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The Effect of Correcting Muscle Asymmetry Upon Chronic Low Back Pain

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "The Effect of Correcting Muscle Asymmetry Upon Chronic Low Back Pain" submitted by C. C. Stuart Donaldson in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

Three treatment techniques (a) EMG biofeedback (single motor unit protocols), (b) biofeedback-assisted progressive muscle relaxation, and (c) lecture and discussion, were studied on 36 volunteers to determine their effectiveness upon muscles (erector spinae) involved with chronic low back pain (CLBP).

The EMG amplitude and bilateral difference of the erector spinae were monitored over time for each group, across five conditions (lying, sitting, standing, and movement, high and low). The biofeedback group showed decreased EMG activity over time for all conditions; the education group was similar except for the movement scores (which increased), while the relaxation group scores followed no consistent patterns. Pearson coefficients showed significant correlations between the EMG measures and pain for sitting and movement.

Multivariate and univariate procedures were utilized to analyze 7 dependent variables. Data from the MPQ and VAS-General, when analyzed with a two-way repeated measures MANOVA, showed a significant ($p < .05$) reduction in pain both over time and for group by time. Univariate analyses showed a similar pattern for the MPQ and for time only for the VAS-General. Post hoc analysis of the MPQ showed the biofeedback group significantly ($p < .05$) lower in reported pain than the relaxation group at follow-up. Four assessment VAS scales (considered as components of the VAS-General score) and two treatment VAS scales significantly ($p < .05$) decreased over time when analyzed using two-way ANOVAs. A second two-way MANOVA performed on the Hypochondriasis (Hs), Depression (D), and Hysteria (Hy) scales of the MMPI showed a significant ($p < .01$) reduction over time. Two-way ANOVAs showed the Hs and Dep scales of the MMPI significantly ($p < .01$) reduced over time for the biofeedback and relaxation groups. A similar pattern for the Hy scale approached statistical significance ($p < .06$). Two-way ANOVAs performed on posture per the Posture Evaluation Kit, and activity as rated on the Behavior Checklist, were not significant.

As 35/36 subjects demonstrated learning it was concluded that learning can reduce muscle activity of the erector spinae, reduce non-specific arousal factors, and effectively reduce reported pain. It was concluded that learning occurred as a result of (a) specificity of information and (b) rate of implementation. Reductions in the MMPI scales were related to the reduction in reported pain. The pain-spasm-pain and biomechanical models of chronic pain were both tentatively accepted as mechanisms of pain. Limitations of the study and directions for future research are outlined.

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DEDICATION

TO MARY DONALDSON

With appreciation for all that you are.

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CHAPTER ONE

The Enigma of Chronic Low Back Pain

Introduction

Chronic low back pain (CLBP) presents one of the more significant and difficult challenges facing the health care professional. It is reported that in the United States 75 million people suffer from back pain (Fine, 1985; Loeser, 1980). In Alberta the Workers' Compensation Board (WCB) spends approximately 25% of its yearly budget on the rehabilitation of back injury (Gibeau, 1982). Of these injuries, 70% will recover within 1 month, 90% within 3 months, while 4% will be afflicted for longer than 6 months (Cailliet, 1984). It is estimated that 70% of all North Americans will experience a significant bout of CLBP (Fine, 1985).

Despite the prevalence of the problem there is little agreement as to the etiology of CLBP. While numerous models have been postulated, as Cailliet (1981) states, "determination of the patient who will progress into chronic pain behavior, in spite of understood acute pain and in defiance of proper treatment, remains an unsolved need" (p. vi).

Often advances in one field of science, when applied to a different field, lead to advances in that field. In the last 20 years rehabilitation medicine has developed techniques in the application of artificial sensory feedback to problems of motor disturbance, (e.g., peripheral neurological disorders) (Mulder, 1985). Basmajian (1983) summarized the status of the field when he wrote "the most dramatic application of biofeedback to large numbers of severely handicapped patients has been in the area of myoelectric biofeedback" (p. 3). Of particular interest to this study is the development of integrated electromyographic (iEMG) techniques and their application to motor disturbances of the low back. Within the last few years interest has grown in the relationship of CLBP to myoelectric activity. Despite increased activity and research in this field, the nature of the relationship is not clearly established and the need for well controlled studies is paramount (Wolf, 1983).

The present study has been motivated by the author's interest in the application of myoelectric retraining techniques to the field of CLBP, in particular, the application of muscle retraining techniques to the activity of the erector spinae muscles in the lower back and the possible development of a theoretical position concerning this activity. The central question posed in this study is "what is the effect of manipulating the muscle activity of the erector spinae upon CLBP, and if there is an effect, what is its theoretical significance?"

General Purpose of the Study

The general purpose of this study is to explore the relationship of muscle activity to CLBP. In particular the study will explore the effect of increasing or decreasing the muscle activity of the erector spinae upon CLBP.

Nigl (1984) suggested that most back pain is caused by "the mechanical dysfunction of neuromuscular tissue" (p. 263). Various neuromuscular models have been postulated in an attempt to account for the mechanism of pain. Of particular interest here are the pain-spasm-pain model and the biomechanical model.

The biomechanical model (Price, Clare, & Ewerhardt, 1948) suggests that faulty patterns of muscle activity affect the biomechanics of movement producing pain. The pain-spasm-pain model suggests that pain produces muscle spasm which in turn produces further pain in a cyclic manner. The physical stressor theory (Travell & Rinzler, 1952) and the psychosocial stressor theory (Sargent, 1946; Sarno, 1976) have both been proposed as the primary factors involved in the pain-spasm-pain model. The physical stressor theory suggests that the pain is originally caused by physical trauma (i.e., muscle irritation), while the psychosocial stressor theory suggests that emotions cause a pattern of chronic bracing and maladaptation.

This study specifically examines the effect of changing muscle activity by the use of three different treatment techniques. One procedure will employ iEMG biofeedback techniques as developed in rehabilitation medicine in an attempt to increase and balance muscle activity. A second procedure (relaxation training augmented by iEMG biofeedback) will attempt to reduce and balance muscle activity. The third procedure will be didactic, attempting to modify behaviors and attitudes which indirectly affect the muscle activity.

It is important to emphasize the exploratory nature of this study. While the field of rehabilitation medicine employs iEMG techniques on a regular basis, little is known about the use of these techniques with CLBP. A review of the literature shows little integration between the various fields concerned with CLBP, leading to seemingly inconsistent and conflicting results. Much of the available literature is of the case study variety or is poorly controlled, further confusing matters. As will be evident from the literature review which follows, many issues remain unresolved.

In summary, the general purpose of this study is to explore the relationship of muscle activity to CLBP by manipulating the motor activity of the erector spinae in three different treatment conditions. Through this study it is hoped that advances in the theory of muscle control and in the theory and treatment of CLBP will be of benefit to the chronic low back pain sufferer.

Theoretical and Practical Significance

As previously mentioned the mechanisms of chronic pain are poorly understood (Cailliet, 1984). Investigation of the neuromuscular aspects of CLBP directly explores this field. Muscle spasm and biomechanical factors are reported to be involved in the maintenance of CLBP, yet the nature of the mechanism of pain and the various etiological factors have yet to be unravelled. Examination of the issues of muscle activity and the method of its control indirectly explores this area. If one method of treatment can be shown to be more effective than the others, then light will be shed on the related mechanisms of pain.

Of interest to the health care professional is the issue of efficacy of treatment. Is one technique better or more effective than the others and if, so under what conditions?

In the study of CLBP numerous variables have been postulated as to causal factors. Through this study the nature of the relationship between CLBP and postural, psychological, and behavioral variables will be explored. Timmermans and Sternbach (1976) and Melzack and Wall (1982) conclude that certain personality variables are reactive to pain and return to baseline with a decrease in pain. However, others (i.e., Sargent, 1946; Sarno, 1976) postulate that personality factors cause an individual to have CLBP. Further clarification of this issue may be possible from the results of this study.

The practical implications of this study are evident. As various authors (Cailliet, 1984; Nigl, 1984) suggest, neuromuscular problems account for 70% of all back injury. A study which examines the nature of CLBP and methods of treatment could have an impact upon the costs associated with this dysfunction. From 1974 to 1980 the Alberta Government spent 94 million dollars on back injury (Gibeau, 1982). A reduction of these costs would impact the health care system and the Workers' Compensation System. But more importantly it could return CLBP sufferers to a more harmonious and productive existence.

Definition of Terms

The following definitions will be employed in an effort to clarify the terms utilized in this study:

1. Pain . The definition of pain will be that of the International Association for the Study of Pain (IASP): "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage" (IASP Subcommittee on Taxonomy, 1979, p. 250).

2. Chronic low back pain . Pain located in the back bounded by the lower thoracic vertebrae (T10) to the lowest point of the sacrum (S5). The pain will vary in intensity but be present most of the time with an onset of at least 1 year prior to the study.

3. Biofeedback . Biofeedback is defined "as the technique of using equipment (usually electronic) to reveal to human beings some of their physiological events, normal and abnormal, in the form of visual and auditory signals in order to teach them to manipulate these otherwise involuntary or unfelt events by manipulating the displayed signals" (Basmajian, 1983, p. 1).

