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THE EFFECTIVENESS OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS) ON DIFFERENT QUALITIES OF EXPERIMENTALLY INDUCED PAIN

BY

MAUREEN JANET SIMMONDS

A THESIS

SUBMITTED TO THE FACULTY OF

GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF PHYSICAL THERAPY

EDMONTON, ALBERTA

FALL 19[illegible]

ISBN 0-315-65087-7

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Maureen Janet Simmonds

TITLE OF THESIS: THE EFFECTIVENESS OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS) ON DIFFERENT QUALITIES OF EXPERIMENTALLY INDUCED PAIN

DEGREE: Master of Science

YEAR THIS DEGREE GRANTED: Fall 1990

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled, " THE EFFECTIVENESS OF TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS) ON DIFFERENT QUALITIES OF EXPERIMENTALLY INDUCED PAIN", submitted by Maureen Janet Simmonds in partial fulfilment of the requirements for the degree of Master of Science in Physical Therapy.

Jean Wessel

(Supervisor)

Date: June 29 1970

DEDICATION

This work is dedicated with love to my family. To my parents who provided me with a love for learning, and from whom I inherited the ability and the stubborness to see this project through. To my husband David, whose love, help, and support made this project possible. Also, to my two little boys, Chad and Kent. Their energy, enthusiasm, and love, provided a positive and stabilising influence as I experienced the roller-coaster ride of graduate school.

ABSTRACT

The present study addressed the question of whether the quality of the pain experienced has an influence on the efficacy of transcutaneous electrical nerve stimulation (TENS). Previous research has established the multidimensional nature of the pain experience, and the effectiveness of TENS in a variety of clinical and experimental pain conditions. However, the significance of the sensory quality of pain, and the influence that it has on pain management techniques has not been established.

Pain was mechanically induced in 40 healthy, pain free volunteers (20 males, 20 females) with two different instruments which evoked different qualities of pain. Pain threshold and pain tolerance were measured with each instrument, and subjects described the sensory quality of the induced pain, using the sensory adjectives of the McGill pain questionnaire (MPQ).

Subjects were stratified by sex and then randomly assigned to experimental or control groups. Pre-test pain threshold and tolerance measures were obtained, and MPQ words were chosen to describe the pain at each level and with each instrument. The experimental group was stimulated with conventional TENS for 20 minutes, and a control group had sham TENS applied for the same time period. Post-test pain threshold and tolerance were then measured.

The dolorimeter evoked pain which was described as dull pressure, and the forceps algometer evoked a sharp pinching pain. TENS significantly increased the pain threshold to the dolorimeter ($p < .05$), but had no effect on the threshold from the forceps algometer. The sham TENS group exhibited a significant decrease in pain threshold of the dolorimeter ($p < .05$), whilst there was no difference in forceps pain threshold. No significant effects were found at pain tolerance levels. In summary, pain quality was found to influence the analgesic effect of TENS at the pain threshold level.

ACKNOWLEDGEMENTS

A great many people contributed in many different ways to this thesis, and my thanks go out to all of them. I would particularly like to extend my gratitude to my advisor, Dr. Jean Wessel, who gave so generously of her time and provided sound guidance and assistance. I would like to thank Dr. Roger Scudds, my committee member, for sharing his expertise, for his support, and for the confidence he has shown in me. My sincere thanks are also extended to Dr. Eugene Lechelt, my committee member, for his psychological input and his encouragement. Special thanks are also owed to Barbara Luckhurst, fellow student, research assistant, and support, who helped make Graduate school fun, and kept the data collection period in its true perspective. Finally, to the clinicians, students, and patients, with whom I have worked over the years and from whom I have learned so much - thank you.

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CHAPTER ONE

THE PROBLEM

Introduction

Pain is the most common problem for which people consult a physician. It is also one of the most challenging problems in medicine (Melzack, 1982). The costs of pain to the individual and to society are enormous. In 1982, the cost of pain and disability in the United States was $122.3 billion (Osterweis, Klienman & Mechanic, 1987). The psychosocial costs to the patient and their family are also great; they may have to deal with a decline in income, role alteration, and activity limitations (Clark Mims, 1989).

Many efforts have been made to define pain. The most widely accepted definition is that proposed by the International Association for the Study of Pain (IASP) in 1979: 'Pain is "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage"'(Merskey, 1979). This definition acknowledges the fact that pain is a multidimensional experience.

According to Melzack (1988), there are three main components to the pain experience: 1) evaluative, 2) affective and, 3) sensory. Within the sensory domain different characteristics of intensity and quality of pain can be experienced. Gracely (1983), considers the sensory

characteristics of pain in terms of its intensity, its unpleasantness, and its qualities of pressure, temperature, or vibration. The sensory quality of pain perception is very variable and at the present time it is unclear whether the sensory quality of pain is a dominant factor which affects the success of pain management techniques.

Electrical stimulation in the form of transcutaneous electrical nerve stimulation (TENS) has been used by physical therapists as an adjunctive pain management technique since the late 1970's, with various levels of success. Whether the quality of the pain experienced has an influence on the efficacy of TENS is not known.

Conventional TENS, has high frequency (80Hz) and low intensity parameters. As such it is thought to selectively stimulate large sensory nerve fibres. The activity of these nerve fibres inhibits the transmission of small fibre impulses at the dorsal horn. The Gate-control theory of Melzack and Wall (1965), is based on this postulated effect. TENS has been shown to be effective in alleviating pain under different clinical and experimental pain conditions. In a literature review, Woolf (1989) listed conditions successfully treated with TENS, and conditions for which TENS was unsuccessful. Some clinical conditions, for example; post-operative or obstetric pain appeared in both lists. The conflicting outcomes from such studies may be due to different stimulus

parameters, electrode placements, or the characteristics of the pain treated with TENS.

The effect that the quality of pain may have on the effectiveness of TENS has not been specifically addressed. Mannheimer and Lampe (1984) noted that acute pain of a superficial nature, including causalgia - which is a cutaneous burning pain, responds best to conventional TENS. Whereas, pain that is more long standing and is deep and achy in quality responds best to low frequency TENS. However, this statement is based on clinical impressions rather than empirical evidence. The question of whether the quality of pain per se, is a factor that affects the success of TENS has not been specifically addressed.

Although experimental pain serves as a model for acute rather than chronic clinical pain, its study is useful in that it provides information in regards to the sensory component of pain transmission and modulation. This information is of value for the understanding and management of clinical pain (Gracely, 1989). Experimental pain will be used in the proposed study, as it is felt to be a more accurate reflection of the sensory component of pain (Wolff, 1983) and TENS primarily affects this sensory component. Experimental pain has some advantages over clinical pain in terms of its study for the following reasons: (i) the stimulus used to evoke pain is easily measurable and reproducible, (ii) base-line measures of no pain can be taken, (iii) the stimulus can be

applied in a standardised setting, and (iv) it is possible to control for extraneous variables (Wolff, 1983).

The major differences between experimental and clinical pain are that in experimental pain:

1. The subject has control of the upper intensity and duration of the noxious stimulus.
2. Experimental pain studies tend to measure the sensory-discriminitive aspect of pain. Whereas, studies of clinical pain tend to address the motivational-affective dimension (Chapman, 1983).

Purpose of the Study

At the present time it is not known whether the specific sensory quality of pain is a factor that influences the response to treatment by TENS. This is true for both clinical and experimentally induced pain. The use of experimentally induced pain in a controlled situation helps to isolate the sensory component of the pain. The importance of sensory quality as a factor affecting pain response can then be assessed.

The purpose of this study was the following.

1. To determine whether conventional TENS is effective in modulating pain perception in the controlled experimental situation.
2. To determine whether the sensory quality of the pain affects the magnitude of the response to TENS.

Operational Definitions

Pain threshold is the point at which pain is just perceived on an ascending stimulus trial (Wolff, 1983). This is different from sensation threshold which is that point at which the subject can just perceive the stimulus.

Pain tolerance is the point at which the subject is no longer willing to tolerate the intensity or duration of noxious stimulation (Wolff, 1983).

Conventional TENS is TENS which provides a strong comfortable sensory stimulation. The electrical parameters are: pulse rate 80 Hz, pulse width 100 usec, and intensity adjusted to provide the required sensation (Mannheimer & Lampe, 1984).

Sham TENS is TENS which is applied in the usual manner but no electrical stimulation occurs.

Pain quality is the subjective perception of the distinctive sensory characteristic of the pain. Pain quality is not a characteristic of the intensity level of the pain but it may be related to it.

Dolorimeter is a device used to measure the quantity of a stimulus required to evoke pain.

Delimitations

This study is delimited to:

1. The testing of healthy pain free subjects, between 18 and 55 years of age.

2. The measurement of experimentally induced pain threshold and pain tolerance with pressure and pinch dolorimeters.
3. Assessment of the pain quality evoked with each of the stressors as measured by the MPQ.
4. The application of conventional or sham TENS.

Limitations

The study is limited by:

1. The reliability of the stressors - pressure dolorimeter r= .9 (Scudds, and Fischer, 1988.), forceps stressor r= .9 (Appendix B).
2. The calibration accuracy of the stressors.
3. The intratester reliability of the application of the stressors by the tester.
4. The application of TENS in a similar manner to all subjects.
5. The ability of the subjects to understand and complete the MPQ.

Research Hypothesis

The following research hypotheses will be tested:

1. Active TENS will increase the pain threshold and tolerance measures obtained with each stressor.
2. There will be a significant difference between the quality of pain evoked by each stressor.

3. There will be a differential effect of TENS on the two stressors.

CHAPTER TWO

REVIEW OF THE LITERATURE

Overview

Two major areas are reviewed in this chapter. The first is pain and and the second is TENS. Each topic is reviewed separately prior to a review of the use of conventional TENS in clinical and experimentally induced pain.

The first section addresses the extent of the problem of pain, and this is followed by a discussion of the multidimensional aspects of pain. The different types of pain and the characteristics of each type are then considered. A discussion of the methods of pain induction and the requirements of pain stressors completes this section.

The topic of TENS is reviewed in the following manner. The different modes of TENS, and their hypothesised electrophysiological effects are first presented. This is followed by a review of the use of conventional TENS in clinical pain and experimentally induced pain.

The Problem of Pain

Pain is a problem for the individual sufferer and also for society. In 1984, Bonica noted that pain was the most frequent cause of suffering and disability affecting the quality of life for millions of people. He also estimated that 40% of Americans required some form of medical management for acute and chronic pain, and moreover the pain was inadequately managed (Bonica, 1984). In a discussion of pain and litigation, Chapman and Brena (1989) described the phenomenon of pain as "epidemic". Survey data reported by Crooke, Ridout, and Browne (1984) showed that eleven percent of the general population may suffer from persistent pain.

Any estimation of the cost of pain is confounded by the fact that most cost estimates are based on disability rather than pain. The assumption is made that all people who are unable to work due to disability, are also suffering from pain. In 1982, the financial cost of pain and disability in the United States was $122.3 billion. This figure was comprised of; $67.4 billion for cash, disability and transfer payments, $51.9 billion for medical care payments and $3 billion for direct service expenditures e.g. vocational rehabilitation (Osterweis, Klienman & Mechanic, 1987).

The financial costs of pain are an important measure, but they do not reflect the psychosocial costs to the individual and to their family. These qualitative costs are much harder to assess, but are an integral part of the pain

equation. Pain sufferers and particularly those with chronic pain, may have to deal with a decline in income, role alteration, and activity limitations (Clark Mims, 1989). The presence of chronic pain may also lead to feelings of depression and helplessness, and the stress of dealing with these problems may lead to serious family conflicts. Social withdrawal may also occur as patients impose limits on activity, and become focused on bodily symptoms.

Nature of Pain

Although pain is an experience common to most people its definition remains enigmatic (Feurstein, 1989). Pain is a subjective experience. Therefore, each person arrives at their own definition of what pain is, based on their previous painful experiences, and on their theoretical orientation.

Early definitions of pain were quite specific. They defined pain as a basic sensation such as hunger or sight and they closely tied the definition of pain to tissue damage or injury (Wall, 1979). For example, an often cited definition of this nature is that proposed by Mountcastle (1968), "Pain is that sensory experience evoked by stimuli that injure." The problem with this type of definition is that it assumes a direct relationship between pain and injury, but this is not always the case. Pain can occur without apparent injury and injury can occur without pain (Melzack, 1988; Melzack, Wall and Ty, 1982).

Conversely vague psychosocial pain definitions do not address the sensory aspect of pain at all, e.g. " Pain is whatever the person says it is, existing whenever he says it does" (MaCaffrey, 1979). The limitations of these definitions have been addressed by The International Association for the Study of Pain (IASP).

The IASP definition of pain (Appendix C) is accepted as a working definition by most pain specialists (Feuerstein, 1989). Although this definition is unwieldy in its full form, it is comprehensive and acknowledges the complexities and the multidimensional nature of pain. Three dimensions, or domains, of pain are acknowledged: cognitive-evaluative, motivational-affective, and sensory-discriminative (Weisenberg, 1989).

The cognitive-evaluative domain is that aspect of the pain experience that is concerned with the "meaning" that the person attaches to the pain. This meaning will affect the reaction to a painful experience. Cognitive approaches to the management of pain include; educating patients in how their thoughts affect their pain, and teaching them how to improve their coping strategies (Weisenberg, 1989).

The second domain of pain is the emotional-motivational domain. Anxiety, fear, and depression are the most common emotional concomitants of pain and their presence may heighten the perception of pain (Craig, 1989). These emotional-

motivational processes of pain are central to the experience and expression of pain.

The third domain is sensory-discriminitive and is the main focus of this study. This domain includes the actual sensory properties of the painful experience such as intensity, quality, location, and duration of the pain. The following section discusses some of the sensory characteristics of pain in more detail.

Sensory Characteristics of Pain

Not all pain feels the same, and some pain is more unpleasant than another. The characteristics of the specific complaints of pain are clinically important as they are regularly utilised for diagnostic and treatment purposes. The relationship between the sensory characteristics of pain and pain report is confounded by chronicity. For instance, chronic pain patients tend to describe their pain more in terms of the emotional effect of the pain than the sensory quality of the pain (Doan and Wadden, 1989). This contrasts to acute pain patients who tend to describe their pain primarily in terms of its sensory component and less in terms of the affective component (Reading, 1982). The present discussion is limited to acute pain as this is the type of pain relevant to the present study.

Pain intensity.

A variety of factors determine pain intensity. Nocioceptors are receptors which respond to noxious or potentially damaging stimulation. In order for a nocioceptor to be classified as such, it must be capable of coding the intensity of its stimulation (Besson and Chaouch, 1987). This implies that there is a strong correlation between the intensity of stimulation of the nocioceptor and the intensity of its discharge. However, this afferent discharge from the periphery may be modulated at many different levels before it is received and interpreted at the cerebral cortex. For example, some neurotransmitters such as enkephalin inhibit activity in the nociceptive pathways. Activity in A-beta afferent fibres (Besson and Chaouch, 1987), and the descending endogenous opiate systems inhibit the transmission of A-delta fibre and C-fibre nocioceptive activity at the dorsal horn level (Fields and Basbaum, 1989).

The perception of pain intensity in relation to the nocioceptive stimulus is dependent on the type of stimulus. Specific nocioceptors are selectively responsive to different types of stimulation e.g. mechanical or thermal, and they also exhibit different response characteristics (Campbell et al,1989). For example, Type I A-fibre mechano-heat nocioceptors (AMH) adapt slowly to stepped up thermal stimuli and are responsive at temperatures higher than those for Type II AMHs. Type II AMHs however, adapt much quicker to

repetitive stimulation. The other important nocioceptor is the C-fibre mechano-heat nocioceptor (CMH). Human judgement of pain intensity and CMH activity in the monkey shows a close match to the same amount of heat stimulation (Campbell et al, 1989).

Mechanical stimulation evokes a response of proportional magnitude in CMHs. However, differential adaptation rates of the CMHs do occur with sustained mechanical stimulation. Another interesting phenomenon is that sustained noxious stimulation can lead to an increase in pain perception. This may be due to recruitment of AMHs in an adjacent receptive field (Campbell et al, 1989).

