	*Period 3*
Maximum Time (min)	42.9 ± 13.8	51.40 ± 13.6	42.9 ± 17.1
Sham TENS (control)	-0.6 ± 2.4	-1.0 ± 0.6	-0.6 ± 0.9
Standard Reflexology	3.4 ± 4.6	2.9 ± 3.2	3.0 ± 3.1
Paired t-test result	ns	ns	ns

PAIN TOLERANCE

	Period 1	*Period 2*	*Period 3*
Maximum Time (min)	47.1 ± 18.5	51.4 ± 16.9	38.6 ± 13.6
Sham TENS (control)	-0.7 ± 8.0	-20.9 ± 12.1	-16.3 ± 12.8
Standard Reflexology	50.0 ± 18.0	51.4 ± 29.6	14.9 ± 11.7
Paired t-test result	**p<0.05**	ns	ns

A two-way ANOVA was carried out to analyse the cumulative effect of treatments and showed there were no significant anti-nociceptive effects for either the mean minimum pain threshold or pain tolerance values. Indeed, the mean minimum pain threshold and tolerance scores shown in Table H2 revealed a nociceptive effect that showed similarities to the results indicated in Chapter 5b, Figure 5.2b. However, whilst the analysis showed no significant effects of treatment on the maximum pain threshold, a paired *t*-test of the data revealed a significant increase in pain tolerance scores following reflexology during period 1 ($p<0.05$) Table H3. Unfortunately there were large standard error values which may suggest large individual differences in subject responses.

H2 DISCUSSION

This result shows a general trend for an increase in the cumulative effect of standard reflexology on pain threshold but indicates that there may be some drop-off in the effect on pain tolerance. There was an initial nociceptive effect following standard reflexology for the mean minimum pain threshold which was significantly different to the sham TENS (control) in period 2 (Figure H1A). This appears to improve with subsequent treatments and subjects take longer before experiencing the initial pain

sensation, Figure H1B. The effect on mean minimum pain tolerance on the other hand, shows an inverse relationship with the latency of effect, Figure H2A and B, which might indicate that the subjects become sensitised to the effects of treatment. The mean maximum pain tolerance was significantly increased during period 1, however, there appears to be a drop-off in the effect with more treatments.

Conclusion

The minimum and maximum results have shown that repeated standard reflexology treatments may produce a cumulative increase in pain threshold with a subsequent decrease in pain tolerance. However, this was an extremely small group of subjects with previous experience of reflexology who were paid to participate in the trials. There were large standard errors and variances amongst the individual subject values and further work is warranted with a larger cohort.

Appendix I

TABLE OF PRESSURE VALUES

Foot region ⇨	**Medial Edge**	**Arch**	**Heel**	**Ankle**
Foot type ⇩	Average pressure P_{max}	Average pressure P_{max}	Average pressure P_{max}	Average pressure P_{max}
STATIC				
Normal healthy	141.4	136.2	171.0	86.0
Calloused	128.0	123.7	133.3	117.4
Moist, full	125.7	123.5	125.4	124.3
Ethnic soft, spongy	120.1	93.5	166.9	143.7
Child	1.3	0.9	1.5	2.6
Oedematous	62.3	133.8	157.2	81.6
Hard, dry, sensitive	116.5	159.2	177.7	141.4

Foot region ⇨	**Medial Edge**	**Arch**	**Heel**	**Ankle**
STANDARD DYNAMIC	Average pressure P_{max}	Average pressure P_{max}	Average pressure P_{max}	Average pressure P_{max}
Normal healthy	161.6	108.7	112.0	102.8
Calloused	178.0	109.6	122.2	122.3
Moist, full	146.9	99.3	92.0	101.9
Ethnic soft, spongy	121.2	109.3	121.0	109.8
Child	5.3	5.0	6.6	5.9
Oedematous	154.9	98.6	85.6	74.0
Hard, dry, sensitive	130.7	88.9	141.2	104.8

Foot area ⇨	**Spine**	**Arch**	**Heel**	**Ankle**
LIGHT DYNAMIC	Average pressure P_{max}	Average pressure P_{max}	Average pressure P_{max}	Average pressure P_{max}
Normal healthy	68.6	50.0	42.6	51.8
Calloused	88.9	69.7	70.2	68.7
Moist, full	109.0	60.6	64.3	56.7
Ethnic soft, spongy	52.3	42.1	60.5	53.3
Child	3.1	3.5	4.2	4.0
Oedematous	78.8	52.7	58.9	37.4
Hard, dry, sensitive	91.2	62.1	67.0	66.4

Tables I1: Average maximum pressure values (P_{max}) for all foot types. Applied using a) static pressure, b) *standard* dynamic pressure and c) *light* dynamic pressure in seven different foot types across the four foot regions i) medial edge, ii) arch, iii) heel and iv) ankle.

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