4. Integrated Electromyography (iEMG/EMG) . Referred to in either context, this is a form of biofeedback in

which the myoelectric signal of the striated muscle is the physiological system under study.

5. Symmetry . Symmetry in this study will refer to the myoelectric activity of the erector spinae muscles, when compared side to side across the spine.

6. Erector Spinae . Refers to those muscles (the iliocostalis lumborum, the longissimus thoracis, and the multifidus) which run parallel to the spine on either side with their origin at the sacrum (Kendall & McCreary, 1983). May also be referred to as the lumbar/thoracic paraspinals.

7. Single Motor Unit (SMU) . Refers to the nerve cell body, its axon, terminal branches and all the muscle fibres supplied by these branches.

Summary of the Study

The present study is designed to investigate the efficacy of three kinds of treatment on CLBP. The result should provide information relevant to the etiology of CLBP as well. Of particular interest is the effect of manipulating myoelectric activity. Myoelectric activity will be (a) increased through the use of biofeedback training, (b) decreased by means of relaxation procedures (augmented with biofeedback), or (c) indirectly controlled by the modification of attitudes and behaviors (an educational program).

Little is known about the etiology of CLBP, or the effect of different treatment techniques upon it. It is hoped that through this study a small step may be taken towards understanding and alleviating this complex problem.

CHAPTER TWO

Review of the Literature

Pain

Pain has captured the attention and scientific curiosity of mankind since the beginning of time. In early recorded history debate existed as to the nature and definition of pain. Today, little has changed. A review of the literature reveals little consensus as to the definition of pain, method of analysis or optimal courses of treatment. Often scientific positions are taken with little concrete support for the position. The literature review which follows has attempted to outline these divergent views. This section is not intended to debate the various models, as much as it is intended to acquaint the reader with a brief background as to the various theories and subsequent rationale for the adoption of an integrated model as this paper's working model.

Early Models

Pain was studied from several different points of view in early Greece. Theories ranged from diseases of the soul, to religious, to poisons of the body. Melzack and Wall (1982) cite a study by Aristole of a young woman and her pain which was reportedly related to her love for a married man. Generally, these types of theories abounded with treatment focused more on the "soul" than the physical.

Sensory Models

At the turn of the 19th century interest in the physical causes of pain led to the development of various models, two of which dominated the field. Based upon the works of Sherrington (1906) the medical model assumed a direct connection between the amount of tissue damage and the reported level of pain. The Specificity Theory, as it has become known, postulated that there is a direct pain pathway between the body and the brain with the signal not mediated by any other factors except the amount of tissue damage (Melzack & Wall, 1982). Paralleling and competing with the development of the Specificity Theory was the Pattern Theory first suggested by Goldscheider in 1894 (Melzack & Wall, 1982). The Pattern Theory suggested that pain was transmitted through the sensory pathways, for example the mechanical receptors pathway, but was differentiated by the brain through differing impulse patterns.

Since the work of Beecher (1975) the idea of a one to one correspondence between tissue damage and reported pain has fallen into disfavor. For example, Waddell (1987) reports a correlation of $r = .27$ between orthopedic findings and pain as measured on a Visual Analogue Scale. Numerous factors appear to affect the reported pain . For example cultural background, age, and sex (Notermans & Toploff, 1975; Procacci, Bozza, Buzzelli, & Corte, 1975; Woodrow, Friedman, Sieglaub, & Collen, 1975), sports training (Ryan & Kovacic, 1975), personality (Melzack & Wall, 1982), and meaning of the injury (Beecher, 1975) influence the reported pain.

Integrated Models

Melzack and Wall in 1965 (cited in Melzack & Wall, 1982) proposed that pain was a multi-faceted phenomenon under the control of several factors such as sensory input, emotional and cognitive factors, and environmental stimuli. Known as the Gate Control Theory, this theory lead researchers to explore new and complex areas of pain research. Some of these areas included the regulatory properties of the central nervous system, the effects of psychological factors and personality variables, and electrical stimulation techniques (which led to the development of Transcutaneous Nerve Stimulation [TNS] for pain control). As a consequence of this theory researchers started exploring numerous aspects of pain.

Acute/Chronic Pain

One avenue explored was that of examining pain from both the acute and chronic aspects. In the acute stages it is thought that pain serves a protective function for when an injury occurs pain (a) alerts the individual that something is wrong, (b) triggers a response that serves to minimize the injury, and (c) initiates the healing processes (Melzack & Wall, 1982).

Little is known as to what causes the change from acute to chronic pain. Approximately 4% of all persons who injure their back continue to experience back pain 6 months after the onset (Cailliet, 1984).

With only 20 - 30% of low back pain sufferers showing objective signs of disease (Nachemson, 1983), much effort was directed towards trying to develop psychological theories as a method of explaining pain particularly CLBP. Several authors, (e.g., Engel, 1959; Reich, 1970) developed various theories in an effort to account for chronic pain and CLBP in particular.

In addition, much effort was directed towards distinguishing organically based sufferers from those psychogenically based sufferers. The basis of this conceptualization is that the learning of pain behaviors (i.e., moaning) may take place independently of the tissue damage (Feuerstein, Papciak, & Hoon, 1987). Three processes (respondent conditioning, operant conditioning, and social learning) have been suggested as the mechanisms involved. This line of investigation led to the development of numerous treatment techniques. For example, Fordyce (1976) and his associates have focused upon behavior modification of the observable pain behaviors. Similarly, Sternbach (1974, 1976, 1983) and Sternbach, Wolf, Murphy, and Akeson (1973) have developed a program for "low back losers". Family therapy using a systems model approach suggests that the individual sufferer represents the pathology of the family (Waring, Weisz, & Bailey, 1976). Caldwell and Chase (1977) proposed a classical conditioning model in which acute pain is converted to chronic pain through learning. Each model has its supporters, each demonstrating some success with various groups of CLBP sufferers. However, much controversy exists as to whether they are changing the actual pain or merely the reported pain. Furthermore, as Turk and Flor (1984) suggest, none of these theories has enough evidence from controlled research to support its position.

Each of the above models is similar in that they try to explain pain from a single factor perspective. The effect of this has been to simplify a complex problem, arriving at inconsistent findings which further confuse the issue.

Current Trends

The development and subsequent refinement of the Gate Control Theory by Melzack and Wall (1982) has also led to a change in formulation from the single factor model to studying chronic pain from an integrated perspective. This perspective examines several factors (e.g., psychological and physical), considering the relative contributions of each factor (Keefe, Brown, Scott, & Ziesat, 1982). The biopsychosocial model as proposed by Loeser (1982) follows directly from this perspective. Illness is conceptualized as having four components: a) nociception, b) pain, c) suffering, and d) pain behavior. Each component is viewed as contributing to the chronic pain modulating the perception of and response to the dysfunction. As Waddell (1987) states, "pain can no longer be regarded as merely a physical sensation of noxious stimulus and disease, but conscious experience of pain may be modulated by mental, emotional, and sensory mechanisms and includes both sensory and emotional components" (p. 637).

Hendler (1982) studied pain over time, proposing that from a longitudinal perspective pain may be categorized into four phases: acute, subacute, chronic, and subchronic. The acute phase starts at the time of injury lasting for approximately 6 weeks. Hendler (1982) suggests that during this time period the patient expects to get better, takes analgesics for a brief period of time, and shows a normal pattern when administered a battery of psychological tests.

The subacute phase starts after the acute phase and lasts until about 6 months post-trauma (Hendler, 1982). During this time the patient retains hope of recovery denying any problems, but becomes increasingly preoccupied with the symptoms (e.g., shows an elevation of the Hypochondriasis Scale on the MMPI), and starts to show subtle changes in the personality (i.e., increased irritability, insomnia, social withdrawal), awakens from sleep due to the pain, and increases the use of analgesics and hypnotics. Approximately 6 months post-trauma the chronic pain phase begins. Depression dominates the (MMPI) psychological profile with the corresponding feelings of hopelessness and helplessness. Self-esteem is often very low with marital and sexual problems common. This phase can last up to 8 years post-trauma. The subchronic phase then follows with the patient having learned to live with the pain. Medication use is often discontinued, and the depression lessened, with a return to a degree of efficiency. However, the concern with bodily functioning remains, with the individual readjusted to a life of coping with the pain.

While Hendler's model is descriptive, multifaceted, and has received some empirical support (i.e., data from the MMPI), various authors dispute the classification system. Crook and Tunks (1985) suggest that the duration and body location of the pain do not necessitate the development of psychological and social disorders. In studying 394 Canadian households they found a low correlation between physical difficulty, pain upon activity, and emotional indices. More recent research involving the MMPI suggests that all chronic pain patients do not show the same profile, but differ in a manner that allows for classification into subgroups (Bradley, Prokop, Margolis, & Gentry, 1978; Costello, Hulsey, Schoenfeld, & Ramamurthy, 1987; Curtiss, Kinder, Kalichman, & Spana, 1988; McCreary, 1985; McGill, Lawlis, Selby, Mooney, & McCoy, 1983; Naliboff, Cohen, & Yellen, 1982; Naliboff, McCreary, McArthur, Cohen, & Gottlieb, 1988). While Hendler's model appears to account for some of the variance involved with pain, not all individuals fall into his categories, reflecting a need for further refinement of his system.