The relationship between pain intensity perception, and noxious stimulation is dependent on the type and method of nocioceptive stimulation. The heat threshold for CMHs correlates with heat pain threshold, but mechanical thresholds for both AMHs and CMHs are both lower than mechanical pain thresholds (Campbell et al, 1989). The significance of this is presently not known.

Psychophysical tests of pain perception have been carried out in relation to the microneurographic studies of nociceptive activity. Stevens (1970) used psychophysical methods of measurement to show that the relationship between sensory perception and sensory stimulus intensity, is a power function. He also showed that the exponent is dependent on the type of stimulation used. As noted earlier, the

relationship between the intensity of noxious stimulation and the intensity of the perceived pain is not always a linear function. For example, there is a curvilinear relationship between the intensity of ischaemic pain evoked by the submaximal effort tourniquet test and time (Moore, Duncan, Scott, Gregg and Ghia, 1979). On the other hand the relationship between pain intensity and electrical stimulation has a linear relationship, albeit that the perceived magnitude of the pain is a power function of the applied current (Harris and Rollman, 1983).

Finally, the psychological state of the patient or subject may affect the pain intensity. For example, high levels of anxiety will enhance the perception of pain intensity (Davidson and McDougall, 1969). Attention to the stimulus will increase the intensity of the perceived pain; whereas distraction will decrease it (Melzack, 1989).

Models of hypervigilance and adaptation to pain have both been proposed. The hypervigilance model suggests that pain patients become more sensitive to pain over time (Chapman, 1978). On the other hand, the adaptation model suggests that patients become less sensitive to pain over time (Rollman, 1979). However, there is now evidence which suggests that neither model is totally correct. Rather, factors such as the location of the pain, and the present activity of the painful condition (i.e. whether there is an exacerbation or remission

of the pain), lead to hypervigilance or adaptation (Scudds, 1989).

In summary, it can be said that pain intensity is generally related to the intensity parameters of the noxious stimulus. However, there is a high potential for modulation of the nocioceptive discharge along its ascending pathway.

Pain quality.

The next question to be considered concerns the relationship between pain quality, the nocioceptive stimulus and the type of nocioceptor stimulated. The fact that there are different sensory qualities of pain is well recognised. Tasker and Dostrovsky (1989), describe the spontaneous continuous superficial burning pain of causalgia, which is often associated with a deep, stabbing, crushing, bursting, or tearing pain. Interestingly, it also appears that superficial burning pain is more amenable to treatment by opiates, pentothal, or somatosensory blockade, than deep pain (Tasker and Dostrovsky, 1989).

Yates and Smith (1989), also discuss two different types of pain that generally occur following trauma. They describe the immediate pain as sharp nocioceptive pain, followed at a variable interval by deep, boring, persistent pain which increases. They suggest that the difference in pain quality is due to the different structures stimulated, i.e. the initial pain is due to distortion of perivascular and

periarticular nerve plexuses, whereas the second pain is due to physical distension of joint capsules or fascial compartments.

Physiological studies have revealed two types of pain sensations that are due to the stimulation of different primary afferent fibres (Price, Hu, Dubner, and Gracely, 1977). Highly localized first pain is mediated by A-delta fibres, whereas, diffuse poorly localised pain is mediated by C-fibres. Although this concept of first and second pain has been questioned, it is likely that the concept is correct (Gracely, 1989). The different properties of the pathways may help to explain the differential effects of some treatments. However, only two pathways are proposed and there are many different types of pains.

The relationship between the intensity of pain and the sensory quality is not entirely clear at this point. The sensory quality of pain appears to change as the intensity of noxious stimulation increases. This could be due to the thresholds of different types of nocioceptors or nerve fibres being reached, or it could be due to the release of specific algesic substances.

McGill Pain Questionnaire

The preceeding section gives an indication that the experience of pain is highly complex. It follows therefore,

that an accurate measurement of pain should reflect this complexity.

Prior to the development and use of the McGill Pain Questionnaire (MPQ) (Appendix A) by Melzack and Torgerson (1971), the tools available to measure pain tended to measure the intensity dimension only. Recognition of the multifaceted nature of pain and the limitation of one dimensional pain measurement, led to the development of the MPQ. This comprehensive questionnaire consists of 78 adjectives arranged into categories exhibiting similar pain qualities. The sensory, affective, and cognitive dimensions are represented, and the words within each category are organised according to increasing intensity. Also, the spatial and temporal characteristics of the pain can be determined. Scoring of the questionnaire can be carried out by determining the number of words chosen in total or from each of the three subscales, or by computing the rank values of the words chosen in total and for each of the subscales (Reading, 1989).

The sensory subscale consists of 42 adjectives arranged in 10 categories. The scale names and anchor words are illustrated in Table 2:1, with each category reflecting a different sensory characteristic. The anchor words are the first and last words respectively in each of the categories, and they represent the least and the most intense painful sensation of that quality.

TABLE 2.1

Scale names and anchor words of the sensory domain of the MPQ.

Category	Scale name	Anchor words
Sensory		
1	Temporal	Flickering/pounding
2	Spatial	Jumping/shooting
3	Punctate pressure	Pricking/lancinating
4	Incisive pressure	Sharp/lacerating
5	Constrictive pressure	Pinching/crushing
6	Traction pressure	Tugging/wrenching
7	Thermal	Hot/searing
8	Brightness	Tingling/stinging
9	Dullness	Dull/heavy
10	Sensory miscellaneous	Tender/splitting

Adapted from: Prieto and Geisenger, 1983.

The MPQ is a frequently used dependent measure and it has been found to be reliable and valid for different types of clinical and experimentally induced pain (Klepac and Lander, 1983). Chen and Treede (1985) utilised the MPQ as a dependent measure for the examination of phasic and tonic pain. They found that subjects scored these two types of pains differently on the MPQ. The sensory component of the pain experienced from each instrument was described significantly differently and also the aversive component of the pain was greater for the tonic pain. The two methods used to evoke pain were electrical stimulation through a pin prick on the skin, and, ischaemic pain evoked by the submaximal effort tourniquet test. These methods evoked significantly different sensory pain qualities, which were distinguished by the MPQ. The MPQ was also been sufficiently sensitive to assess the efficacy of different analgesics (Klepac, Dowling and Hanige, 1981; Reading, 1989).

The discriminant validity of the MPQ is evidenced in the fact that the instrument can be used to distinguish between patient groups (Reading, 1989). For example, Reading (1982) compared the MPQ scores of patients with acute episiotomy pain to patients with chronic pelvic pain. He found that acute pain patients tended to choose more sensory words whereas chronic pain patients tended to choose more affective words. He felt that this was indicative of the greater sensory input from the perineum in the acute pain patients. This same trend of word

choice was also found when patients with acute or chronic back pain were compared (Reading, 1982).

Finally, it has been shown that patients with particular pain syndromes tend to choose a similar constellation of words from the MPQ (Melzack, 1975). Thus, it can be seen that painful sensations are both different and similar, i.e. toothache pain and labour pain have different pain qualities, but a toothache will feel similar on different occasions. Moreover, the MPQ can both measure and distinguish between these pains.

The Investigation of Pain

Clinical pain.

Pain research has been undertaken using both clinical and experimentally induced pain. Clinical pain due to a variety of conditions can be differentiated into acute and chronic pain. Acute pain is that pain felt immediately or soon after injury. It is directly related to tissue damage and decreases as the tissue heals. Chronic pain is commonly defined as pain that lasts longer than six months. The relationship between chronic pain and tissue damage is unclear, and the affective component of pain may play a greater role. Also, there is a clinically recognised and challenging syndrome - chronic pain syndrome - in which psychological variables play a more influential role (Wolff, 1983).

The investigation of clinical pain is hampered by the fact that pain is a personal subjective event, and measurement of the nocioceptive input is based on indirect estimation and is limited by the lack of physical correlates (Gracely, 1989). Also, the multidimensional complexity of pain can hinder accurate evaluation. Factors that affect pain report include, culture, coping style, and the emotional and cognitive effect of the injury or illness (Gracely, 1989).

The problems that are encountered with the investigation of clinical pain are lessened with the use of experimentally induced pain. Herein lies the value of using well controlled, reproducible experimental studies on the effects of pain in pain free individuals, when the highly variable emotional and cognitive aspects of pain are far less significant (Reading, 1989).

Experimental Pain.

One advantage with the investigation of experimental pain is that the stimulus used to evoke the pain is easily measured and is reproducible. Also, because base-line measures of no pain can be taken, the stimulus can be applied in a standardised setting, and it is possible to control for extraneous variables. For these reasons it is felt to be a more accurate reflection of the sensory component of pain rather than the affective component (Wolff, 1983). This is supported by experimental studies which have shown that pain

treatments can affect the sensory and reactive component of pain differentially (Price et al, 1986).

Experimentally induced pain is different from clinical pain because the subject has control of the upper intensity and the duration of the noxious stimulus in the experimental situation. Also, experimental pain studies tend to measure the sensory-discriminitive aspect of pain, whereas, studies of clinical pain tend to address the motivational-affective dimension (Chapman, 1983).

Pain stressors.

Different stimulation methods have been used to study experimentally induced pain, and each has different properties. Electrical stimulation is frequently used because it is easy to control and can be applied to any part of the body or to tooth pulp. It also has a fast onset and offset of pain sensation and is repeatable. Harris and Rollman (1983), note that electrical stimulation has the least variation of methods. However, it does not provide a natural sensation, and it directly stimulates primary afferent fibres, including non-nocioceptive afferents (Gracely, 1989). Turskey (1973), noted this when he reported that a rise in sensory threshold occurred following strong shock. This is an important point to consider when repeated pain measures are being taken. In addition, the device must provide a constant current output so that the skin impedance changes which occur

will have a minimal effect on the perceived intensity of the electrical stimulation (Procacci et al, 1979).

Thermal stimulation evokes activity in specific nocioceptors, and is a more natural painful sensation. It has a fast onset but slow offset, and so can not be used for studies with repeated stimulation (Gracely, 1989).

Chemical stimulation methods are not commonly used as there are problems with a slow onset as well as a slow offset of pain. There may also be a potential for interaction of the noxious chemical with the endogenous algogenic and analgesic substances. These problems limit the usefulness of chemically evoked pain. The only advantage to the use of this method is the fact that it provides a natural sensation of pain.

Ischaemic pain is produced by exercising a limb in which circulation is occluded by the use of a tourniquet. It is a natural painful sensation, but doesn't have fast onset or offset of pain (Sternbach, 1983). An effort has been made to control the exercise component of the test in order to try to standardise the amount of ischaemia produced (Moore, Scott, Gregg and Ghia, 1979).

Mechanical stimulation of pain can be evoked by many different instruments that apply pressure to the skin. Both tonic and phasic pain can be evoked by these methods. The pressure algometer (Fisher, 1986) and the forceps algometer (Burgess and Perl, 1967) both evoke tonic pain. On the other

hand the Forgione Barber pressure algometer evokes phasic pain (Forgione and Barber, 1971).

Mechanical devices can produce a wide range of pain intensities and durations. Tissue elasticity, area of stimulation and the rate of compression can all influence the results (Wolff, 1984).

Pain measures.

The pain measures usually recorded during experimental pain studies are pain threshold, pain tolerance, and pain sensitivity range (Wolff, 1983). Pain threshold is that point at which pain is first felt on ascending stimulus trials. Pain tolerance is the point at which the subject withdraws or terminates the noxious stimulation. The pain sensitivity range is the arithmetic difference between pain threshold and tolerance (Wolff,1983).

A psychophysical testing procedure, sensory decision technique (SDT), has also been utilised in experimental studies. SDT is a method used to try to discriminate between the response bias of the subjects and their sensory discrimination. Although its validity has been disputed (Rollman, 1977; Chapman, 1977) it can provide useful information when discrimination is either unchanged or similar between different populations and therefore response bias can be determined (Clark and Clark, 1980 Cited Gracely, 1989).

Summary.

Experimentally induced pain serves as a model for acute pain and its study is useful because it provides information in regards to pain transmission and modulation. Also, the psychophysical procedures used in the study of experimental pain, can be useful for evaluating clinical pain. This is of value for the understanding and management of clinical pain (Gracely, 1989).

Pain Management with TENS

Physical Therapists use a variety of physical and electrical modalities in the management of pain symptoms, one of which is transcutaneous electrical nerve stimulation (TENS). TENS was originally used as a predictive screening device prior to the implantation of a dorsal column stimulator (Long, 1974), but its efficacy as a pain management tool is now well established. It has been utilised by physical therapists for pain management since the 1970's.

The electrical parameters of TENS such as pulse intensity, pulse width and pulse rate, can be varied. It is proposed that the characteristics of these parameters cause selective stimulation of certain primary afferent fibres (Mannheimer and Lampe, 1984). Thus the neurophysiological effect of TENS is dependent upon the stimulation parameters utilised (Table 2.2).

Three modes of TENS are in common clinical use. The electrical parameters determine the mode of TENS, and the proposed neurophysiological mechanisms of effect vary with each mode (Mannheimer & Lampe, 1984).

1. Conventional TENS is the most common mode that is used. This mode has high frequency (80-100 Hz) and low intensity pulse parameters, and is thought to selectively stimulate large A-beta sensory nerve fibres. The activity in the A-beta afferents inhibits the transmission of small fibre nocioceptive impulses at the dorsal horn. This causes a local analgesic effect. The onset of pain relief is generally quite quick, but the offset is very variable (Mannheimer and Lampe, 1984).
2. Low frequency TENS has electrical parameters which include a low frequency (2-10 Hz), a wide pulse width (>200 usecs) and a high intensity of stimulation. It is thought to activate the endogenous descending inhibitory systems, and therefore has a more general analgesic effect (Salar et al, 1981). However, the evidence of this effect is equivocal at present (O'Brien, Rutan, Sanborn and Omer, 1984).
3. Brief intense TENS has high frequency (100 Hz), high intensity and wide pulse width (>200 usecs) parameters. It is thought that this mode produces a peripheral blockade of neural transmission since it has a local

effect of profound analgesia (Mannheimer and Lampe, 1984).

Each mode can be modulated, so that there is an automatic variation in one or more of the stimulation parameters. Finally, a burst mode can be used in conventional or low frequency modes. This mode has internal high frequency pulses within each low frequency pulse burst. Both of these variations are thought by some to be more comfortable and both will reduce accomodation (Mannheimer & Lampe, 1984).

To date, TENS has been used to symptomatically relieve acute, chronic, and experimentally induced pain.

TENS in Acute pain.

Most studies which have assessed the effect of TENS in acute clinical pain have used post-operative or obstetric pain as their models. Subjective pain relief after surgery has been significantly decreased with the use of TENS (Schomberg and Carter-Baker, 1983). Post operative narcotic consumption has been reduced (Soloman, Viernstein & Long, 1980), and post thoracotomy pulmonary function tests have been better in patients who have used TENS post operatively (Ali, Yaffe & Serrette, 1981).

On the other hand, the number of days of hospitalization was not found to be reduced by the post-operative use of TENS (Richardson & Siquiera, 1980). Some more recent studies, have assessed the placebo effect of TENS and found it to be

Table 2.2

Stimulation parameters and physiological effect of the different modes of TENS

	Conventional	Low frequency (Acupuncture)	Brief intense
Rate	High	Low	High
Width	Narrow	Wide	Wide
Intensity	Low	High	High
Site of Action	Segmental at DH	Segmental and extrasegmental at DH and SS peripheral	Segmental and extrasegmental DH (DNIC), BS & nerve
Mechanisms	Gate control CI	Neurohumeral Serotonergic	Conduction block CI, serotonergic

Adapted from Mannheimer and Lampe, 1984.

Key: DH Dorsal horn

CI Counterirritation

SS Supraspinal

BS Brain stem

DNIC Diffuse noxious inhibitory control

significant (Gilbert, Gledhill, Law & George, 1986; Conn et al, 1986). Conn et al, reported statistically significant decreases in pain severity and in analgesic consumption with both sham and active TENS for post operative appendectomy pain. There was a statistically significant difference between active and sham TENS for the first 24 hours, but the difference was not significant after that time. The authors explained these findings in terms of the placebo effect. However a true control group was not utilised. It may be that the influence of the anasthesia in the first 24 hours decreases the placebo response as patients are more drowsy and less cognitively aware. However, it should be remembered that the placebo response for any treatment is approximately 35% (Melzack, 1988).