As this trend towards utilization of an integrated model is relatively new, there are few controlled studies which examine chronic pain, particularly CLBP from this perspective. Naliboff, Cohen, Swanson, Bonebakker, and McArthur (1985) compared 68 CLBP subjects to 35 matched pain free subjects examining physical abilities, level of activity, psychological adjustment, and pain perception. They found the CLBP subjects to have less trunk flexibility and strength, less walking endurance, and poorer psychological adjustment (more depressed, anxious and isolated as measured on the MMPI). Factor analysis suggests that psychological dysfunction was more closely related to physical limitations than to reported intensity of pain. The authors concluded that a rehabilitation approach which focuses upon increasing physical abilities, back protection skills, and reducing psychological maladjustment rather than reducing pain is indicated by the results.

Sixty-three chronic pain patients were studied by Haley, Turner, and Romano (1985) examining the relationship of depression to pain, activity, and sex. A sex difference appeared in which women's depression was closely related to pain, whereas depression was more closely related to impairment of activity for men. Reported pain was only minimally related to activity for either sex. The results of this study are somewhat contaminated by a mixed sample of CLBP sufferers, headache sufferers, knee, and leg pain sufferers making specific conclusions about CLBP difficult.

Gottlieb et al. (1977) treated 72 CLBP patients who had been unresponsive to surgical and/or conservative treatments. A 2 week inpatient treatment approach utilized eight different modalities covering psychological, behavioral, physical and social aspects of the problem. The authors reported that 57 patients showed unimpaired physical functioning and 59 patients had returned to work 1 month later.

Goldsmith (1980) utilized a self-help, multi-element treatment program with 20 CLBP patients (average age of 43, with 10 years pain) in an 8 week (one session per week for 1 and 1/2 hours) treatment program. The experimental group received manuals and training in relaxation techniques, cognitive and behavioral treatment of depression, behavioral self-control, and assertiveness training. The comparison group received manuals and training in bodily repositioning techniques. Pre and post comparisons and a 1 month follow-up indicated that the multi-element group reported significantly less pain as measured by the McGill Melzack Pain Questionnaire (MPQ). However, subtle differences in affective components (as measured by the MPQ) were reported at pretest baseline, which differentiated the most improved from least improved for both groups. Goldsmith (1980) suggested that a complex interaction between subject characteristics (less affective responses on the McGill-Melzack), treatment variables, and outcome measures accounted for the reported changes.

The relations between pain, anxiety, mood and muscle tension were studied by Linton and Gotestam (1985). Sixteen chronic pain patients (etiology not specified) (7 females, average age = 41) were monitored through the use of visual analogue scales for each variable. In addition the number of hours of "downtime" (lying down) was recorded. Pearson product-moment correlations were calculated for all possible combinations. The results indicated a relationship between pain and mood, pain and anxiety, pain and reclining time, anxiety and muscle tension, anxiety and mood, and reclining time and mood. The authors note that the relationships are generally weaker than what would be expected, with a range of values of r from .28 to .53. The authors concluded that great between-individual variance is evident and that psychological variables are related to the experience of chronic pain.

Waddell (1987), Waddell, Main, Morris, Di Paola, and Gray (1984) and Waddell et al. (1982) studied the relationship of pain to physical disorder and disability. A correlation coefficient of $r = .27$ between pain and physical disorder and $r = .54$ for disability and physical disorder with a multiple correlation coefficient of $R = .44$ for the two combined and physical disorder was reported.

In conclusion, it appears that the trend in recent research is to study chronic pain from a multifaceted point of view. While studies suggest an interaction between variables, there is no agreement as to which variables should be studied nor what is the nature of the interactions.

Summary

Pain has preoccupied the scientific curiousity of mankind for centuries. Dissatisfaction with the various theories led to the development of the Gate Control Theory moving away from the model of a simple relationship between tissue damage and pain to one which includes psychological, behavioral, and sensory components. While much research needs to be completed, the use of an integrated model allows examination of how these factors combine to cause and maintain pain.

CLBP and Muscle Activity

Historical Review

It is a well established fact that skeletal muscles are under the conscious control of the central nervous system (CNS). Since muscles were first observed to twitch under electrical stimulation in the laboratories, there has existed a scientific curiosity as to the nature of the electrical activity of muscles and the control processes involved. One of the earliest pioneers (Hough, 1902) studied neuromuscular fatigue with EMG techniques examining the relationship of laboratory induced pain to contraction levels. At the same time Bair (1901) observed that naive subjects could train the retrahens muscle (controls movement of the ear) to contract independently of the surrounding muscles through training provided by EMG methods. A major advance occurred with the works of Jacobson (1938) who formulated that the mind and the body were linked, with activity in one area affecting the activity of the other. Employing EMG techniques, Jacobson studied the effect of progressive relaxation training upon the muscles. Jacobson's works have lead to the development of numerous techniques for the control of anxiety and related dysfunctions. Paralleling this growth was interest in the field of motor control. In the last 20 years artificial sensory feedback has shown rapid growth and development. As critical as Jacobson's work is to the field of clinical psychology, Basmajian's works (1963, 1972, 1976) led the way in the field of rehabilitation medicine. Following Basmajian's pioneering work on single motor units there was a rapid growth in applied research exploring various aspects of muscle activity including muscle fatigue (Komi & Buskirk, 1970), contraction patterns (Merletti, Sabbahi, & De Luca, 1984), types of contractions (Edwards, Young, Hosking, & Jones, 1977; Seidel, Beyer, & Brauer, 1987), and pain (Asmussen, 1956; Newham, Mills, Quigley, & Edwards, 1982).

Advances in electrical equipment paralleled the advances in psychology and rehabilitation medicine. Prior to World War II electronic equipment was subject to artifact except in stringently controlled laboratories. Improved equipment (e.g., bandpass filters) enhanced the validity and reliability of the detection of finite electrical impulses, facilitating the rapid growth of this field into the clinical setting. Combined with computers, several channels of physiological information could be assessed, analyzed, stored, and graphed simultaneously (Olson & Schwartz, 1987). As these advances became available to the different disciplines, electromyography became multi-disciplinary. This is evidenced by the diverse languages and journals in which articles have appeared (i.e., European Journal of Applied Physiology , Medical and Biological Engineering , Ergonomics , Psychological Bulletin , American Journal of Physical Medicine) and the rapid increase in professional membership in related organizations (Olson & Schwartz, 1987).

In summary, since the turn of the century researchers have studied the muscle and the method of control. Through the use of EMG techniques some of the properties of muscle functioning have been revealed, but much research with controlled studies is needed before firm conclusions may be drawn (Mulder, 1985).

Pain Sites

A comprehensive review of the anatomy and physiology of the lower back is outside the realm of this study; for more infomation the reader is referred to Anderson (1978). This section is intended only to focus the reader's attention on the physiology relevant to this study. Cailliet (1977) suggests that there are four possible sites or modes of pain in the back. These are (a) the vertebral bodies, (b) the spinal nerve root (particularly as it exits through the vertebral foramen), (c) the joints of the vertebrae (facet joints), and (d) the various ligaments and muscles.

Various diagnostic procedures (i.e., X-rays, CT scans, mylograms, and discograms) have been developed in an attempt to provide evidence as to the physical cause of pain. Despite these elaborate procedures, 60 - 85% of all cases of CLBP have no discernible physical basis (Cailliet, 1984; Nachemson, 1983; White & Gordon, 1982).

Cailliet (1977) suggested that at least 70% of all back pain is caused by muscle injury. Turk, Meichenbaum, and Genest (1983), in reviewing chronic back pain programs, found that of 32 programs, 15 used neuromuscular treatment outcome as their criterion for improvement. Yet often the diagnosis of muscular or ligamentous injury is by exclusion when the diagnostic procedures are negative (Dolce & Raczynski, 1985; Holt, 1983). As Dolce and Raczynski (1985) state:

> It is typically assumed that muscular/ligamentous strain, tears, spasms, and so on are the underlying pathology and will heal themselves given sufficient time and rest. Unfortunately this is not always the case. In such situations, psychophysiological assessment and treatment may prove advantageous. Input from psychophysiological evaluations may often be able to clarify the problem and suggest specific treatment interventions (p. 504).

In summary, anatomical evidence suggests there are four possible sites of pain. In the majority of cases, muscular/ligamentous injuries are assumed to be the causal factor. This has led to the development of various theories of CLBP involving ligamentous and muscle tissue.

Models of Muscular Pain

While several models of CLBP have been postulated, two models in particular have focused upon the activity of the muscle system. The pain-spasm-pain model proposes that pain is caused by increased muscle tension due to either physical stressors, trauma or posture (Bonica, 1957; Cram, 1986; Lewit & Simons, 1984; Rodbard, 1970, 1975; Simons, 1976; Travell, 1976; Travell & Rinzler, 1952) or psychological stressors (Sargent, 1946; Sarno, 1976, 1982; Sternbach, 1974, 1976). In either case the pain is viewed as a stressor which leads to spasm and more pain and finally a self sustaining cyclic pattern of pain-spasm-pain.