TENS in Chronic pain.

Investigators have reported that TENS significantly reduces subjective pain rating (Wolf, Gersh & Rao, 1981), and analgesic consumption (Santiesteban, 1983), and increases range of motion (Melzack, 1983). However, the success rate of TENS, especially in chronic pain conditions is very variable.

Thorsteinstein et al (1977), reported a 48% success rate with the use of TENS in a heterogenous chronic pain population. Chronic pain was defined as pain which had been present for one month, but the mean duration of pain was four

years ten months. Succcess was determined by "patient preference" for use of the machine, and subjective assessment of pain relief on a four point scale from "aggravation of pain" to "pain relief". The investigators also evaluated different electrode placement techniques and determined that the optimum benefit was obtained with the electrodes placed over the site of pain or over a related nerve trunk. No comparison of effect was determined for different patient diagnoses in relation to optimum stimulation site, amount of pain relief or aggravation of symptoms. A 32% success rate, - which is in the expected range of placebo response, was also reported for placebo TENS. Unfortunately, of the 83 patients assessed, 53 were classed as either hysterical or depressed on the MMPI. This may explain the relatively low albeit significant success rate.

An 83% success rate for TENS was reported by Fried, Johnson and McCracken (1984). However, success was based on a questionnaire response by the patient. Patients who believed that TENS helped to alleviate their pain were classified as successful. Interestingly, the data from this study indicate that 44.6% of the TENS units issued, were provided to patients who were deemed "fully recovered from injury and fit for regular employment". This paradox is probably due to the compensation board not recognising the persistence of pain as a disability. No control group was utilised. Only 47% of the patients who reported that TENS

helped alleviate their pain, were actually working. It is acknowledged that the use of work status is problematic as a dependent measure, due to the differences in occupational demand and the type of pain or injury sustained.

A much better controlled and objective study examined the effect of TENS in patients with rheumatoid arthritis. A determination of the length of time that the wrist could support a weight before pain began or was increased was carried out. Three loading tests were carried out, stimulation by active TENS was commenced and after 15 minutes loading tests were conducted on each wrist. A placebo stimulator was then utilised and loading tests were carried out in the same manner. The results indicated that TENS improved the loading time by more than 75% in 60% of the wrists tested. Neither the placebo stimulator nor the contralateral TENS stimulation achieved improvement at this level (Kumar and Redford, 1982). A similar study was conducted by Mannheimer, Lund and Carlsson (1978) and comparable results were reported.

A placebo device was found to be as effective as to conventional or low frequency TENS, for resting pain, grip strength, joint tenderness, and grip pain in subjects with rheumatoid arthritis in the hands (Langley, Sheppeard, Johnson and Wigley, 1984). However, the authors acknowledged that strong suggestion was used with the placebo, compared with a neutral statement which was provided with the TENS.

Finally, TENS and its placebo effect were assessed in an osteoarthritis population (Taylor, Hallet and Flaherty, 1981). Both placebo and active TENS decreased pain and analgesic consumption, but active TENS provided a significantly greater improvement.

A placebo effect is likely to occur with TENS treatment as it is with any form of medical treatment. However, there is a significant difference between the amount of improvement obtained with active compared to placebo TENS.

TENS is not a panacea, but it has been shown to be effective in alleviating pain in many different clinical and experimental pain conditions. The conflicting results in terms of effectiveness, may be due to different methods of applications or modes of TENS used in different studies. Many early studies used heterogenous groups (Wolf, Gersh & Rao, 1981) and many did not report the parameters or specific method of TENS applications.

The balance of the literature suggests that TENS is most effective for patients with a known organic basis for their pain. It has also been reported to be more effective for extremity rather than axial pain (Woolf, 1989). In addition, Reynolds et al. (1983), reported that older retired patients responded more favourably to TENS if they had pain of less than one years duration, and had undergone limited or no surgery.

Mannheimer and Lampe (1984) presented a list of factors which they felt inhibited the effectiveness of TENS. The list included; senility, dependency, increased pain perception after TENS, prolonged pain, and diazepam and narcotic addiction. In contrast, factors that were felt to enhance the effectiveness of TENS included; optimal electrode placements, stronger stimulation modes, and weaning from medications. Finally, they recommended trying different electrode placements or modes of TENS in cases where there was diminished effectiveness of this modality over time.

The effect that the quality of pain may have on the effectiveness of TENS has not been specifically addressed. Mannheimer and Lampe (1984), note that acute pain of a superficial nature, including causalgia responds best to conventional TENS, whereas pain that is more long standing and is deep and achy in quality responds best to low frequency TENS. However, this statement is based on anecdotal evidence only. The question of whether the quality of pain per se, is a factor that affects the success of TENS has not been specifically addressed.

TENS in Experimental pain

Published reports concerning the effect of TENS on experimentally induced pain have examined factors such as optimal electrical parameters, and optimal electrode

placements. Also, studies comparing the modes of TENS have been carried out. Different methods of applications - including auricular applications - have been used in an effort to assess the physiological effects of the various modes of TENS. The primary discussion in this section concerns the use of conventional TENS and its effects on experimentally induced pain.

Electrical stimulation of pain.

The most common pain stressor utilised appears to be that of electrical stimulation, with the dependent variables being pain threshold and tolerance. Unfortunately, comparison of the results between studies is difficult as there is no standardised methodology.

Janko and Trontelj (1980) reported increases in pain threshold and tolerance to electrical stimulation following TENS. The increase in pain measures was greatest, when high levels of TENS intensity were employed. Barr, Neilson and Soderberg (1986), also reported a significant increase in pain threshold with TENS, however, they noted that the optimal parameter for treatment effect was a rate of 60Hz. On the other hand, no significant change in pain threshold and tolerance levels was found by Jette (1986), or by Rooney and Tronstad (1986). However, Jette actually used a high voltage galvanic stimulator rather than a TENS unit to apply the TENS,

and Rooney and Tronstad used a unit which was designed to stimulate at subthreshold levels.

There may be problems with using electrical stimulation as a pain stressor, whilst at the same time using it to relieve pain. Interference between the different electrical stimuli may occur so that the net electrical parameters are altered. These parameters would not then be optimal for the target afferent fibres. Also, the threshold of a nerve is dependent on its position in relation to the stimulating electrodes, its diameter, and its resting potential (Benton, Baker, Bowman, and Waters, 1981). An electrical stimulus which depolorizes nocioceptive afferents must also depolorize the larger non-nocioceptive afferents because their threshold is lower. The potential ramifications of this effect do not appear to have been reported in the literature.

Even when the electrical stimuli are not applied simultaneously, it is not clear whether the thresholds of afferent nerve fibres will be altered by the first electrical stimulation which will then bias the effects of the second stimulation.

Thermal stimulation of pain.

Woolf (1979), tested the effect of TENS on pain threshold and tolerance to thermally evoked pain. He reported an increase in pain threshold and pain tolerance to thermal stimulation but only at high intensities of TENS. Erikson,

Rosen, and Sjolund (1985), did not use thermal pain measures, but rather, tested the effect of TENS on thermal sensitivity. They reported a decrease in sensitivity to both warm and cold stimulation. This decrease may extrapolate into a decrease in sensitivity to noxious temperatures.

Thermal sensitivity using SDT was also investigated by Callaghan, Sternbach, Nyquist and Timmermans, (1978). It is unclear which mode of TENS was applied, but they reported that no change occurred in healthy subjects, whilst there was improved sensitivity towards normal in a chronic pain population. Finally, whilst low frequency TENS has elevated pain threshold and tolerance levels to cold pressor pain, conventional TENS has not (Ashton, Ebenezer, Golding, and Thompson, 1984).

Stimulation of ischaemic pain.

Ischaemic pain which was evoked by the submaximal effort tourniquet test was found to be sensitive to modulation by TENS (Woolf, 1979; Roche, Gijsbers, Belch, and Forbes, 1984). Ischaemic pain is phasic and the time factor for tolerance is measured. The duration of time that ischaemic pain can be tolerated was reported to be increased by the application of TENS. And Woolf (1979) also reported that the subjective level of pain was significantly decreased.

Mechanical stimulation of pain.

A mechanical stressor described by Russel and Tate was used by Woolf (1979) to evaluate TENS. He applied pressure to the little finger, and stimulated the ulnar nerve with a "moderate intensity" of TENS. He reported an insignificant decrease in pain measures following TENS. Whether this was due to sensitization is not clear, but he did allow 30 minutes between pre and post tests. Woolf did not report on the sensory quality of pain evoked by this stressor.

Summary

Pain is a prevalent and costly problem that is difficult to manage. The complexity of the pain experience contributes to the difficulties in its management. TENS is a modality that is commonly utilised by physical therapists to reduce pain, but the reported success rate of TENS in experimental and clinical pain studies has been variable. The present study is designed to investigate whether one of the components of pain i.e. the sensory quality of the pain experience influences the analgesic efficacy of TENS.

CHAPTER THREE

MATERIALS AND METHOD

Research Design

The research design was a pretest-posttest control group design. Pain threshold measures with two stressors were taken, and the pain quality evoked was assessed using the sensory domain adjectives of the MPQ. The same procedure was then followed for pain tolerance measures. Conventional or sham TENS was applied for twenty minutes, and posttest measures were taken whilst the TENS was stimulating or sham stimulating. Pain threshold and tolerance measures were analysed separately using raw scores and standardised difference scores (refer to Figure 3.1).

Subjects

Forty pain free healthy volunteers who were naive to TENS participated in this study. Subjects were excluded if they; were pregnant, had any pain, had any known or suspected upper limb or cervical pathology, were presently taking any medication, or if they bruised exceptionally easily.

Subjects were the first 20 males and 20 females that volunteered and met the criteria for the study. The mean age of the subjects in the experimental group was 31.7 years with a range from 19 to 50 years, and in the control group was 26.1 with a range from 18 to 35 years. All subjects signed an

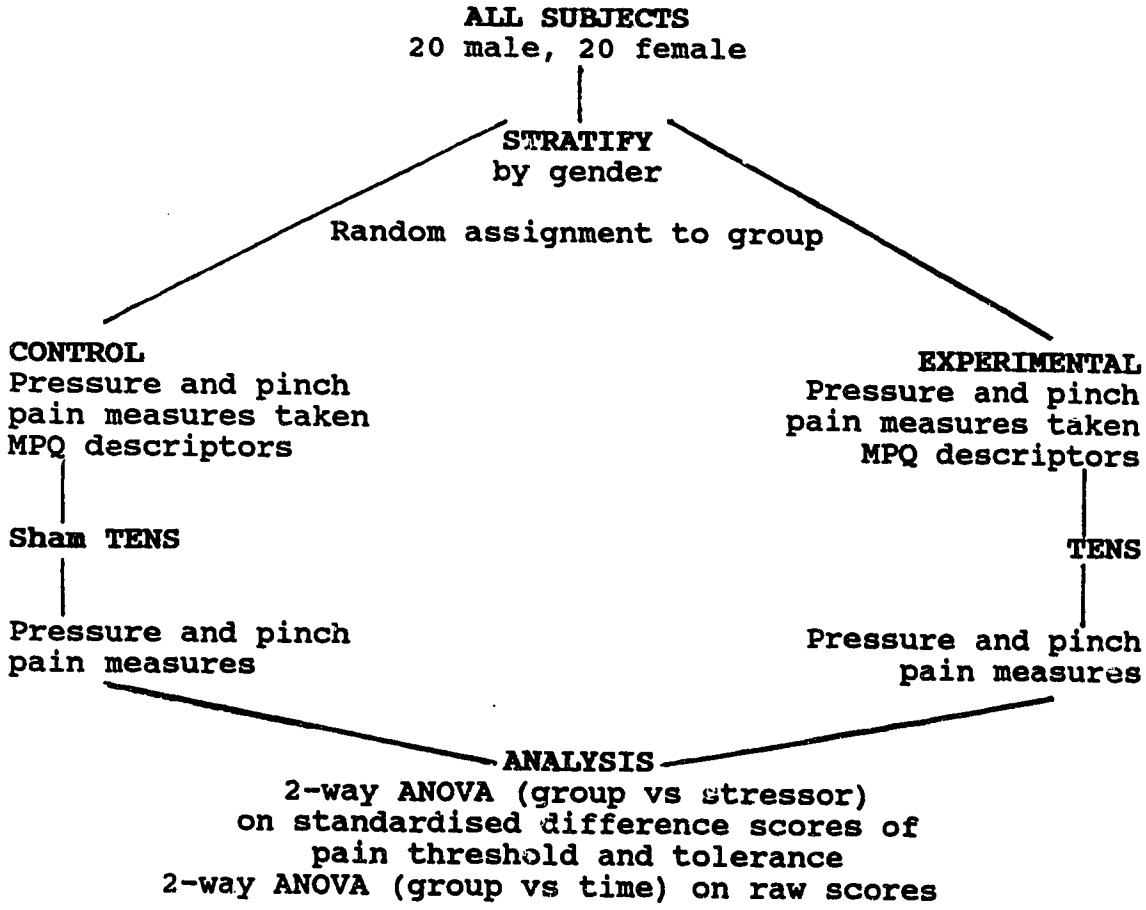


Figure 3.1: Flow chart of study protocol.

informed consent prior to participation (Appendix D). The sample was stratified by sex because men tend to have higher levels of pain threshold and tolerance compared to women (Otto and Dougher, 1985; Rollman and Harris, 1987). Subjects were randomly assigned to treatment or control groups, side to be tested, and order of stressor.

Equipment

Two mechanical pain stressors were used in this study. A variable pressure dolorimeter and a forceps algometer. The MPQ was used to assess the pain quality evoked from each stressor.

The variable pressure dolorimeter (Pain Diagnostics and Thermography, 17 Wooley Lane East, Great Neck, New York.) is a force gauge which is used to apply an increasing amount of pressure through a 1.54 cm^2 surface area (Figure 3.2). The range of pressure that can be measured is between zero and 17 kilograms.

The forceps algometer is a pair of forceps which has an electronic load cell attached (Figure 3.2). The load cell allows for an accurate reading of the amount of applied pressure. The pressure is applied through a 10.6 mm^2 surface, and the range is between 0 kg to a preset upper limit of 2.7 kg. This upper limit was set in order to avoid any tissue damage. The forceps algometer is unavailable commercially and

therefore was constructed at the University based on the original design of Burgess and Perl (1967). Each device was tested for reliability in a pilot project using ten subjects (Appendix E). Both stressors have been validated by other researchers (Scudds, and Fischer, 1989; Llyn & Perl, 1979).

The MPQ (Appendix A) consists of three major classes of adjectives - sensory, affective and evaluative - used by subjects to describe a subjective pain experience (Melzack, 1975). The sensory grouping which was used in this study consisted of 10 categories. Each of these categories is comprised of words which describe a particular type of noxious sensation. The MPQ is frequently used as a measure of clinical and experimentally induced pain, and it has been validated by other researchers (Melzack, 1975).

Figure 3.2: Pressure dolorimeter and forceps algometer.

Procedure

Subjects were told that:

1. The purpose of the study was to assess two different intensities of TENS on pain of different qualities.
2. TENS would be applied either at a strong but comfortable level, or at a subthreshold level.
3. Pain quality at pain threshold and pain tolerance would be assessed by the subjects choosing adjectives from the sensory domain of the MPQ. They should check one word from the sensory adjectives, that they felt best described the nature of the pain that they experienced. They could also check any other descriptors from the other categories on the MPQ. A different sheet of descriptors was used for each measure.
4. Pain threshold is the point at which the sensation first becomes "just painful", and pain tolerance is defined as the point at which "they no longer wished to tolerate the stimulus."

Pressure algometer: Pressure was applied by the investigator to the dorsal aspect of the fifth metacarpal at approximately mid-shaft level (Figure 3.4). The approximate rate of application was one kilogram per second. This device produced a dull pain. After testing, some subjects had a slight skin indentation which soon diminished.

Forceps stressor: The forceps pinched the skin on the medial aspect of the hand, at the middle of the fifth metacarpal

(Figure 3.5). The sensation evoked was one of sharp, burning pain which subsided as soon as the pressure was released. Some subjects had a visible indentation of the skin which quickly disappeared. Skin or tissue damage was not apparent with either of these devices.

The pre-test measures of pain threshold and pain tolerance for each stressor were collected by the principal investigator who was blinded to the type of TENS used. Subjects were seated with their hand screened behind a curtain (Figure 3.5), they were requested to inform the investigator when the stimulus first became painful - pain threshold, and secondly when they no longer wished to tolerate the stimulus - pain tolerance. At this point the stimulus was immediately removed.

TENS was applied by a trained research assistant. The unit and stimulation parameters are described in Appendix F (see Figure 3.6). Electrodes were positioned on the medial aspect of the wrist and medial, distal aspect of the 5th metacarpal (see Figure 3.3). The polarity of the electrodes was the same for all subjects, with the cathode placed distally. The objectives of the study and the procedure were then restated.

For sub-threshold stimulation (sham TENS), the TENS unit was turned on until the subject just perceived the stimulation, and then it was turned off. The alternative stimulation intensity (active TENS) was strong but comfortable

and was maintained at the same level of perception. During the stimulation period, subjects in both groups were asked every five minutes whether the stimulation intensity needed to be adjusted in order to maintain it at the preset perception level. Adjustments were made by the research assistant as necessary. The subjects were also instructed not to indicate to the investigator, which intensity of TENS was being applied.

Testing of pain threshold and tolerance was repeated after the TENS had been stimulating for twenty minutes, and was carried out whilst the TENS was stimulating. The order of stressor was the same as for the pretest. TENS was discontinued and removed as soon as posttest pain measures were taken.

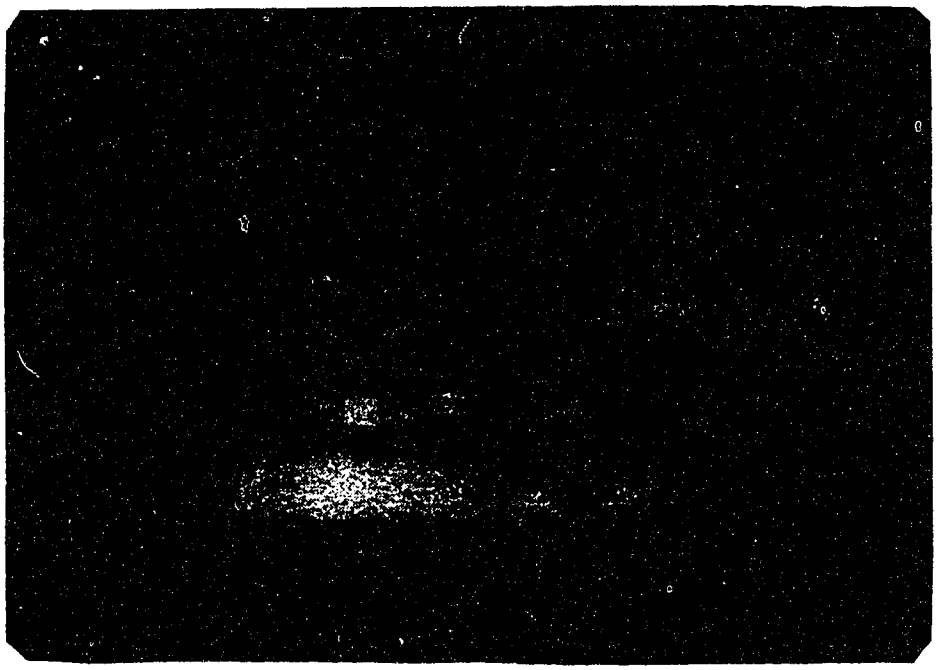


Figure 3.3: Screening of subjects hand during testing

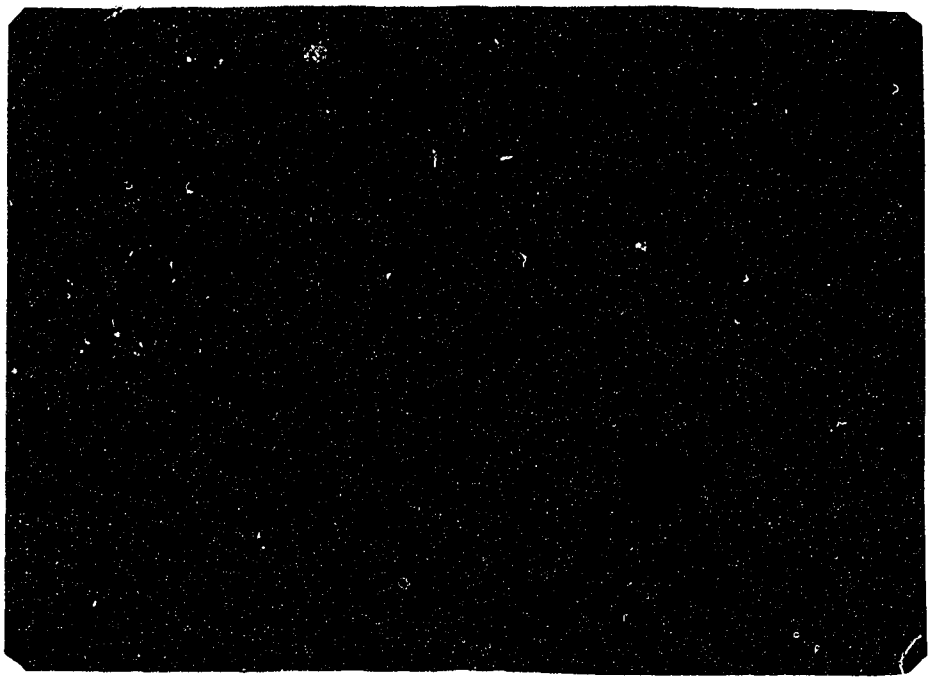


Figure 3.4: Testing with the pressure dolorimeter

Figure 3.6:

Data analysis

Descriptive statistics were computed for the MPQ words chosen, and for the dependent variables: pain threshold and pain tolerance. T-tests were utilised to test for gender differences on each of the pretest pain measures. Pain threshold and pain tolerance were analysed separately using a two way ANOVA (group vs time). Post hoc Neuman Keuls analyses were computed when the ANOVA revealed significant differences ($p < .05$).

Standardised difference scores for pain threshold and tolerance were computed for each subject. The following formula was utilized, with the mean difference score and standard deviation of difference score being that of the total number of subjects (n=40):

$$\text{Standardized score} = \frac{\text{individual diff. score} - \text{mean diff. score}}{\text{standard deviation of diff. score}}$$

(Lovejoy, 1975). A two way analysis of variance (stressor vs group) was then carried out. Post hoc Neuman Keuls analyses were computed when indicated. Pearson product moment correlations were calculated on pain threshold and tolerance measures, in order to examine the relationships between the measures and the methods, after the manner of Campbell and Fiske (1959).

Ethical Considerations

Subjects were informed of the nature of the study verbally by the investigator and were then given a written information sheet (Appendix D). They were given time to read the document and to ask any questions concerning the study procedure. Informed consent was then obtained from those who wished to participate in the study. Subjects were made aware that participation in the study was voluntary, and that they could withdraw at any time without predjudice.

Pain tolerance and pain threshold measures were both necessary because each measure is independent of the other (Harris & Rollman, 1983). Pain threshold is felt to be reflective of afferent physiological functioning whereas pain tolerance is more reflective of the psychosocial aspects of pain. Also, the noxious stimulation was applied only momentarily at pain tolerance level. Both stressors have been used many times and no lasting damage has occurred.

The aim of this study was to determine whether the quality of pain was a dominant factor which influenced the effectiveness of TENS. Thus, a verbal report of pain quality was necessary. This fact precluded the use of animal models.

CHAPTER FOUR

RESULTS

McGill Pain Questionnaire Descriptors

The frequencies of the words chosen from the MPQ at pain threshold are presented in Figure 4.1. The sensation evoked at pain threshold with the dolorimeter was described in terms of being pressing, crushing, dull, hurting, heavy or boring by 35 subjects (78.5%). A total of ten different words were chosen by the subjects, with four categories of descriptors chosen. The sensation evoked at pain threshold by the forceps was described as pinching, tingling, sharp, stabbing, pricking, beating or flickering by 25 subjects (62.5%). A total of 11 different words were chosen by the subjects for this stressor from five categories of descriptors.

The number of words chosen to describe the sensation at pain tolerance increased with both of the stressors (Figure 4.2). Fifteen words were chosen to describe the pain from the dolorimeter with six different categories represented. However, 70% of the words chosen described the pain as dull to heavy or pressing to cramping in quality. Conversely, 18 different words were selected to choose the sensation evoked by the forceps with seven different categories represented. Only seven percent of subjects chose words which were also used to describe the dolorimeter, whereas, 93% of subjects

chose a different constellation of words to describe the stimulation evoked by the forceps.

Gender

A comparison of raw scores at baseline was made in order to determine whether there were any significant gender differences. The t-test results from this analysis showed that male subjects scored significantly higher on all pain measures (Table 4.1). However, there was no difference between males and females in their response to TENS as revealed by t-test on the raw scores.

Pain Threshold

The means and standard deviations of pre- and post-test pain thresholds measured with the dolorimeter (Dthr), are presented in Table 4.2 and Figure 4.3. The two-way ANOVA (group vs time), showed a statistically significant interaction ($p < .05$). Post hoc Newman Keuls analysis revealed that test scores decreased (i.e. more pain) for the control group and increased (i.e. less pain) for the experimental group after treatment.

The means and standard deviations of pain threshold measured with the forceps (Fthr) for each group are presented in Table 4.3 and Figure 4.4. The two-way ANOVA (group vs time), showed no statistically significant main effects or interaction.

Table 4.1

Comparison Men and Women on Pre-test Scores of Pain Threshold and Tolerance

Variable	Mean		t-value	p-value
	male n=20	female n=20		
Dthr	8.58	6.31	2.82	.008*
Dtol	13.33	10.66	2.98	.005*
Fthr	1.71	1.20	3.95	.000*
Ftol	3.53	2.04	3.99	.000*

* significant difference (p <.05)

Abbreviation key:

Dthr - pain threshold measured with the dolorimeter

Dtol - pain tolerance measured with the dolorimeter

Fthr - pain threshold measured with the forc

Ftol - pain tolerance measured with the forceps

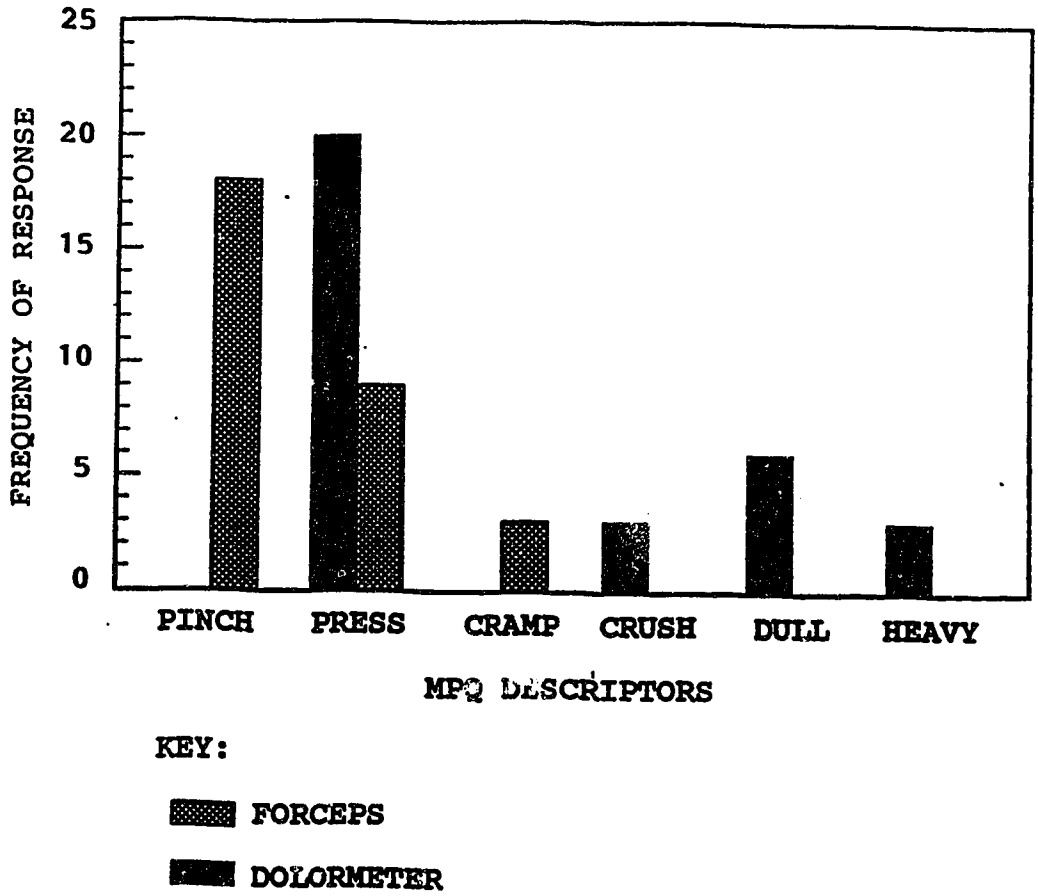


Figure 4.1: Descriptors chosen by more than three subjects at pain threshold

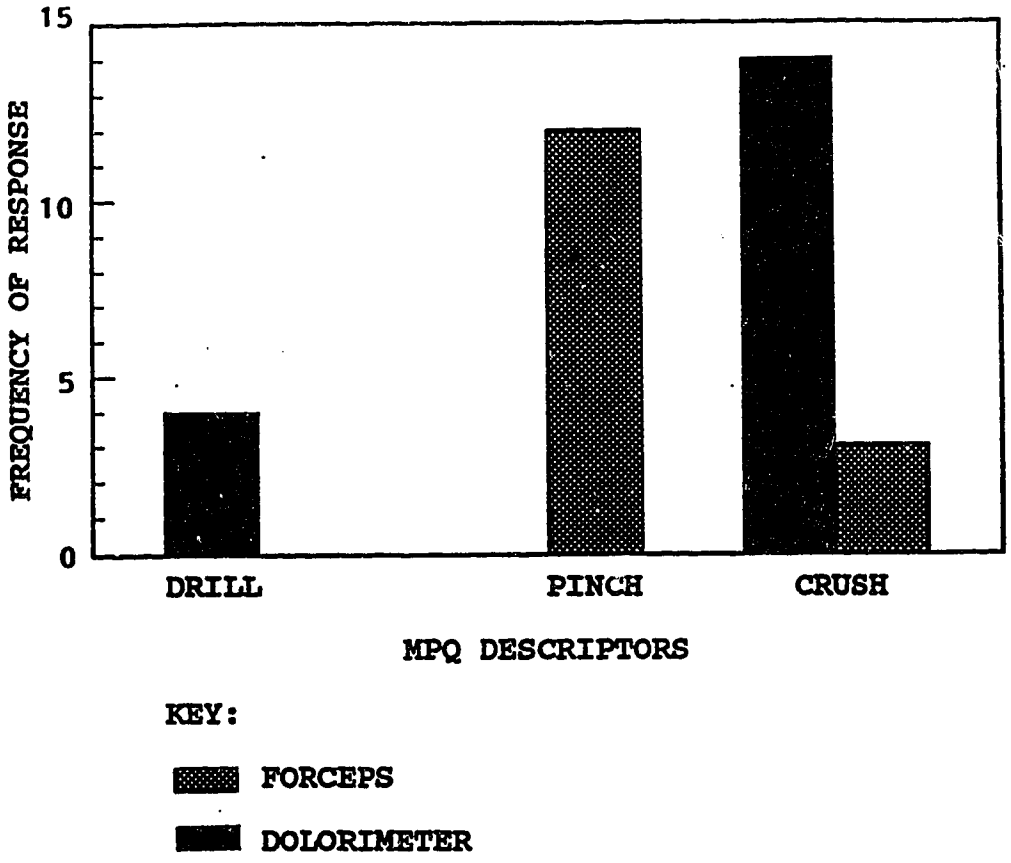


Figure 4.2: Descriptors chosen by more than three subjects at pain tolerance

Descriptive statistics for the standardised difference scores are presented in Table 4.4. A two-way ANOVA revealed a significant group-instrument interaction ($p < .05$). Post hoc analysis showed that there was a significant difference between groups with the dolorimeter only ($p < .05$), but there was no significant difference between the instruments and in the control group. Figure 4.5 illustrates this interaction. All ANOVA summary tables are presented in Appendix G.