The second model originally proposed by Price et al. (1948) suggests that CLBP is caused by biomechanical factors acting on the vertebral bodies. Several authors (Cram, 1986; Floyd & Silver, 1955; Janda, 1978; Wolf & Basmajian, 1978; Wolf, Basmajian, Russe, & Kutner, 1979; Wolf, Nacht, & Kelly, 1982) suggest that an imbalance of muscle activity during standing and when moving produces a biomechanical imbalance of the vertebral bodies leading to activation of the pain sensitive structures contained in the spinal ligaments.

The above models may not be mutually exclusive (Dolce & Raczynski, 1985) as spasm occurring unilaterally may produce an imbalance as noted in the biomechanical model. Conversely, a biomechanical imbalance may produce muscle spasm in a reflexive manner (Basmajian, 1983). Cram (1986) has interwoven these views into a comprehensive working model suggesting that muscles may produce pain due to (a) emotional reactivity, (b) postural disturbance, or (c) muscle shortness (causing a biomechanical imbalance).

In summary, most of the pain associated with CLBP is thought to be caused by muscles and ligaments. Recent advances in electronic instrumentation have allowed for the accurate monitoring of muscle activity leading to the development of new models of CLBP. Two models (the pain-spasm-pain and biomechanical models) have been proposed as the mechanism of pain, but more research is needed before the merits of each may be determined.

The Treatment of CLBP

During the last century psychologists have applied learning principles to the assessment and treatment of physical disorders. Starting from the early works of Thorndike (1898), as cited by Fischer-Williams, Nigl, and Sovine (1986), the ideas of conditioning theory were applied to disease processes. Jacobson (1938) applied conditioning principles, pairing relaxation training to anxiety problems in the belief that the two states were incompatible. The introduction of operant conditioning (Skinner, 1938) spurred the development of new treatment techniques leading to the development of the field known as behavior modification. In particular the application of learning principles to the area of physical dysfunction has led to the creation of an interdisciplinary field of study known as behavioral medicine. Pomerleau and Brady (1979) defined behavioral medicine as "the clinical use of techniques derived from the experimental analysis of behavior (behavior therapy and behavior modification) for the evaluation, prevention, management, or treatment of physical disease or physiological dysfunction...(p. xii).

Presently there exist numerous therapies and programs designed for the treatment of various dysfunctions. A comprehensive review of the application of learning principles to physical dysfunction is outside the scope of this study. However the reader is referred to the works of Gentry (1984) and Turk et al. (1983) for reviews of the field.

The field of psychophysiology studies autonomic or skeletal muscle patterns which serve to distinguish the sufferer from the normal. By identifying these patterns it is hoped that: (a) They may be of some diagnostic value, and (b) they may be useful in assessing the course of treatments (Feuerstein et al., 1987; Gracely, 1979; Hoon, Feuerstein, & Papciak, 1985). Of interest to this study is the application of learning principles to skeletal muscle patterns particularly in CLBP. The basic principle for these approaches is that modification of the muscle activity will lead to a change in the reported pain. Generally three types of programs have been utilized. These are (a) relaxation training, (b) biofeedback, and (c) educational programs. A review of each of these areas as it relates to CLBP follows.

Relaxation Training

Jacobson (1938) in his research of anxiety and muscle tension started from the premise that anxiety and a low level of muscle activity are incompatible responses (Patterson, 1979). Through the training of a low level of arousal, the individual is assumed to interrupt those processes which cause or maintain the CLBP. These processes, in particular, are thought to be increased muscle tension, blood pressure, heart rate, respiratory rate, and adrenalin outflow (Melzack & Wall, 1982). This increase in activity is thought to intensify pain through the production of feelings of tension and irritability or indirectly by facilitating activity in neuron pools that project pain signals directly to the brain (Melzack & Wall, 1982). Various authors (Benson, Beary, & Carol, 1974; Benson, Kotch, Crassweller, & Greenwood, 1977; Linton & Gotestam, 1985; Peniston & Kao, 1985) have demonstrated that relaxation training produces a change in psychophysiological responses, affecting the pain-spasm-pain cycle through decreasing the muscle spasm in particular, and the level of arousal in general.

Relaxation training would also appear to directly affect the pain-spasm-pain model by acting upon the psychosocial stressors. Sargent (1946) and Sarno (1976, 1982) suggested that the increased tension is due to ineffective coping with environmental and emotional stress. Linton and Gotestam (1985) state "it seems logical that pain-producing situations would also, through learning, begin to produce a good deal of anxiety. What may develop is a type of fear or anxiety attack which intensifies the discomfort of the noxious stimulation" (p.91). Relaxation tends to decrease the perceived pain even when the degree of noxious stimulation is controlled (Linton & Gotestam, 1985).

In an outcome study, Johnson and Hockersmith (1983) treated 510 CLBP patients (253 female) who reported an average of 1.17 back surgeries with 2 years off work. The average age was 42 and 70% were involved in litigation. The treatment program consisted of 6 weeks (a total of 50-60 hours of treatment) of EMG biofeedback. The tension level of the upper torso was monitored utilizing a wrist to wrist electrode placement. The subject started out in a reclining position, fully supported in a chair, and over time step by step progressed to an upright position. Progression to the upright position was determined by the use of the EMG recordings with 3.8 mv or less held for 45-60 minutes used as the criterion. In addition the subjects completed a seven point pain rating scale before and after each session. The authors used the EMG readings as evidence of relaxation. The mean EMG readings decreased from 11.6 to 5.3 mv for the first minute recording, and from 9.2 to 4.3 mv for the sixtieth minute recording. Concurrently, the mean reported pain rating dropped from 4.3 (before treatment) to 2.3 (after treatment). Unfortunately the design of this study is contaminated as some of the subjects received other types of treatment during training. However, the use of the concurrent recording of EMG readings and pain measures suggests "that biofeedback played a major role in the patient's rehabilitation" (Johnson & Hockersmith, 1983, p. 310).

In summary, relaxation training appears to affect both the physical and psychological aspects of the pain-spasm-pain cycle. As Turner and Chapman (1982) suggest this combined effect has made it a popular choice as a method of treatment today.

Educational Training

The basic premise of educational programs is that provision of information will result in a change in behaviors particularly the targetted behaviors. Training programs share three implicit assumptions: (a) educational programs are effective in teaching the desired behaviors, (b) workers are motivated to apply the learning, and (c) the resultant change leads to a reduction in back pain (Evans, 1984). There is little evidence from which to draw conclusions about the effectiveness of these programs. Berguist-Ullman and Larson (1977) studied a "back school" program. They found that participants of the program, when compared to a control group, showed a reduction in the duration of the reported pain. Berwick, Budman and Feldstein (1989) studied 222 adults with low back pain of at least 2 weeks duration. They found that a 4 hour back school psychoeducational program had no measurable impact upon the reported level of pain (Visual Analogue Scale measurements) or the functional status (as measured by the Sickness Impact Profile). Evans (1984) reviewed 23 back education programs available in Alberta. All programs claimed to be effective but no data are available to support these assertions.

Information gathered from the area of stress management (Kendall, 1983) suggests moderate support for the efficacy of information provision as a means of controlling stress. The author suggests that several variables (amount of information, specificity of information, and information receiving and processing) need to be considered before optimum results can be expected.

In summary, education programs have a basic premise that the provision of information will result in the reduction of pain. What little research there is, is equivocal, permitting no firm conclusions to be drawn without more study.

Biofeedback Training

Biofeedback treatment of CLBP follows directly from learning principles. Biofeedback is thought to contain elements of classical conditioning, operant conditioning, cognitive behavior modification, and volition. However the exact mechanisms of learning and control are still subject to much debate (Fischer-Williams et al., 1986; Staudenmeyer & Kinsman, 1976). Originally biofeedback was thought to be an example of conditioning with the feedback considered to be positively reinforcing to the individual. However, McGuigan (1975) apparently demonstrated that individuals can learn to control physiological processes when the principles of conditioning are violated. More recently biofeedback techniques have been linked to self-control and the various self-control strategies that have been developed, especially in the area of cognitive behavior therapy. As Fischer-Williams et al. (1986) state "since biofeedback requires some coordination between peripheral and cortical responses, its development can be viewed as a synthesis of the mechanistic (operant conditioning) and humanistic (cognitive behavior therapy) traditions within the field of applied learning theory" (p. 31). Of all the fields of biofeedback, electromyography has demonstrated the greatest application of these principles.