Pain Tolerance

The pain tolerance measures obtained in this study are not an accurate reflection of pain tolerance to the two different stressors. This is because an upper limit of mechanical stress was determined a priori for both the dolorimeter and the forceps in order to avoid any tissue damage. Subjects were not advised of this upper limit prior to testing. At pre-test, four subjects (2 control, 2 experimental) did not reach pain tolerance before the upper limit of mechanical stress was reached with the dolorimeter. Thirteen subjects (4 control, 9 experimental) did not reach pain tolerance with the forceps stressor.

Table 4.2

Group Means and Standard Deviations of Raw Scores for Pain Threshold Measured with the Dolorimeter

	Pre test kg/cm^2 Mean (SD)	Post test kg/cm^2 Mean (SD)
Control	7.00 (2.44)	6.33 * (2.11)
Experimental	7.88 (3.06)	9.03 * (3.36)

* significantly different from pre test ($p < .05$)

+ significantly different from control group

Table 4.3

Group means and standard deviations of raw scores for pain threshold measured with the forceps

Group	Pre test $kg/10.6mm^2$ Mean (SD)	Post test $kg/10.6mm^2$ Mean (SD)
Control	1.37	1.47
	(.48)	(.63)
Experimental	1.54	1.61
	(.48)	(.78)

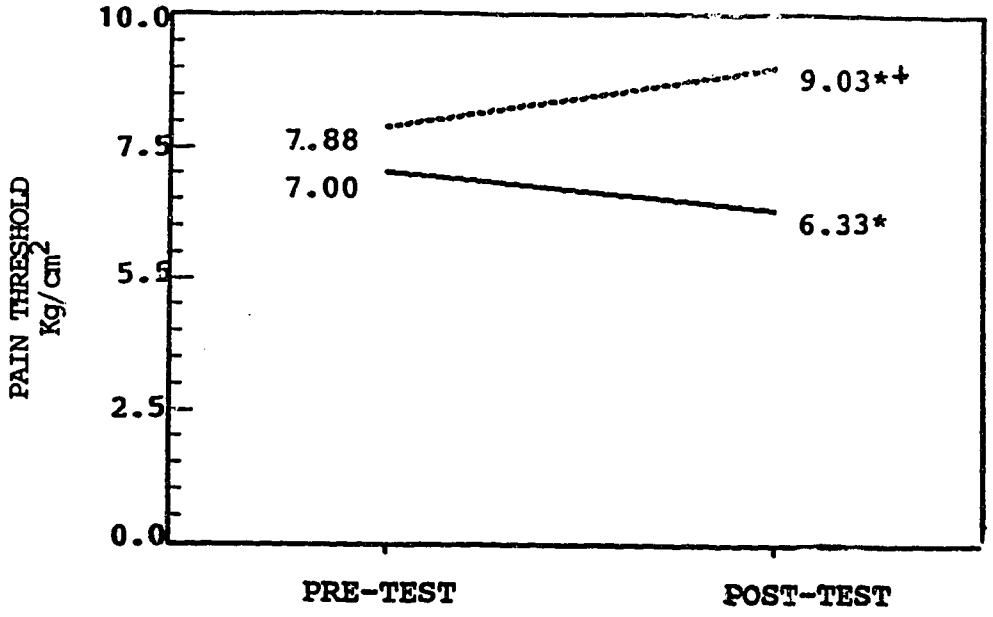
* significant difference ($p < .05$)

Table 4.4

Group means and standard deviations of the standardised difference scores for pain threshold

Instrument	Experimental Mean (SD)	Control Mean (SD)
Dolorimeter	-.28 (.49)*	.28 (.50)
Forceps	.08 (.85)	-.08 (.81)

* significantly different from control ($p < .05$)



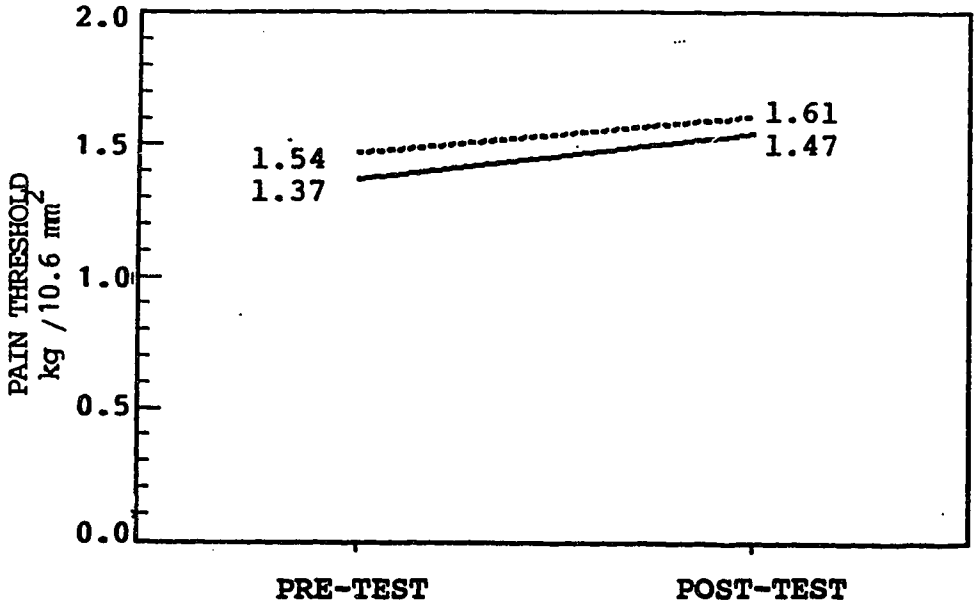
* significantly different from pre-test ($p < .05$)

\+ significantly different from control group

——— EXP = experimental group

—— CONTROL = control group

Figure 4.3: Pre and post test raw scores for each group at pain threshold measured with the dolorimeter

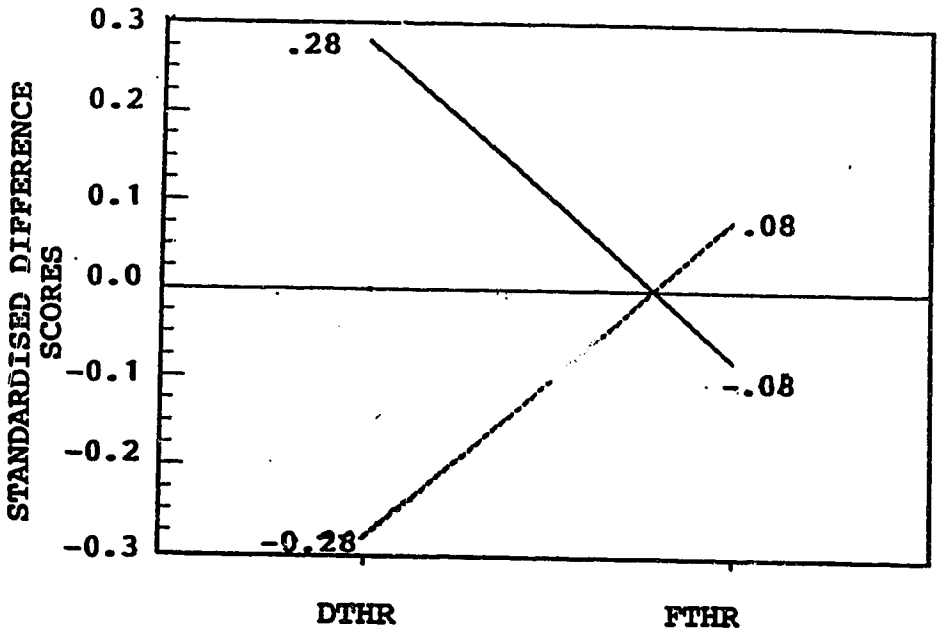


* significant difference ($p < .05$)

_____ EXP. = experimental group

_____ CONTROL = control group

Figure 4.4: Pre and post test raw scores for each group at pain threshold measured with the forceps



EXP. = Experimental group

CONTROL = Control group

DTHR = Pain threshold measured with the dolorimeter

FTHR = Pain threshold measured with the forceps algometer

Figure 4.5: Standardised difference scores for pain threshold with dolorimeter and forceps for each group (negative score = increase in post test measure)

The descriptive data for the pain tolerance measures obtained in this experiment include the data from the subjects not reaching pain tolerance. They are presented in Tables 4.5 and 4.6 and in Figures 4.6 and 4.7.

Despite the limitations of the pain tolerance data, it was submitted to the same analysis as the threshold data. The standardised difference scores are presented in Table 4.7. and Figure 4.8. A two way ANOVA was run but no statistically significant differences were revealed.

Table 4.5

Group means and standard deviations of raw scores for pain tolerance measured with the dolorimeter

Group	Pre test kg/cm^2 Mean (SD)	Post test kg/cm^2 Mean (SD)
Control	11.52	10.80
	(3.10)	(3.26)
Experimental	12.47	12.29
	(3.13)	(3.72)

* significant difference ($p < .05$)

Table 4.6

Group means and standard deviations of raw scores for pain tolerance measured with the forceps

Group	Pre test $kg/10.6mm^2$ Mean (SD)	Post test $kg/10.6mm^2$ Mean (SD)
Control	2.22	2.18
	(.53)	(.55)
Experimental	2.35	2.47
	(.38)	(.39)

* significant difference ($p < .05$)

Table 4.7

Group means and standard deviations of the standardised difference scores for pain tolerance

Instrument	Experimental Mean (SD)	Control Mean (SD)
Dolorimeter	-.06 (.79)	.06 (.54)
Forceps	-.15 (.53)	.15 (.53)

* significant difference ($p < .05$)

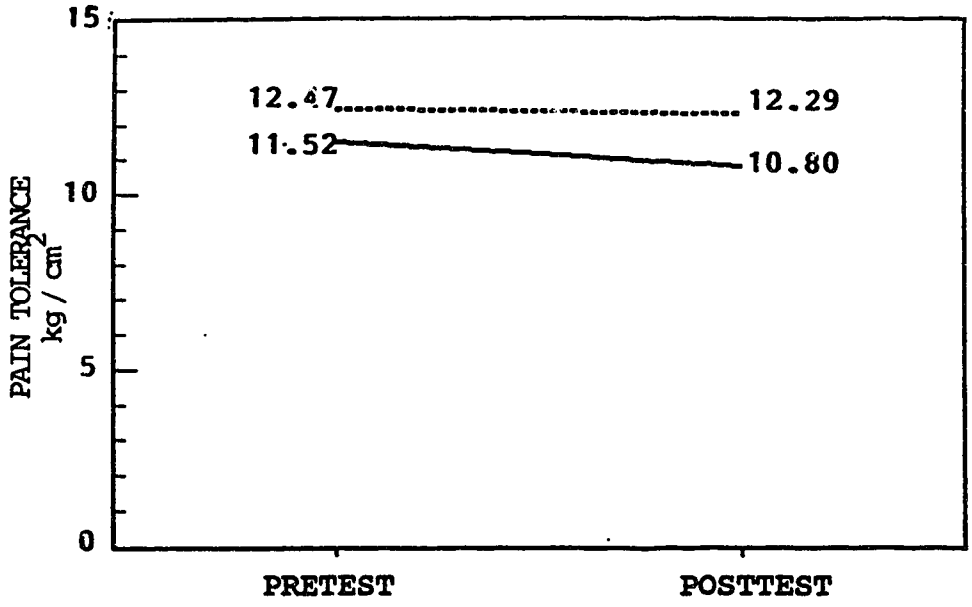
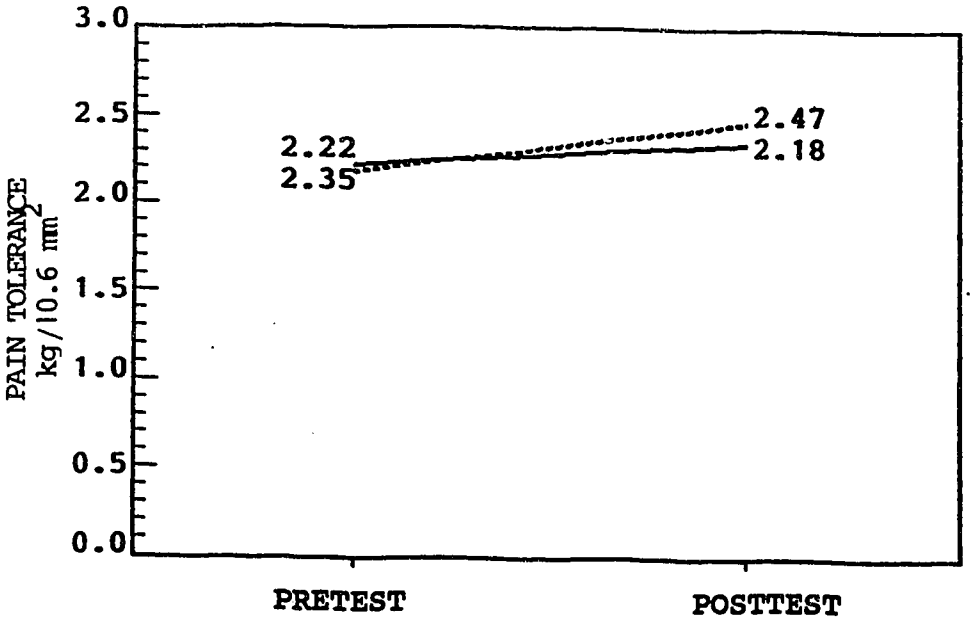


Figure 4.6: Pre and post test raw scores for each group at pain tolerance measured with the dolorimeter



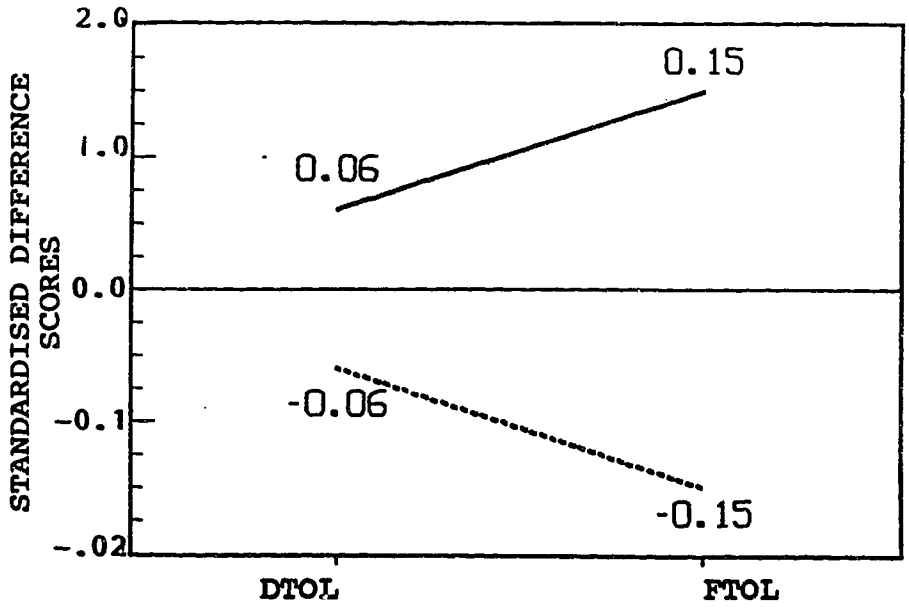
* significant difference ($p < .05$)

Key:

——EXP. = experimental group

—— CONTROL = control group

Figure 4.7: Pre and post test raw scores for each group at pain tolerance measured with the forceps



Key:

------ EXP. = experimental group

—— CONTROL = control group

DTOL = Pain tolerance measured with the dolorimeter

FTOL = pain tolerance measured with the forceps algometer

Figure 4.8: Standardised difference scores for pain tolerance with dolorimeter and forceps for each group (negative score = increase in post test measure)

Summary of pain threshold and tolerance results

The experimental group raw scores illustrate an increase in all post test pain measures except for pain tolerance measured with the dorimeter. However, only pain threshold measured with the dolorimeter is statistically significant. This contrasts to the raw score measures in the control group. The control group showed a decrease for all post-test measures, except for pain threshold measured with the forceps. The reduction in pain threshold and pain tolerance measured with the dolorimeter was statistically significant at the $p < .05$ level.