Electromyography

Before proceeding into a discussion of electromyography, a brief review of muscle physiology will be undertaken in order to acquaint the reader with some necessary concepts. Guyton (1971) indicates that all skeletal muscles in the body are composed of numerous muscle fibres ranging in diameter from 10 to 100 microns. Each muscle fibre contains several hundred to several thousand myofibrils, which in turn are composed of myosin and actin filaments. The muscle fibre is innervated by a motor unit (see Chapter I for the definition) which comes from the ventral horn of the spinal cord (Basmajian, 1988). The number of fibres that are innervated by a motor unit varies from a few in the smaller muscles (e.g., muscles involved with eye movement) to a great many in the larger muscles of the limbs. The fibres that are innervated by a single motor unit are spread throughout the muscle and are intermingled with fibres innervated by other motor units. Muscle contraction occurs when an electrical impulse, which is transmitted by the axon of the motor unit arrives at the muscle, activating a biochemical process which causes the filaments to contract. The size of the contraction is determined by (a) the rate of the impulses transmitted by the motor unit, and (b) the number of motor units which are active at that moment.

Muscle contraction itself is not accessible (Peek, 1987), but the electrical aspects of the contraction may be recorded. The surface electrode picks up the electrical aspects of the contraction including the number of spikes, amplitude, rise time, and amplitude-rise time (Komi & Viiasalo, 1976). This electrical signal which is measured in microvolts (one millionth of a volt) is thought to represent the amount of force generated by a muscle. Bigland and Lippold (1954) originally proposed that the EMG signal corresponded with the generated force at the 0.9 level in a linear manner. Since then various studies have supported this position with some qualifications. Bouisset (1973), Fujiwara, Miura, Numasaki and Hasue (1979), and Vredenbregt and Rau (1973), when comparing EMG readings to the force generated, found a linear relationship for isometric contractions. Further studies have demonstrated that the mathematical relationship varies somewhat depending upon the size of the muscle studied (Janda, 1983), load (Vredenbregt & Rau, 1973), fatigue (Mulder & Hulstijn, 1985a; Stulen & De Luca, 1979; Vredenbregt & Rau, 1973) and position of the joint (Vredenbregt & Rau, 1973). Movement also affects the relationship. As movement is initiated the relationship becomes curvilinear (Vredenbregt & Rau, 1973). However, as movement continues the relationship becomes linear.

In summary, as Bouisset (1973) suggests, the EMG signal appears to adequately represent the force generated by a muscle especially in isometric contractions and after movement has been initiated.

Through biofeedback procedures the electrical activity of the muscle (and consequently the amount of force generated) may be either increased or decreased. Generally the field of rehabilitation medicine has employed procedures for increasing muscle activity. This is particularly evident in the application of these techniques to dysfunctions involving CNS problems (i.e., strokes), peripheral nerve problems (i.e., degenerative nerve disorders), and motor disorders (i.e., torticolis). The rationale for these applications came from research studies involving the SMU. Hefferline (1958), recording from the masseter muscle with surface electrodes, reported acquired control of the SMU. Since then numerous studies (Basmajian 1963, 1967, 1972, 1979; Basmajian, Baeza, & Fabrigar, 1965; Carlsoo & Edfeldt, 1963; Harrison & Mortensen, 1962; Scully & Basmajian, 1969; Simard & Basmajian, 1966) have studied the properties of the SMU. Yates (1980) summarized the existing research.

> 1. If feedback is not provided the subject will experience great difficulty in isolating an SMU.
>
> 2. If biofeedback is provided an SMU may be isolated and rapidly controlled by most subjects in a few minutes.

3. Subjects are able to isolate SMUs from other SMUs.

4. Subjects eventually can produce any one of the SMUs in his command in any order.

5. The frequency of the rate of firing may be varied.

6. No relationship between manual dexterity or personality variables and SMUs has been shown.

7. Auditory biofeedback appears to be better in establishing control.

8. This skill is retained even when the biofeedback is withdrawn.

9. Acquisition of this skill does not follow a genuine learning curve.

10. SMU control has been demonstrated in many muscles (p. 74).

Yates (1980) goes on to cite other controlled clinical studies (Basmajian & Newton, 1974; Lloyd & Leibrecht 1971; Simard & Ladd, 1969) indicating that SMU learning has been found to be effective under conditions of distraction, and in the presence of gross activity in other muscles. Yates concludes:

> The voluntary control of SMU activity represents perhaps the most unequivocal example of the importance of feedback in the biofeedback literature. It illustrates the specificity of control that can be achieved. Until feedback training is provided, control (relying on proprioceptive feedback alone) is weak and unstable, whereas following training control can be maintained when the feedback display is not longer present (p. 78).

The retraining of muscles follows directly from the research on SMU training. Muscles that were considered to be weakened and dysfunctional were retrained to recruit appropriately (increased amplitude and correct temporal integration), while those that showed excessive activity (spasticity or spasm) were retrained to decrease activity.

The literature pertaining to the retraining of muscles is not as definitive as that for SMU training, with mainly clinical studies reported from the field of rehabilitation medicine. EMG biofeedback used in conjunction with standard rehabilitation techniques has been demonstrated to be effective in the treatment of strokes (Binder-Macleod, 1983), spinal cord injury (Wolf, 1983), and spasticity (DeBacher, 1983). Wolf and Binder-Macleod (1983a) compared the effects of EMG biofeedback (retraining weakened hip and ankle muscles) to a control group, upper extremity retraining group, and a general relaxation training group. The authors concluded that the experimental group (n = 7) showed a significant improvement in range of motion at the ankle and knee due to increases in EMG output. In a further study Wolf and Binder-Macleod (1983b) provided 22 chronic stroke patients with EMG biofeedback. The subjects were taught to control spasticity and then increase the activity of the weakened muscles. When compared to a control group, the experimental group showed significant improvement in numerous neuromuscular measures but not in functional measures. Examination of pretreatment differences suggested that maximal benefit was gained by those subjects that had a greater range of motion and less spasticity. Brudney (1982) studied 60 paraplegics who were from 2 to 9 years post-trauma. Using strengthening techniques (increasing microvolt amplitude) and reintegration procedures (training in the correct sequencing of muscle firing patterns) reestablishment of varying degrees of function occurred in 60% of the subjects. Age, sex, and length of time post-trauma were not predictive of outcome. Receptive aphasia was found to be detrimental to the retraining. These results are consistent with the works of Binder-Macleod (1983) who reported on the application of these techniques to patients in his clinic. In another uncontrolled study, Dale, Anderson and Lutton (1983) reported increased activity in the wrist flexors of a 21-year-old quadraplegic (4.5 years post-trauma) after a 20 month treatment program. However, causality is difficult to establish as the EMG treatment was integrated with standard forms of physiotherapy.

In contrast to those studies which have focused upon increasing muscle activity, a number of studies have focused upon decreasing muscle activity. These studies have mainly come from the fields of rehabilitation medicine (which has focused upon the control of spasticity) or clinical psychology which employs these techniques in the decrease of arousal. In rehabilitation medicine spasticity is controlled before strengthening techniques are applied (DeBacher, 1983). The individual is shown the increased activity and told to decrease same (the exact method to do this is not known). This may be followed by having the subject continue to maintain the lowered activity while they are put through passive range of motion exercises and then while actively recruiting antagonistic muscles (DeBacher, 1983). A survey of the research literature by DeBacher attests to the effectiveness of EMG biofeedback training in decreasing spasticity and in restoring normal function. However most of the studies are clinical in design with little controlled outcome data.

Mulder and Hulstijn (1985a, 1985b, & 1985c) studied the role of different forms of feedback in learning a novel motor task in normal individuals. When compared to proprioceptive, visual, and tactile feedback, force and EMG feedback were found to be more powerful in developing voluntary control. In a follow-up study the authors trained three groups of normal individuals to perform a difficult movement under different feedback conditions (immediate, delayed, and no feedback conditions). A significant difference was found between the two feedback conditions and the no feedback groups with the two feedback groups acquiring the desired motor skills more effectively. The authors concluded that the specificity of the information was the critical variable as delay of the feedback showed no detrimental effects when compared to the immediate feedback group.

In summary, the research suggests that the establishment of voluntary control over SMUs is possible under a number of diverse conditions. However, the literature pertaining to the control of muscle groups is not as clear. Several uncontrolled studies and a few controlled ones suggest that retraining muscles (increasing or decreasing activity) is possible, but the mechanisms involved, the limitations, and efficacy are still to be determined.

Electromyography and CLBP

The principles described above, may be applied to the modification of the paraspinal muscle activity in an effort to affect CLBP. By far the majority of the studies employing biofeedback with CLBP have utilized EMG procedures as the instrument of choice either as the dependent or the independent variable. When employed as the dependent variable EMG measures (either amplitude or left-right asymmetry) have been compared to reported pain levels in an effort to establish the measure as a objective index of muscle spasm. This has been completed for various positions and postures (Kippers & Parker, 1984) and, to a lesser extent, during movement. Other studies have utilized the EMG measure as an independent measure where the activity of the muscle has been modified by biofeedback procedures employing the reported pain as the dependent measure. A review of the literature reveals that much of the material is anecdotal in nature or single case studies. There exist very few well controlled studies with adequate controls which demonstrate that learning has occurred. As Turk and Flor (1984) state, "there are considerable methodological and design problems involved in the majority of EMG biofeedback studies with chronic back pain..." (p. 222). Of the 16 studies they reviewed, only 2 were found to employ controls; of these 1 only was concerned with CLBP. They go on to note that conflicting results from various EMG studies allow for no firm conclusions, as in some studies the frontalis muscle was utilized for training, and generalization to the back may not be expected. Shellenberger and Green

(1986), in reviewing biofeedback studies in general and low back pain studies in particular, found that all studies except one did not demonstrate that learning had taken place. The authors concluded that EMG biofeedback cannot be regarded as effective until the existence of learning has been demonstrated. As Dolce and Raczynski (1985) suggested, the results of the studies of EMG and CLBP should be treated as tentative with more research needed.

Within these limitations, some patterns are discernible. EMG measurement of myoelectrical activity is viewed as an index of the level of contraction or state of tension/relaxation (Barber & Adrian, 1982; Basmajian, 1983; de Vries, 1966; Fischer-Williams et al., 1986; Kravitz, Moore, & Glaros, 1981). Granted this premise, a number of CLBP studies have shown that elevated EMG readings are related to the reported pain level. Cram and Engstrom (1986), using surface EMG procedures, compared a sample ($n = 200$) of pain patients to a sample ($n = 104$) of nonpain patients examining the left and right aspects of 11 muscle groups while sitting and standing. The results suggested that the muscle activity of the chronic pain population was significantly higher ($p < .025$) with 47% of the sites showing increased activity. The CLBP group ($n = 137$)

showed a significant difference ($p < .0005$ and $p < .05$ for the left and right sides, respectively) at the L3 level during standing. However, this study was confounded by age differences between groups and needs to be replicated. Cobb, de Vries, Urban, Luckens, & Bagg (1975) injected seven subjects with a solution of 6% sodium chloride at the L1 level of the paraspinals while monitoring the reported pain levels and EMG activity. They found the reported pain level clearly corresponded to the increase in EMG activity for 6 of the 7 subjects. They concluded that "muscle spasm (even when mild) is accompanied by muscular hyperactivity which can be evaluated by suitable electromyographic techniques" (Cobb et al., 1975, p. 86).

The bilateral EMG activity of the lumbar paraspinals of 207 subjects representing six different diagnostic groups (29 no pain controls, 20 spondyloarthritis, 52 disk disorders, 66 musculoskeletal disorders, 17 in various combinations of the above, and 23 with miscellaneous diagnoses) were studied in six different positions (standing, bending from the waist, rising, sitting with back supported, sitting with back unsupported, and prone) by Arena, Sherman, Bruno and Young (1989). The results showed a significant ($p < .01$) main effect of diagnosis with the control group demonstrating lower mean EMG activity than the disk disorder or musculoskeletal groups.

Reduction of the EMG levels either with relaxation training techniques, biofeedback techniques or a combination of both have been reported to reduce the pain level (Belar & Cohen, 1979; Hendler, Derogatis, Avella, & Long, 1977; Keefe, Black, Williams, & Surwit, 1981; Large, 1985; Large & Lamb, 1983; Nigl & Fischer-Williams, 1980; Nouwen, 1983; Nouwen & Bush, 1984; Nouwen & Solinger, 1979; Peck & Kraft, 1977). In summary, these studies appear to support the premise of muscle spasm as a contributor to the development and maintenance of CLBP.

Numerous other investigators have followed the lead of Price et al. (1948) in examining the bilateral asymmetry of CLBP. Cram and his associates (Cram, 1986; Cram & Freeman, 1986; Cram & Steger, 1983) have explored various aspects of left-right paraspinal asymmetries either during sitting or standing. These studies suggest that the CLBP sufferer displays elevated EMG readings and bilateral asymmetries, and these readings differentiate them from headache sufferers. Floyd and Silver (1955) found that CLBP sufferers, when compared to healthy controls, showed excessive erector spinae muscle activity during flexion. Middaugh and Kee (1988) report a poor recovery of baseline (return to premovement EMG levels) after flexion/extension was characteristic of CLBP sufferers. Wolf and Basmajian (1978) compared the paraspinal activity of 66 "normal" subjects to 9 CLBP subjects of which 6 had undergone surgery for herniated disk at L4-5 or L5/S1. Muscle activity was aberrant for the pain group for each of the movements (flexion, extension, and rotation in either direction) with flexion/extension producing asymmetrical patterns and rotation producing symmetrical patterns. The authors interpreted the reduced recruitment as a reflection of a guarding or bracing pattern. However, this result must be regarded with caution as there are no studies of the effect of surgery on EMG activity. Normative data were collected by Wolf et al. (1979) on 120 nonpain subjects (equal numbers of both sexes). Using a standard bilateral placement for the erector spinae, they studied dynamic (flexion-extension, stooping and rotation - either direction) and static (sitting and rotation sitting) activity. The results showed that non-CLBP subjects showed a symmetrical pattern of activity during trunk flexion and extension. During standing they report that very little activity is observed, but as the individual flexes forward there is a burst of activity of the erector spinae until quiescence at approximately 45 degrees. This process is reversed for extension. Trunk rotation from a standing position produced significantly greater activity on the contralateral side. Significant age-sex interactions were noted for the dynamic activity but not for static. The authors conclude that posture and gender play a significant role in muscle activity. Jones and Wolf (1980) reported on a single case study of a 35-year-old male who complained of CLBP of 24 months duration. Six lumbar blocks and twice weekly chiropractic manipulations had failed to relieve the pain. EMG data, when compared to normals, were significantly greater and a bilateral imbalance, with the right side elevated, was noted.

The clinical rationale for the treatment of muscle asymmetry is rather well outlined by Wolf et al. (1982). The presence of abnormal recordings from the paraspinals forms the basis for the utilization of dual channel EMG techniques in this study. Utilizing a single case design (ABABA), a 22-year-old female with CLBP of 5 months duration was assessed with the McGill Melzack Pain Questionnaire and bilateral EMG procedures. Abnormal patterns were noted for the left paraspinals during left and right rotations. During training the activity of the left and right paraspinals was provided simultaneously to the subject who was taught to equalize the activity during standing, then flexion and stooping, and finally to produce asymmetry during rotation. Training was conducted three times per week for 5 weeks. Scores on the McGill Melzack dropped to 0 during the feedback sessions and at follow-up. The EMG readings moved in the expected directions (towards symmetry) but the study is weakened by the lack of evaluation data during training. The authors conclude that training to reduce asymmetry of the paraspinals is a valuable tool in neuromuscular reeducation, but the limitations of the technique and its integration with other techniques needs to be established.

Ahern, Follick, Council, Laser-Wolston and Litchman (1988) compared 40 CLBP subjects to 40 matched non-pain controls on lumbar EMG paraspinal activity during static (sitting and standing) and dynamic (flexion/extension) assessments. The authors report that the absolute levels of EMG activity during quiet standing did not differ between groups. However, dynamic assessment revealed the CLBP group with an average level of EMG activity lower than the controls (36.3 mv, SD = 36.1 and 60.9 mv, SD = 25.1, respectively). Employing discriminant analysis techniques, dynamic assessment procedures correctly classified 84.6% of the CLBP sufferers and 87.5% of the controls. Ahern et al. (1988) suggest that the results support the biomechanical model of back pain and recommend the use of dynamic assessment procedures.

In summary, the studies support both models. Elevated EMG readings in the area of the reported pain are commonly found as predicted by the pain-spasm-pain model, while bilateral asymmetry, as associated with the biomechanical imbalance model, is also well documented.

Conclusion

Since the development of the Gate Control Theory, pain is thought to be multifaceted in nature. The application of this type of thinking to chronic pain, particularly CLBP, has recently lead to the study of this phenomenon from a multifaceted point of view. While no definitive criteria exist, a review of the research literature on pain suggests that (a) psychophysiological correlates, (b) personality variables, (c) reports of pain, and (d) behavioral correlates are most commonly studied by psychologists today.

The use of psychophysiological techniques, particularly EMG procedures, has lead to the further understanding of muscle functioning. The research literature indicates that SMU training is valid and reliable under a number of different conditions. The retraining of muscle groups is not as clearly established, with the studies suggesting that retraining is possible but the mechanisms, limitations, and efficacy need to be documented.

The application of EMG techniques to CLBP follows directly from the study of muscle functioning. The pain-spasm-pain model proposes that pain is caused by increased muscle activity (spasm), while the biomechanical model suggests that pain is caused by a muscle imbalance across the spine. A review of the literature suggests that muscle spasm and the reported pain may be decreased with EMG techniques. The literature pertaining to the treatment of biomechanical imbalance is not so definitive. What studies there are suggest that increasing the appropriate muscle activity does lead to a reduction in pain, but these studies are mainly single subject studies or are confounded by other treatments. Furthermore, the literature is lacking in well controlled studies and there is little demonstration that learning, which is the mechanism of change, has in fact occurred. Consequently no firm conclusions can be drawn from the literature.

A well controlled study which examines the relationship of muscle activity to CLBP by modifying the muscle activity is needed. If the pain-spasm-pain model is correct, then reduction of the muscle activity to a prescribed level through the use of progressive relaxation techniques combined with EMG feedback should produce a decrease in reported pain, an increase in activity, and a decrease in the affective components. If the biomechanical model is correct, then an increase in the muscle activity on the lowered side to a prescribed level should produce a decrease in reported pain, an increase in activity, and a decrease in the affective components. If these models are not mutually exclusive then both these approaches should produce the expected results.