Correlation of Pain Measures

A Pearson product moment correlation was conducted to analyse the associations of pain threshold and pain tolerance measures, for pre- and post- tests, and between stressors. Table 4.8 presents the correlation matrix and indicates the level of significance between statistically significant correlations. The highest degree of association is between pre- and post- pain threshold or tolerance, measured with the same stressor (e.g. Dthr and Pdthr .84 $p = .001$, and Ftol and Pftol .78 $p = .001$). Conversely, the least correlated measures are between threshold and tolerance levels measured with different stressors (e.g. Dthr Pftol .31 n.s.). Correlations in the middle of these levels are for pain threshold and tolerance measures using the same stressor (e.g

Dthr Dtol .57 p = .01), and for either threshold or tolerance measures using different stressors (e.g. Dthr Fthr .62 p = .01).

Table 4.8

Pearson Product Moment Correlation Matrix for Pain Measures

	Dthr	Dtol	Fthr	Ftol	Pdthr	Pdtol	Pfthr	Pftol
Dthr	1.00							
Dtol	.57**	1.00						
Fthr	.62**	.44*	1.00					
Ftol	.37*	.75**	.47*	1.00				
Pdthr	.84**	.62**	.66**	.45*	1.00			
Pdtol	.52**	.77**	.47*	.67**	.59**	1.00		
Pfthr	.46*	.35	.66**	.48**	.46*	.43*	1.00	
Pftol	.31	.62**	.40*	.78**	.40*	.69**	.48**	1.00

1-tailed significance: * - .01 ** - .001

Abbreviation key:

Dthr = pain threshold with dolorimeter

Dtol = pain tolerance with dolorimeter

Fthr = pain threshold with forceps

Ftol = pain tolerance with forceps

P suffix = post test of the same measure

CHAPTER FIVE

DISCUSSION

The main results indicate that the stressors used in this study evoked a different sensory quality of pain. The results also show that the sensory quality of pain is an important factor which determines the effectiveness of TENS. TENS was effective in raising the pain threshold to dull pain as represented by the dolorimeter, but was ineffective for the sharp pinching pain from the forceps. No conclusions can be drawn with regards to the pain tolerance data due to a ceiling effect.

McGill Pain Questionnaire

The results show that the instruments used in this study elicited two distinctly different sensory qualities of pain. In addition, very few subjects chose words from either the affective or the cognitive domain. These results indicate that the pain experience was primarily sensory.

The lack of affective words chosen to describe the phasic pain evoked in this study is in agreement with the results of Chen and Treede (1985). Using the MPQ, they found that tonic pain had a much greater aversive component than phasic pain.

The use of the dolorimeter and forceps algometer in this study was found to be particularly valuable. The MPQ revealed that the sensory quality of evoked pain was distinct but that

the aversive quality was minimal and similar for each instrument. The quality of evoked pain was also akin to a naturally occurring familiar painful experience.

The size, and the method of application of each instrument was comparable and so the psychological impact of each instrument was similar. This is confirmed by the lack of descriptors chosen from the affective or cognitive domains of the MPQ.

In this study, the MPQ was used to determine that the sensory quality of pain was distinctly different for the stressors. Thus, subjects were limited to the choice of one word to describe the sensory experience. Some subjects spontaneously volunteered a second descriptor after the stressor had been removed. It has been suggested that the first pain is due to a-delta nocioceptive transmission, whereas second pain is due to nocioceptive activity in the higher threshold, slower conducting C-fibres (Price, Hu, Dubner, and Gracely, 1977).

The word choice for pain tolerance shows a much greater variation than that for pain threshold. Although there were still dominant words chosen for each of the stressors, there was a large number of other words selected to describe the primary sensation evoked. This finding was evident with each of the stressors, but the forceps showed a greater variation. Whether this is due to the fact that the sensory quality of pain changes as intensity increases is not clear. Subjects

were not permitted to choose more than one word to describe the sensation, and the spread of word choice may simply be an indication that more words would have been chosen to describe the pain at tolerance if this had been possible.

The rank of the words chosen also increased from pain threshold to pain tolerance. This is expected and is indicative of the validity of the MPQ as a pain assessment tool.

Gender Effect

The results of this study revealed a significant gender effect. Males scored higher than females on all pain measures, and the level of significance was very high. There were also more male subjects reaching the upper limit of the stressors. Thirteen subjects did not reach pain tolerance with the forceps and 11 of these subjects were men. All four of the subjects who ceilinged with the dolorimeter at pain tolerance were men. This data is in agreement with other investigators who have reported significantly higher pain values in men (Fischer, 1986; Otto and Dougher, 1985).

The high tolerance values for men has posed problems for researchers, as it is difficult to obtain a true measure of pain tolerance, without causing tissue damage. One group of investigators studying pain tolerance to noxious heat and cold, stated that they only studied pain tolerance in females,

because their preliminary work suggested that too many male subjects would ceiling (Davidson and McDougall 1969).

Despite the significant differences between pain measures of males and females, the gender of the subjects did not affect the results obtained by TENS. No significant difference was present between males and females in their response to TENS.

Pain Threshold

Pain threshold is felt to be more reflective of physiological rather than psychological functioning. The primary effect of TENS is also felt to be based on neurophysiological function. Therefore it is reasonable to expect a change in pain threshold following TENS. However, the findings of this study indicate that it depends upon how pain threshold is measured, as to whether TENS will effect a change in this measurement.

The significant interactions revealed by the two way ANOVA's indicate that it was the particular combination of group and instrument that was significant (Blalock, 1979). TENS was effective in raising the pain threshold to dull pressing pain, but it did not raise the pain threshold to sharp pinching pain.

The data from the main study also confirm the trends, that were indicated in the pilot study i.e. TENS was most effective for increasing the threshold to dull pain, whilst

having no significant effect on sharp pain. This point is important to note as it does provide credibility to the pilot study.

The results from the study are at variance with those of Woolf (1979), and Nathan and Rudge (1974) but their sample sizes of eight and five respectively, were too small to show statistically significant changes. They also evoked sharp pain by mechanical means, and the present study found that TENS did not modulate this quality of pain on the hand. Jette (1986), and Barr et al (1986), both reported that TENS did not increase pain threshold to electrically evoked pain. In the latter study, TENS was only applied for four minutes: this may not have been an adequate stimulation period. Preliminary testing for the pilot study revealed that post-test pain threshold measured after two minutes of TENS did show a minimal increase. However, a greater increase in pain threshold occurred after ten minutes of TENS, and a further increase occurred after 20 minutes of TENS. This phenomenon may be due to facilitation of the afferent pathways by TENS, or due to an increase in the TENS intensity every five minutes.

Fourteen subjects participated in the study by Jette (1986). This sample size may not be large enough to show any statistically significant effects. Jette also completed post test measures after the TENS was terminated. This may have

affected the results as high frequency TENS does not have much carry-over of effect.

Both of these investigators used electrical stimulation to induce pain. The simultaneous use of electrical stimulation as a pain stressor and a pain modulator may be problematic. As noted earlier, the target afferent nerve fibres are different for each of the stimulators but the thresholds of individual fibres may be a function of individual "set" and of depth. In general nerve fibres which are larger in diameter and more superficial will have a lower threshold than smaller and deeper nerve fibres (Benton, Baker, Bowman, and Waters, 1981). Thus, it is unlikely that TENS will depolorize small nocioceptive afferents as their threshold is high. However, it is likely that the electrical stressor will depolorize non nocioceptive afferents as well as the target nocioceptive afferents. The ramifications of this are not really clear at this point.

Finally, both Wolf and Nathan induced pain on the hand and electrically induced pain is perceived to be a sharp, piercing pain (Chen and Treede, 1985). This quality of pain even when mechanically induced, was not found to be modulated well by TENS in the present study. Therefore, it is likely that larger sample sizes, and simultaneous testing of pain with TENS would not have made a difference to their results.

In summary it can be seen that TENS has a differential effect on pain threshold, a difference which is based on the

sensory quality of the evoked pain. The effect of TENS is to raise the pain threshold of dull pain, but to have no effect on the pain threshold of sharp pain.

Pain Tolerance

The results from the two way ANOVA's for pain tolerance showed no statistically significant effects. Several reasons account for these results.

The primary problem with the testing of pain tolerance is that of the ceiling effect. The upper limit of stress was set conservatively in order to avoid any possibility of tissue damage. The degree of increase of post test scores therefore is not known, and so no conclusions can be drawn from the results.

The pilot study did not suffer from the constraints of a ceiling effect. All the pain measures were lower than in the main study, for two possible reasons. The first, is that there were a disproportionate number of females in the pilot study. Of the 20 tests completed, only two were completed on males. This contrasts to the main study in which 20 males and 20 females participated. The second reason, for the lower values in the pilot study was the test location. All pain measures tended to be lower on the arm than on the hand, and this served to lower the group mean scores in the pilot study.

The differential sensitivity of specific body locations has been reported in the literature (Lynn and Perl, 1977).

This was confirmed by the pilot data. It suggests that the more sensitive body locations would be more useful for the testing of pain tolerance, especially if males are to be tested.

The data from the hand differs from that reported by Fischer (1986). He reported lower tolerance values on the hand - over bone, than in the arm - over muscle. However, it appears that Fischer may have tested over the "knuckle" or joint rather than over the midshaft of the phalanx or metacarpal. Joint stress did not occur during the data collection for this study, so that the measurement obtained was one of bone pain rather than joint pain. The pain tolerance data for muscle on the forearm (mean = 9.79 $kg.cm^2$) is similar to that presented by Fischer. He reported average pain tolerance values of 9.5 and 10.2 $kg.cm^2$, for supraspinatus and deltoid respectively.

The results from the pilot study do not suffer from the ceiling effect. However, caution must be used in the interpretation of the results as, no control group was utilised, subjects were not naive to TENS, and investigator bias cannot be ruled out.

In the pilot study, TENS was found to significantly increase pain tolerance to the forceps when measured on the arm ($p < .05$), but it had no effect at all on the hand. This may be due to the higher sensitivity on the arm, so that there is a potential for a greater increase in the post test scores.

It could also be due to the lower intensity of TENS which was used in the forearm. The use of a lower intensity of TENS was necessary in order to limit motor activity. Although a high intensity of TENS is generally more effective in raising pain tolerance and threshold levels (Janko and Trontelj, 1980), there has been some suggestion that subthreshold levels of TENS are also effective (Barr, Neilson and Soderberg, 1986).

The dolorimeter measures showed an increase in raw scores on both the hand and the arm, but the increase in post test scores was not significant for either location. However, this increase did become statistically significant when the total limb data was analysed (n = 20). Thus there may be a differential effect of TENS which is dependent on the quality of pain, as post-test pain tolerance values increased when measured with both instruments. However, the location of testing is important, and the intensity of TENS utilised may also be a factor for consideration.

The results of the pain tolerance tests from the pilot study are somewhat different from those of the main study. But these differences explain some of the findings reported by other investigators. For example, Woolf (1979) and Nathan and Rudge (1974), reported that TENS had no significant effect on pain tolerance to mechanical stimulation. However the sample sizes for each study were eight and five respectively. These are not large enough sample sizes to show significance with changes of this magnitude.

Also, it appears from the description of the instrument used by Woolf (Russel and Tate, 1975), that the sensation evoked was probably sharp in quality, and was used on the hand. The results from the present study show that sharp pain on the hand was not modulated effectively by TENS.

The proximity of the electrodes to the test location and the intensity of TENS may influence the efficacy of this modality. It has been reported that local electrode placements have the best effect in terms of increasing pain threshold and pain tolerance (Andersson, Ericson, Holmgren and Lindquist 1977; Andersson and Holmgren, 1978). In the present study, the electrodes were placed either side of the test location, so that a parasthetic sensation was perceived in the area.

It is difficult to determine the actual electrode placements used by Woolf (1979). But it appears that they may have been on the arm rather than the hand, and Wolff measured pain threshold and tolerance on the fingers. Nathan and Rudge (1974), applied TENS to the arm, whilst testing pain threshold and tolerance on the fingers.

A high intensity of TENS has had the best effect in terms of increasing pain threshold and pain tolerance (Andersson, Ericson, Holmgren and Lindquist 1977; Andersson and Holmgren, 1978; Woolf, 1979), but subthreshold intensities have also been effective for increasing pain tolerance (Barr, Neilson and Soderberg, 1986).

In the present study a strong but comfortable parasthesia was induced on the hand, but only a weak parasthesia could be utilised on the arm. It is possible that intense dull pain is most effectively modulated by a relatively strong intensity of TENS, whereas intense sharp pain is more effectively modulated with a lower intensity of TENS.

The hypotheses of this study in regards to pain tolerance were firstly, that TENS would increase the pain tolerance measure to each stressor, and secondly, that there would be a differential effect of TENS. No conclusions can be made based on the data from the main study, as the pain tolerance data was compromised by ceiling effects. The pilot data should be interpreted cautiously, but it seems to suggest that both hypotheses were correct. However, controlled pain tolerance tests need to be repeated with either females only, or over a more sensitive area than the hand. It would also be interesting to determine whether sharp and dull pains respond in a differential manner to different intensities or different modes of TENS.

Correlations

Correlations were computed in order to determine that there was generality but also discriminant validity across pain measures as suggested by Harris and Rollman (1983). High correlations were revealed on most pain measures. The highest correlations were between thresholds or tolerances to each

instrument, and the lowest were between pain threshold and pain tolerance measured with different instruments. High correlations were also present between pre and post test on the same measure.

The reason for such high correlations is probably due to the similarity of stressors in terms of their psychophysical properties. Both stressors evoke mechanical pain which does not increase monotonically, and provide a familiar painful stimulus. This contrasts to electrically induced pain which is unfamiliar to many subjects and where the perceived magnitude of pain increases as a power function of current.

The high correlations across pain measures indicate that there is generality across the pain measures of threshold and of tolerance, when measured with either instrument. The lower correlation between the measures of threshold and tolerance, and the even lower correlations between measures and across stressors are an indication of discriminant validity.

Clinical Relevance

This experiment was undertaken with the use of experimentally induced pain, and it was determined that TENS had a differential effect, on different qualities of pain. The results confirm clinical anecdotal evidence which suggests that the quality of pain is a factor that determines the effectiveness of TENS.

The results indicate that conventional TENS, as applied in this study, was most effective for reducing dull pain. These findings make intuitive sense. Bright sharp superficial pain such as occurs after a sunburn is mechanosensitive (allodynia), i.e. non-noxious stimuli such as light touch may then be perceived as painful. TENS depolorizes large primary afferent nerves such as those that transmit light touch information. Thus the same mechanism that causes noxious mechanosensitivity may lead to the aggravation of sharp pain by TENS. Normally TENS should evoke a strong but comfortable sensation, but this is sometimes perceived as uncomfortable over sharply painful areas.

Dull pains are often alleviated by rubbing or massaging the painful area. This generates activity in the large primary afferent nerve fibres, an activity which limits the transmission of small nocioceptive fibre activity. By using this same analgesic mechanism, TENS can be applied strongly and effectively over the painful area.

Several questions now need to be addressed. The primary question concerns whether pain quality is predictive of the effectiveness of TENS in the clinical pain population. Anecdotal evidence suggests that this is the case.

Why there is such a differential effect and why TENS does not tend to work well for sharp pain is not clear at this point. The particular method of application and the TENS parameters used may improve its effectiveness. The question

of whether TENS should be applied in a differential manner that is specific to the quality of pain being experienced, remains unanswered.