The present study fulfilled this need. Three treatment programs were studied. One group (relaxation group) was trained to reduce muscle activity through the use of modified progressive muscle relaxation techniques aided by EMG feedback at the end of each session. A second group (biofeedback group) was trained through EMG biofeedback techniques to increase the muscle activity of the paraspinal processes which show lowered activity. A discussion and lecture format was utilized with a third group (educational group) to instruct these subjects in the various concepts of the models and how to apply them to their lifestyle.

CHAPTER THREE

Method

Subjects

Recruitment

All subjects were volunteers who were advised of the study through either a written notice (see Appendix A) or public announcement. The notice was mailed to unions, safety personnel of various companies, doctors, chiropractors, university professors, and appeared in two newsletters. The public announcements were made during speeches given by the author.

Selection

All volunteers were screened three times: (a) during the initial contact, (b) during an initial interview, and (c) by the consulting physician.

Initial Contact and Criteria for Selection.

Interested persons contacted the author who discussed the study, answered any questions and screened out the inappropriate volunteers. As the focus of the study was the relationship of CLBP to muscle activity selection was based on the criteria listed below.

1. Experience chronic low back pain in the area between the top of the buttocks and the bottom of the shoulder blades.

2. Experience the pain for at least 1 year.
3. Experience the pain daily.
4. Be between the ages of 18 and 55.
5. Not involved with long term disability or litigation.

Sixty-nine people volunteered for the study. Of these, 18 were rejected as not meeting the criteria. Table 1 lists the reasons for rejection.

TABLE 1

Reason For Rejection

Reason for Rejection	Number
Age (too old)	4
Physical Problems	6
History of Surgery	2
Pain Criteria not met	3
Withdrew	3

<u>Initial Interview</u> .

The rest of the subjects were seen in an initial interview by the author. The purpose of the interview was to inform the subjects fully of the nature of the study, the treatment methods, the safeguards for confidentiality, to answer any concerns, and to verify the initial screening. No more subjects were rejected at this stage. The subject signed a consent form (see Appendix B) and an authorization form (see Appendix C) which permitted information to be obtained from their family doctor. The authorization form was mailed to the physician, who subsequently returned it. As they volunteered, the subjects were assigned a number in consecutive order from 1 to 36. This number, rather than their name, appeared on all documents in an effort to protect confidentiality and was used later to assign them to a treatment group. Demographic data (see Appendix D) were then collected and forwarded to the consulting physician.

<u>Consulting Physician</u> .

All subjects were seen by the same consulting physician. Utilizing the demographic data and a standard physical assessment (see Appendix E), the subjects were further screened for possible neurological and disc problems. The consulting physician also reviewed any questionable replies from the family physician. The final acceptance into the study was made by the physician.

<u>Physician Criteria for Exclusion</u> .

The consulting physician excluded any subjects who demonstrated any of the following:

1) a history of back surgery
2) a straight leg raise which produced pain at less than 70 degrees
3) a loss of reflexes
4) weakness in the lower limbs

5) a severe scoliosis

6) a gait abnormality affecting the biomechanics of the spine

7) any other significant disease

The physician rejected two subjects; 1 for neurological reasons and 1 with a history of back surgery.

After the physician's assessment and before the pre-treatment assessment, another 9 subjects dropped out of the study citing personal reasons (e.g., not enough time to participate, a death in the family, a car accident) for their exit. One other subject became ineligible due to back surgery. Three subjects dropped out of treatment due to personal reasons, leaving a total of 36 subjects.

In the situations where the number was assigned and the subject subsequently dropped out, the number was left unfilled until the 36 numbers were assigned, then the numbers were refilled consecutively starting with the lowest number.

Summary

All subjects were volunteers recruited through notices and speeches. The subjects were selected on the basis of criteria designed to exclude other possible sources of reported pain such as neurological factors, disc problems, and secondary gain. Of the 69 people who volunteered, 49 were accepted into the study, and 36 completed it.

Procedure

Pretreatment Assessment

The pretreatment assessment of the subjects occurred within 2 weeks of the physician's acceptance of them into the study. The assessment followed a routine format with the same examiner used in all cases. Wolf (1983) suggested that a single blind procedure is most suited for EMG studies. In this study the examiner was blind to the subject's treatment group.

The subject was seated in a comfortable chair and asked to complete the McGill-Melzack Pain Questionnaire, a Visual Analogue Scale, and a Behavior Checklist. The instructions for the McGill-Melzack Pain Questionnaire were from page 12A of the McGill Comprehensive Pain Questionnaire Interviewer Guide and were followed exactly (see Appendix F). For the Visual Analogue Scale the subject was instructed to read the printed directions on the form (see Appendix G), and then to make a mark on the line that best indicated the present level of pain. For the Behavior Checklist the subject was instructed as follows:

> Below is a list of common activities. Please rate how often you perform each of these activities by

> rating them on a scale of 0 (if you never take part in the activity) to 5 (if the activity is something you always do). If the activity is not applicable due to the season or some other reason, please mark N/A beside that activity.

The subject was then presented with the MMPI and instructed to read the directions. Any questions were answered by the examiner and the subject was then instructed to complete the MMPI at home. Finally, posture was evaluated by having the subject stand in front of a clear plastic chart with his/her back to the examiner. The subject secured a belt across the top of the hips and was told to stand in what they considered a normal comfortable position for them. The assessor marked on the chart the location of the bottom of each ear lobe, the nape of the neck, the tips of each shoulder, the middle of the lower back, and the tops of the hips.

After the posture assessment, an electromyographic (EMG) assessment was conducted with the subject assessed in four positions (lying, sitting, standing, and moving). Determination of the placement of the electrodes was done as follows. The subject was instructed to indicate the location on the spine which presented the greatest amount of pain (Floyd & Silver, 1955). This was marked with felt pen. The location was then recorded by measuring the distance from a straight line between the dimples at the top of the sacrum to the point of greatest pain. This was recorded for use in the post treatment assessments. All procedures followed the Biofeedback Society of America standards. First the skin was scrubbed with rubbing alcohol and then abraded with velcro skin rasps from Medicotest Laboratories. Electrode gel (EKG Sol, Burton, Parsons, & Co.) was inserted into the cups of 10 mm silver/silver chloride electrodes with double sided adhesive collars utilized to attach the electrodes. Four electrodes were attached, two on either side of the spine, 2.5 cm away from the spineous processes, 3 cm from center to center, centered about the pain. The resistance was measured using an ohm meter, with any electrode showing greater than 50,000 ohms resistance rejected and reattached until a reading of less than 50,000 ohms was met. A universal reference was located on the spineous processes equidistant from the active electrodes. Analogue data was transmitted to an Apple IIe computer utilizing the Biofeedback Institute of Los Angeles BIOCOMP 2001 system through infrared signal (90 Hz). Data were obtained simultaneously from both set-up sites and converted to digital information at the rate of 15 samples per second. The system calibration utilized for the EMG data was root mean square (RMS) as the RMS varies with the force of muscle contraction, the maximum range of error being 6% (Basmajian, 1967). The bandpass filter setting was that of 80 to 400 Hz (Toomin, 1982). This frequency range was selected as it adequately represents the whole frequency spectrum (Cram, 1986), but minimizes interference from the activity of the heart. The data was automatically stored by the computer which calculated the maximum and average scores in microvolts.

Static Assessment .

For the lying condition, the subject lay supine on a massage table with pillows underneath the head, lower back, and knees. The hands were placed on the stomach. The subject was instructed to lie quietly for 6 minutes and the EMG data recorded. Upon completion the subject was instructed to indicate on the previously used VAS the associated level of pain for this part of the assessment.

The subject was then seated in a chair, staring straight ahead, with the head and arms fully supported, and the feet flat on the floor. The subject was instructed to sit quietly for 6 minutes while the EMG data was recorded. The VAS was completed as per the lying condition.

For standing the subject was instructed to stand in what he/she considered was a normal comfortable position, with the hands at the side, and staring straight ahead. This was held for 6 minutes and the EMG data recorded. The VAS was completed as per the lying condition.

The average score of the 6 minutes for each side of the back in each of the above conditions was recorded.

Dynamic Assessment .

For movement the subject was instructed upon command to bend slowly forward from the waist as far as was comfortable, and to hold that position until ordered to slowly return to the upright position. The arms were allowed to fall free at the sides. The movement was demonstrated by the assessor before the subject proceeded. The complete movement required approximately 7 seconds in total. The maximum contraction for either side was recorded, as was the corresponding reading for the other side. The VAS was completed as per the lying directions.

The total time required for the pretreatment assessment was approximately 1 hour.

Post treatment Assessment #1

Within 4 days of completing the training, all subjects were reassessed by the same assessor in a manner identical to the first assessment.

Post treatment Assessment #2

Three months after the second assessment, the subjects were reassessed by the same examiner in a manner identical to the pretreatment assessment.