It would now be useful to repeat this experiment in a clinical population. This would help to clarify the relationship between experimentally induced and clinical pain, and make it clearer whether the results from this study can be generalised to clinical pain. If the findings from this study are replicated in a clinical population, it would be useful to determine whether different applications and modes of TENS can be most beneficially applied to different qualities of pain.

It also seems likely that if the sensory quality of pain is a factor that affects the effectiveness of TENS it is also a factor in many other pain management techniques.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

The purpose of this study was to establish if the sensory quality of pain was a factor in determining the effectiveness of TENS. Two distinct qualities of pain were induced experimentally using a forceps algometer and a dolorimeter. Reliability of the forceps algometer was established in a pilot study using eleven subjects.

Forty subjects (20 female, 20 male) participated in the main study. They were randomly assigned to the treatment or control groups and there were an equal number of males and females in each group. Pre-test measures of pain threshold and pain tolerance were taken and subjects chose a descriptor from the sensory domain of the MPQ to describe the pain experience. Conventional or sham TENS was applied for 20 minutes and post-test measures were taken whilst the TENS was stimulating.

The data was analysed using a two-way ANOVA (group vs time) with raw scores, and a two-way ANOVA (group vs instrument) using standardised difference scores. Post hoc analysis used the Newman Keuls test. Pearson product moment correlations were computed to assess the relationship between pain measures. The probability level for all tests was $p \leq .05$.

The following conclusions can be drawn based on the results of the present study:

1. The forceps algometer was a reliable instrument and evoked a pain sensation that was described as a sharp pinching.
2. The dolorimeter evoked a pain sensation that was described as a dull pressure.
3. Males had significantly higher values than females on all pain stressor measures.
4. Conventional TENS significantly increased the pain threshold to dull pressure.
5. A significant decrease in the pain threshold to dull pressure was found in the control group.
6. Conventional TENS had no effect on sharp pinching pain.
7. Pain threshold measured with the dolorimeter was highly correlated to pain threshold measured with the forceps. The same high correlation was present for pain tolerance measures.
8. Relatively low correlations were found between measures of pain threshold and pain tolerance.

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APPENDIX A

McGILL PAIN QUESTIONNAIRE

DESCRIPTORS

MPQ DESCRIPTORS

Choose ONE word from categories 1 - 10 which best describes the sensation experienced.

1. Flickering Quivering Pulsing Throbbing Beating Pounding	2. Jumping Flashing Shooting	3. Pricking Boring Drilling Stabbing Lancinating	4. Sharp Cutting Lacerating
5. Pinching Pressing Gnawing Cramping Crushing	6. Tugging Pulling Wrenching	7. Hot Burning Scalding Searing	8. Tingling Itchy Smarting Stinging
9. Dull Sore Hurting Aching Heavy	10. Tender Taut Rasping Splitting		

You MAY choose ANY words from the following categories if they describe the sensation experienced.

11. Tiring Exhausting	12. Sickening Suffocating	13. Fearful Frightful Terrifying	14. Punishing Gruelling Cruel

15. Wretched
    Vicious
    Blinding
    Killing

You MAY choose ANY words from the following categories if they describe the sensation experienced.

16. Annoying
    Troublesome
    Miserable
    Intense
    Unbearable

You MAY choose ANY words from the following categories if they describe the sensation experienced.

17. Spreading
    Radiating
    Penetrating
    Piercing

18. Tight
    Numb
    Drawing
    Squeezing
    Tearing

19. Cool
    Cold
    Freezing

20. Nagging
    Nauseating
    Agonizing
    Dreadful
    Torturing

APPENDIX B

RAW DATA FROM FORCEPS

RELIABILITY TEST

Table A.1

Raw data from pilot reliability study for the rate of application of the forceps stressor

Subject	Rate of application of stressor	
	Test 1	Test 2
	Degrees	Degrees
01	105	105
02	105	105
03	110	110
04	106	105
05	105	103
06	110	111
07	107	108
08	109	110
09	103	103
10	104	100

APPENDIX C

INTERNATIONAL ASSOCIATION FOR THE STUDY OF PAIN

PAIN DEFINITION

PAIN DEFINITION

The IASP definition of pain is accepted as a working definition by most pain specialists (Fenerstein, 1989). The full form of this definition and its accompanying note is as follows.

> Pain is: "An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage.

Note: Pain is always subjective. Each individual learns the application of the word through experience related to injury in early life. Biologists recognize that those stimuli which cause pain are liable to tissue damage. Accordingly, pain is that experience which we associate with actual or potential tissue damage. It is unquestionably a sensation in a part or parts of the body, but it is also always unpleasant and therefore always an emotional experience. Experiences which resemble pain, e.g. pricking, but are not unpleasant should not be called pain. Unpleasant abnormal experiences (dysthesiae) may also be pain but are not necessarily so because, subjectively, they may not have the usual sensory qualities of pain.

Many people report pain in the absence of tissue damage or any likely pathophysiological cause; usually this happens for psychological reasons. There is usually no way to distinguish their experience from that due to tissue damage if we take the subjective report. If they regard their

experience as pain and if they report it in the same ways as pain caused by tissue damage, it should be accepted as pain. This definition avoids tying pain to the stimulus. Activity induced in the nocioceptor and nocioceptive pathways by a noxious stimulus is not pain, which is always a psychological state, even though we may well appreciate that pain most often has a proximate physical cause."

Taxonomy Committee of the International Association for the Study of Pain (Merskey, 1979).

APPENDIX D

CONSENT FORM

CONSENT FORM

THE EFFECTIVENESS OF TENS ON DIFFERENT QUALITIES OF EXPERIMENTAL PAIN

I, _____, freely and voluntarily consent to participate in a study conducted by Maureen Simmonds, graduate student in Physical Therapy.

I understand that transcutaneous electrical nerve stimulation (TENS) is a mode of treatment frequently used by physical therapists to relieve pain. At the present time it is not known whether the quality of the pain experienced affects the amount of pain relief obtained by TENS.

I understand that the purpose of this study is to test the effectiveness of different intensities of TENS on two different qualities of pain.

I have been informed that pain will be induced by pressure and pinch on my hand. I will be asked by the investigator to state at which point the pressure or pinch stimulation first becomes painful (pain threshold), and when I wish to terminate the stimulus (pain tolerance). At this latter point the stimulation will stop immediately. I will be given a list of adjectives from which I choose the word or words which describe the pain I experienced. Finally, TENS will be applied to my hand, and pain threshold and tolerance measures will be repeated.

I understand that an indentation mark may occur on my skin. This mark should soon disappear, and the risk of tissue damage is very small.

I understand that access to records obtained during this study will be limited to those individuals associated with the research. To ensure confidentiality, subjects and their records will be identified by number. The code sheet which lists the number assigned to each subject, will be accessed by the principal investigator only.

I understand that I may decline to enter or may withdraw from this study at any time without predjudice. I have been given the opportunity to ask questions about the study and these have been answered to my satisfaction. I understand that I may ask further questions at any time by calling the investigator Maureen Simmonds at 492-2068 or 892-3000. I understand that I may also call Maureen Simmond's advisors: Dr. Jean Wessel at 492-2988 or Dr. Roger Scudds at 492-7378, if I have questions regarding the study. I understand what is required and acknowledge receipt of a copy of this form.

Subject_____ Date_____

Witness_____ Date_____

Investigator_____ Date_____

APPENDIX E

PILOT STUDY RESULTS

PILOT STUDY

The pilot study was primarily carried out in order to determine that the forceps stressor was a valid and reliable instrument, that it evoked a different sensation of pain than the dolorimeter, and that neither instrument was likely to cause any tissue damage. It was also necessary to determine that the instrument could be applied by the tester in a consistent manner. That post test measures could be taken whilst the TENS was stimulating, without the tester being made aware of the group to which the subject belonged. Two body locations were tested - one (over bone) was on the dorsal and medial aspect of the hand at the mid - metacarpal level, the second (over muscle) was located around the middle of the proximal third of the forearm on the dorso-lateral aspect.

Instrument Reliability

The forceps stressor was calibrated by means of a strain gauge. The applied weight stress was converted into microvolts which were recorded with an analogue meter and a chart recorder. The instrument was then tested by the application of different amounts of pressure applied at differing rates. The instrument was tested on the primary investigator to ensure that there was a distinct point at which the sensation became painful, and that tissue damage was unlikely at the pain tolerance level. Calibration was

rechecked prior to its use on subjects and was found to be accurate.

Further testing of the instrument was carried out in order to test the two stressors. This test consisted of applying each of the instruments in turn to six consenting subjects. The subjects were asked to choose the descriptors from the MPQ which described the sensation that was evoked at pain threshold and pain tolerance with each of the instruments. The results indicated that the stressors evoked a different sensation which could be measured by the MPQ.

Intratester Reliability

Intratester reliability for the rate of application was determined by using the angle of slope from the chart recorder output, which measured the rate of applied pressure from the instrument (Figure A.1). The angles from the last [illegible] of tests were measured with a protractor. The mean [illegible] was 106.4 degrees with a standard deviation of 2.5, and [illegible] mean of Test 2 was 106 degrees with a standard deviation of 3.6. Test retest reliability of the rate of application was determined using a Pearsons product moment correlation coefficient. The result of the correlation coefficient was $r = .9316$.

Subjects.

Twelve subjects participated in the pilot study and all signed an informed consent. One subject was tested on the arm only, and ten subjects were tested on two locations. The two tests were carried out on contralateral limbs and separated by at least 24 hours. The age range of the subjects was between 23 and 43. Two subjects were male and ten were female.

The data from the hand of one subject was excluded from the analysis as the tolerance measure was much less than that of threshold which indicated that the test was inaccurate. The number of data sets subjected to statistical analysis was ten for the hand and ten for the arm. The raw data for the pilot study are presented in Appendix B.

Methodology.

The purpose of the pilot study was explained to the subjects and informed consent was obtained. The hand was tested first on all subjects who were given the choice of side to be tested. The order of stressor was alternated. A pre test measure of pain threshold was taken and the subject was asked to choose one word from the MPQ which best described the sensation experienced, the same procedure was then carried out for the tolerance measure. Electrodes were then applied to the skin three to four inches apart, and proximal and distal to the area under test. TENS was applied

at a strong but comfortable intensity for twenty minutes, subjects were questioned on the perceived intensity every five minutes and adjustments were made if necessary to maintain the strong but comfortable level of stimulation. After twenty minutes of TENS stimulation, post test measures with descriptor selection were taken in the same manner as for pre test measures. No control group was included in the pilot study.

Results.

Data was analysed for the limb group (n=20), and also, the data from the arm and the hand were analysed. Descriptive statistics were calculated for pre and post pain threshold and tolerance measures with each of the two stressors, and for the MPQ words chosen. Paired students t-tests were conducted to determine whether there were statistically significant differences between pre and post test measures of pain threshold and pain tolerance. Table A.1 presents the limb group data. Means and standard deviations of pre and post test pain measures obtained with each instrument are presented along with the results from students t-tests and their significance level. Tables A.2 and A.3 present the data from the hand and arm respectively.

The results show that both threshold and tolerance measures are lower on the arm compared to the hand.

A predetermined upper limit of mechanical stress was set for each stressor in order to prevent tissue damage. The upper limit for the dolorimeter is 17 $kg.cm^2$., and the upper limit for the forceps was set at 2.7 $kg.10.6mm^2$. This limit led to some subjects not reaching pain tolerance levels. One subject did not reach pre test pain tolerance with either device and this occurred for both test sites. Four subjects did not reach pre test pain tolerance on the hand when measured with the forceps. Post test pain tolerances with the dolorimeter were not obtained for two subjects when tested on the arm. Post test pain tolerances were not obtained for six subjects on the hand.

The results of the t-tests for limb group pre post test scores show a significant difference for pain threshold ($p < .001$) and pain tolerance scores ($p < .05$) when measured with the dolorimeter. The results from the hand show a significant difference for pain threshold when measured with the dolorimeter ($p < .05$), and the results for the arm show a more significant change ($p < .005$) for the same measure. Pain tolerance changes on the arm when measured with the forceps achieved a statistically significant increase ($p < .05$).

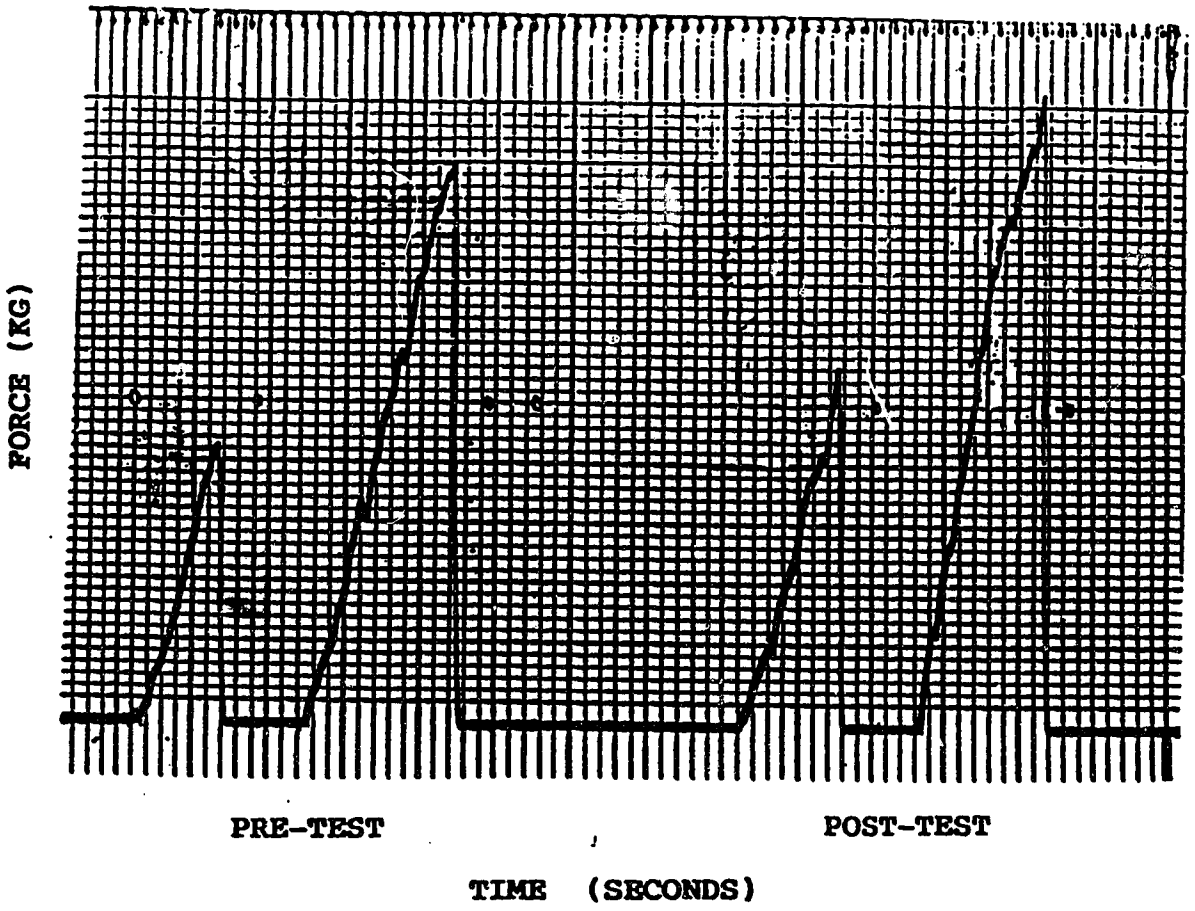

Figure A.1: Chart recorder output for forceps algometer.

The MPQ adjectives chosen to describe pain threshold and pain tolerance with each of the stressors are presented in Figure A.2 to A.5. Subjects chose a distinctly different set of words to describe the sensation evoked by each stressor. Fifty five percent (11 subjects) described the dolorimeter as dull to heavy in quality, and 15% (3 subjects) described the sensation as pressing. On the other hand, 50% (10 subjects) described the sensation evoked by the forceps at pain threshold to be pinching, and 40% (8 subjects) described it as sharp to cutting. The results indicate that the instruments do evoke a different sensory quality of pain.

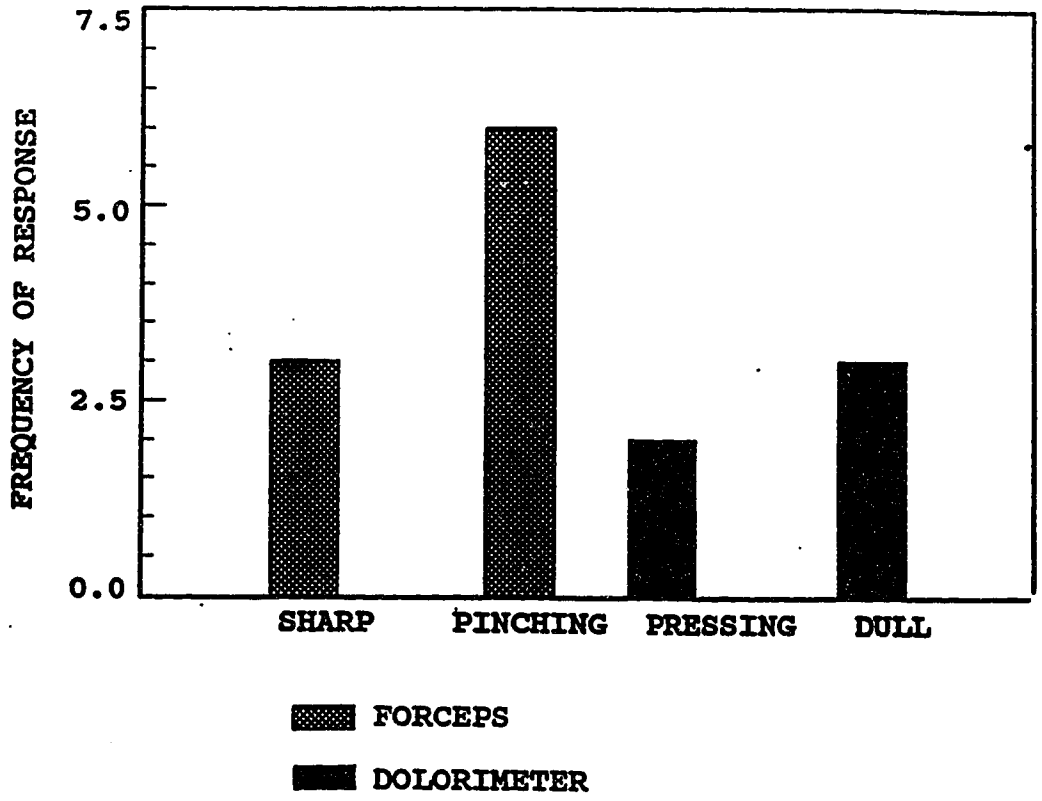

Figure A.2: MPQ words chosen by more than one subject to describe the sensation at pain threshold on the hand.

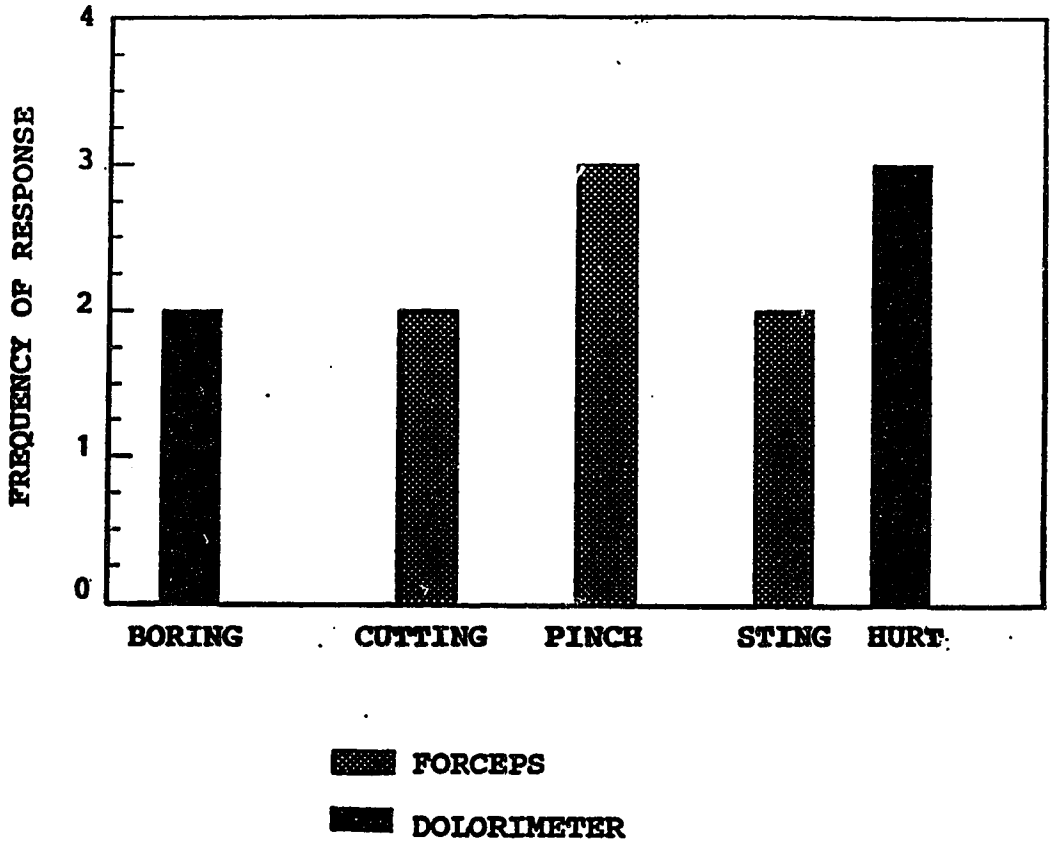

Figure A.3: MPQ words chosen by more than one subject to describe the sensation at pain tolerance on the hand.

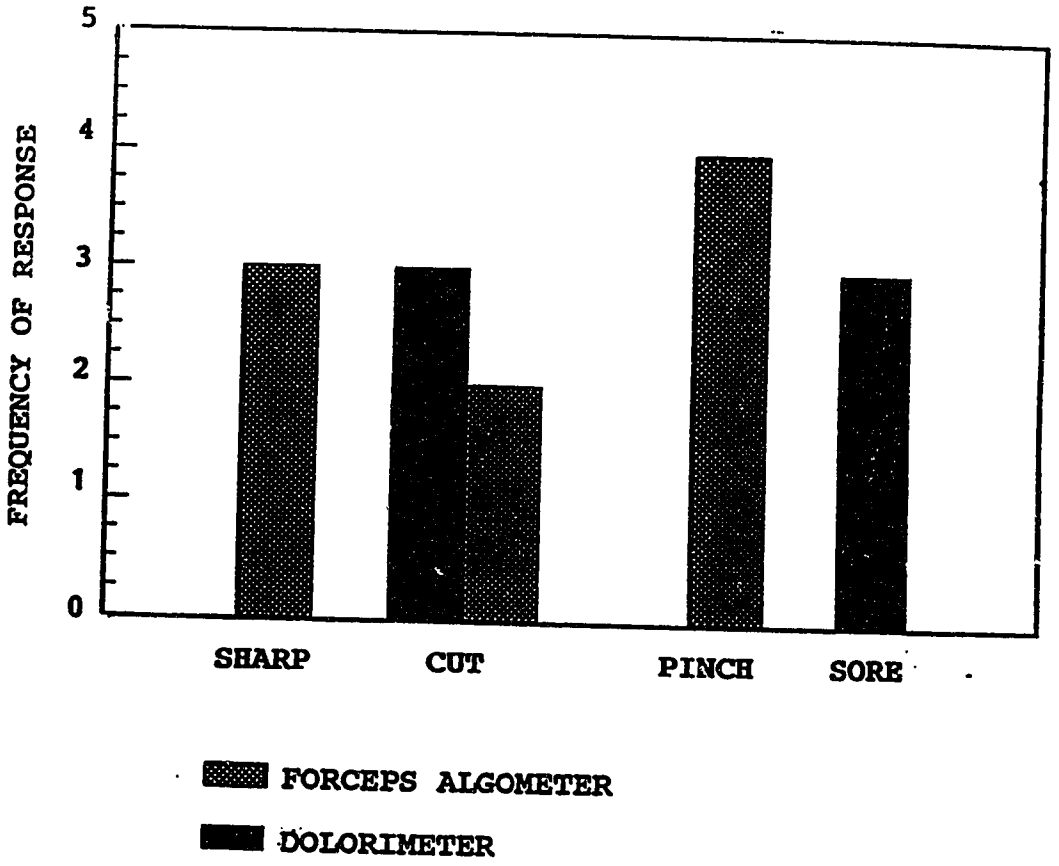

Figure A.4: MPQ words chosen by more than one subject to describe the sensation at pain threshold on the arm.

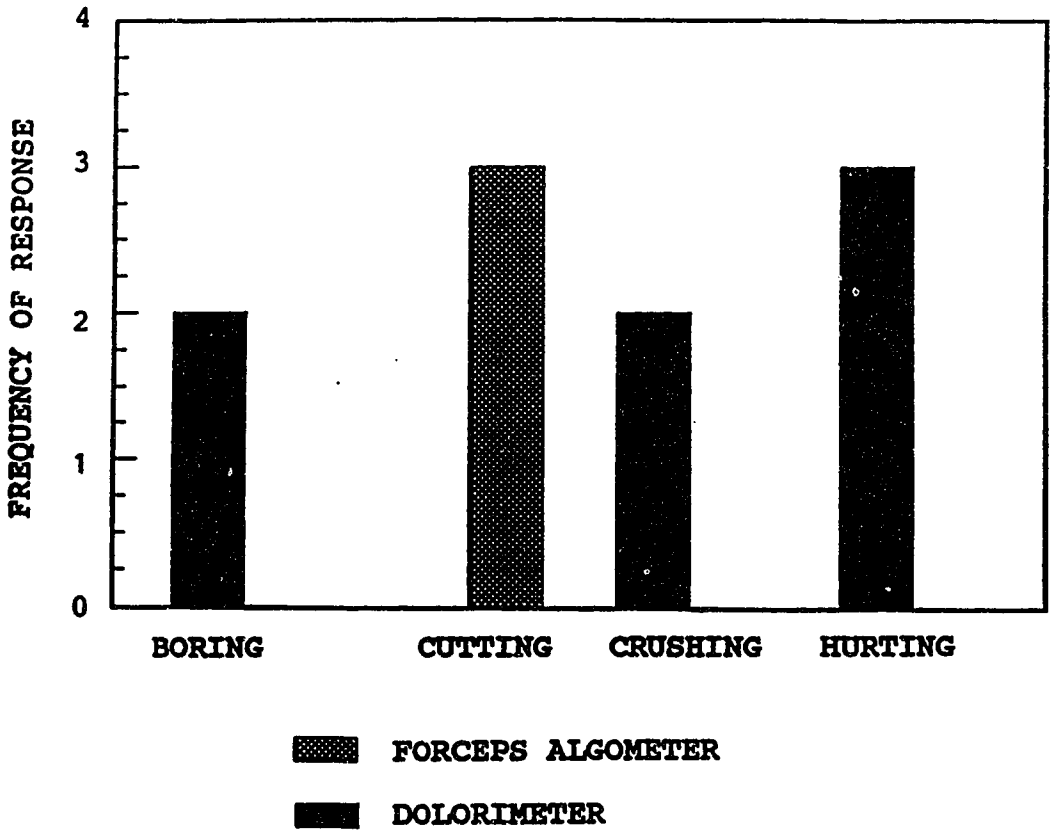

Figure A.5: MPQ words chosen by more than one subject to describe the sensation at pain tolerance on the arm.

Table A.1

Pain threshold and tolerance measures on the limb before and after the application of TENS (N=20).

Variable	Pre-test Mean(SD)	Post-test Mean(SD)	p-value
DThr	4.39 (1.78)	5.68 (2.212)	.001**
DTol	10.36 (3.851)	12.05 (3.468)	.05 *
FThr	1.16 (.410)	1.29 (.513)	.171
FTol	2.25 (.635)	2.37 (.558)	.237

* significant difference ($p < .05$)

** significant difference ($p < .001$)

Abbreviation key:

DThr = Pain threshold with dolorimeter

DTol = Pain tolerance with dolorimeter

FThr = Pain threshold with forceps

FTol = Pain tolerance with forceps

Table A.3

Pain threshold and tolerance measures on the hand before and after the application of TENS (N=10).

Variable	Pre-test Mean(SD)	Post-test Mean(SD)	p-value
DThr	4.85 (1.642)	6.44 (1.913)	.05*
DTol	10.93 (3.508)	12.42 (3.586)	.137
FThr	1.42 (.231)	1.60 (.507)	.186
FTol	2.66 (.441)	2.66 (.519)	.980

* significant difference ($p < .05$)

Abbreviation key:

DThr = Pain threshold with dolorimeter

DTol = Pain tolerance with dolorimeter

FThr = Pain threshold with forceps

FTol = Pain tolerance with forceps

Table A.4:

Pain threshold and tolerance measures on the arm before and after the application of TENS (N=10).

Variable	Pre-test Mean(SD)	Post-test Mean(SD)	p-value
DThr	3.93 (1.880)	4.91 (2.319)	.01 **
DTol	9.79 (4.274)	11.68 (3.498)	.112
FThr	.89 (.377)	.98 (.287)	.529
FTol	1.85 (.539)	2.07 (.443)	.05*

** significant difference ($p < .01$)

* significant difference ($p < .05$)

Abbreviation key:

DThr = Pain threshold with dolorimeter

DTol = Pain tolerance with dolorimeter

FThr = Pain threshold with forceps

FTol = Pain tolerance with forceps

APPENDIX F

TENS EQUIPMENT INFORMATION

TENS INFORMATION

The TENS unit was an Eclipse Model No.7723, Medtronic Inc., Neuro Division, 6951 Central Avenue, NE, PO Box 1250, Minneapolis, Minn 55440.

The electrical parameters for conventional TENS were:

Pulse rate - 80 Hz

Pulse width - 125 usecs

Intensity - sufficient to cause a strong but comfortable parasthesia

Electrodes:

- Tenzcare 6860, 53 mm x 34 mm, 3M Canada, London, Ontario.

Suppliers:	TENS unit	Electrodes
	Electromed Services,	3M Canada,
	Edmonton, Alberta	London, Ontario

APPENDIX G

ANOVA SUMMARY TABLES

Summary of 2 way ANOVA, for standardised difference scores at pain tolerance. Group vs instrument (df 1,38)

Part of model	F-ratio	Probability
Instrument	.12E-5	p = .99
Group	1.44	p = .24
Group x Instrument	.55	p = .46

Summary of 2 way ANOVA, for standardised difference scores at pain threshold. Group vs instrument (df 1,38)

Part of model	F-ratio	Probability
Instrument	.12	p = .74
Group	3.06	p = .08
Group x Instrument	4.64	p = .04*

* alpha = 0.05

Summary of 2 way ANOVA for raw scores pain threshold with dolorimeter. Group vs time (df 1,38)

Part of model	F-ratio	Probability
Group	315.19	p = .04*
Time	1.12	p = .30
Group x Time	16.08	p = .000*

* alpha = 0.05

Summary of 2 way ANOVA for raw scores pain threshold with forceps. Group vs time (df 1,38)

Part of model	F-ratio	Probability
Group	1.12	p = .30
Time	2.06	p = .16
Group x Time	.02	p = .88

Summary of 2 way ANOVA for raw scores pain tolerance with dolorimeter. Group vs time (df 1,38)

Part of model	F-ratio	Probability
Group	1.55	p = .22
Time	1.55	p = .22
Group x Time	.56	p = .46

Summary of 2 way ANOVA for raw scores pain tolerance with forceps. Group vs time (df 1,38)

Part of model	F-ratio	Probability
Group	2.20	p = .15
Time	.61	p = .44
Group x Time	2.53	p = .12