Treatment

Assignment to Treatment Group

Upon completion of the initial assessment, the subjects were randomly assigned to one of three treatment conditions on the basis of their number. A table of random numbers (Interstate Commerce Commission, 1949) was consulted with the first number (1 - 36) appearing in the table assigned to group one, the second to group two and so on for all subjects. After all the numbers had been assigned, any number that was vacant due to people dropping out was reassigned in order from smallest to largest. Each treatment group comprised 12 subjects.

Organization of Sessions

All subjects received ten 35-minute sessions. The first session was spent in orientating the subject to the program. Sessions 2 to 9 were spent in treatment, with the last session utilized to measure learning through various testing procedures. At the end of the fifth session subjects were instructed to practise at home what they had learned. At the end of the tenth session subjects were instructed to "apply what they had learned." All subjects were instructed not to receive any other treatment during the duration of the study.

Treatment Group 1 - Biofeedback

At the start of the first session the subject was instructed in the concept of muscle asymmetry, what the lower reading meant, and the relationship of the readings to biomechanical imbalance and the spine. Discussion then followed as to biofeedback in general, EMG biofeedback in particular, and how EMG techniques are applied to muscle problems and back pain. The flexor and extensor bundles of the dominant forearm were studied using routine EMG procedures. The dominant forearm was selected as it was usually uninjured and is neurologically sophisticated. By using bar graphs, the subject was shown muscle contraction patterns for various movements (e.g., making a fist, extending the wrist). He/she was then asked to hold the arm and hand still and try to make the graph of the lower reading go up (increase the activity of the lower reading - usually the extensor bundle). It was explained that there was no right or wrong way of doing this and that most people used trial and error. All subjects managed to learn how to to this within 6 minutes. When they succeeded, subjects were asked to concentrate on exactly what the mental process was that they had used and to describe this to the trainer. The process was discussed with a view to enabling the trainee to develop a cognitive strategy on how to increase muscle activity without moving. Finally this was explained by the trainer in terms of isometric/isotonic contractions and the use of mental techniques in developing the contractions. This process continued until the trainer was satisfied that the trainee understood the concepts of isometric/isotonic contractions and mental imagery, or 35 minutes had expired.

Sessions 2 to 9 followed a standard format. When the subject first came in he/she was asked to complete two Visual Analogue Scales. The first scale (a line 10 cm in length) was employed to measure the present level of the intensity of the pain and to alert the trainer to any severely elevated levels of pain where treatment may be contraindicated. The subject was instructed to make a mark on the line which best represented the present intensity of pain (see Appendix G). The second Analogue Scale measured 10 cm in length, the purpose of which was to document the <u>change</u> in pain from the previous treatment session. Midpoint on the scale (5 cm) reflected no change, while the 0 cm point indicated the pain was 100% worse and the 10 cm point indicated 100%

better. The subject was instructed to make a mark on the scale which best represented the amount of change from the previous session (see Appendix H).

The site that had been assessed by the examiner was utilized for training in all sessions. The area was scrubbed with rubbing alcohol but not abraded, as daily abrasion of the same site was found to develop tenderness of the area. Cram (1986) indicates that compared to other methods of preparation, this method is more than adequate. Two silver/silver chloride electrodes (10 mm in diameter) were attached 2.5 cm from the spineous processes on either side of the spine over the belly of the paraspinal muscles. The distance from center to center of the electrodes was 3 cm. The electrodes were connected by shielded cable to a telemeter which transmitted the data by infrared signal to a BIOCOMP 2001 System. Bar graphs displayed the EMG activity simultaneously in the correct spatial arrangement. The subject was instructed to employ the techniques developed in the first session to increase the activity of the side that showed the lower reading (from the movement assessment). Each training session consisted of two trials. A trial lasted for 6 minutes and was subdivided into six, 1-minute subtrials. The subject was instructed to increase the activity at the start of each minute. If the subject had not obtained an increase in activity after 20 seconds of effort they were told to let the muscle relax for the remainder of that subtrial. If the subject succeeded in increasing the activity they were told to hold it for approximately 10 seconds, then to let the muscle relax for the remainder of that subtrial. All training was undertaken in the standing position as sitting puts the lower back into a flexed position (Middaugh & Kee, 1988). The trainer, during the trials, offered encouragement and positive reinforcement when learning was demonstrated.

When the subject obtained symmetry (both sides at approximately the same level) no further training was completed as this would have produced an asymmetry in the opposite direction. Instead the subject was instructed to stand quietly while readings were taken for two 6-minute trials.

After session 5, the subjects were instructed to practise what they had learned at home and to report any problems to the trainer. Feedback from the reports was viewed as an index on how well the training was progressing with adjustments recommended by the trainer where necessary.

Session 10 was similar to sessions 2 to 9 in that the Visual Analogue Scales were first administered. The subject was hooked up in the usual manner. Instructions were then given that this was a test and the subject would be asked to demonstrate learning by demonstrating control of the target muscles. Using the same length of trial as for the training sessions, the subject was asked once a minute to contract the targetted muscle and hold the contraction for approximately 10 seconds. At the end of the 10 seconds the subject was told to let the contraction go. If the subject succeeded in correctly contracting the muscle six of six times, the session was terminated as the criterion for learning was considered demonstrated. If this criterion was not met, the subject was given a second chance using the same criterion of success.

After the test the subject was instructed to practise what they had learned whenever the pain returned.

Treatment Group 2 - Relaxation Training

At the start of the first session the subject was introduced to the concepts of asymmetry and muscle spasm. In particular it was explained how the higher readings from their back indicated the presence of muscle spasm and how the relaxation program was designed to control the spasm. Pages 49, 50, 52, and 53 (Bernstein & Given, 1984) which outlined the relaxation procedures were read to the subject by the trainer. After discussion of the procedures, the subject was talked through a modified version of progressive muscle relaxation training. This involved having the subject tense and relax 16 various muscle groups (see Table 2). In addition, the subject was taught how to position themself correctly in a recliner chair in the maximally reclined position.

Sessions 2 to 9 followed the same procedures. The subject started the session by completing two Visual Analogue Scales identical in form and content as the scales utilized in Group 1. After completion of these, electrodes were attached to the subject in the standard wrist to wrist placement (Johnson & Hockersmith, 1983). The subject was maximally reclined in the chair supported by a pillow in the lumbar region. Instructions were given for the subject to relax and to minimize movement for 6 minutes, while the EMG cross-body recordings were taken. Johnson and Hockersmith (1983) suggest that this is a valid measure of the amount of muscle activity in the upper torso, reflecting more accurately than forehead readings the level of arousal. These readings were averaged and recorded as pretreatment data.

The subject was disconnected from the EMG and instructed to take three long and deep breaths, exhaling slowly. The training followed the protocol as outlined in Table 2. The subject was instructed to tense the dominant hand and forearm holding it for 7 seconds. Instruction was then given to relax for 10 seconds, followed by directions to tense the same area for another 7 seconds, and then to relax again. This last relaxation lasted approximately 25 seconds. The total time for each muscle group was 1 minute, totalling 16 minutes for training. After the 16 muscle groups were covered, the trainer listed each muscle group asking the trainee to indicate any areas of tension by raising a finger.

TABLE 2

Muscle Groups and Method of Tensing

Muscle Group	Method of Tensing
1. Dominant hand and forearm	Make a tight fist while allowing the upper arm to remain relaxed.
2. Dominant upper arm	Press elbow downward against chair without involving lower arm.
3. Nondominant hand and forearm	Same as dominant.
4. Nondominant upper arm	Same as dominant.
5. Forehead	Raise eyebrows as high as possible.
6. Upper cheeks and nose	Squint eyes and wrinkle nose.
7. Lower face	Clench teeth and pull back corners of the mouth.
8. Neck	Try to raise and lower chin simultaneously.
9. Chest, shoulders, and upper back	Take a deep breath; hold it and pull shoulder blades together.
10. Abdomen	Try to push stomach out and pull it in simultaneously.
11. Dominant upper leg	Try to tense the large muscle on top of leg against two smaller ones underneath.
12. Dominant calf	Point toes toward head.
13. Dominant foot	Point toes downward, turn foot in, and curl toes gently.
14. Nondominant upper leg	Same as dominant.
15. Nondominant calf	Same as dominant.
16. Nondominant foot	Same as dominant.

For any areas of tension the training was repeated once. The subject was instructed not to move while the trainer reconnected the EMG. The post training measurement was taken in a manner identical to the pretraining measurement. This data was then shared with the trainee focusing on what the results meant (i.e., a low reading meant that relaxation was achieved while a high reading suggested difficulties in relaxing).

Session 10 was identical to sessions 2 to 9 except the trainee was advised that this was a test and to relax to the best of their ability. EMG recordings were then taken in the usual manner, with the post training data recorded.

After the testing was completed the trainee was instructed to practise what they had learned during the follow-up phase.

<u>Treatment Group 3 - Education</u>

During the first session the subject was introduced to the theories of pain (pain-spasm-pain model and the biomechanical model) and the relationship of muscle activity to CLBP. Also discussed was the orientation of the program, the limitations due to research, and the outline of the course. Any questions were answered.

Sessions 2 to 9 followed the course as outlined in Table 3 and detailed in Appendix I. At the start of each session the subject filled out two Visual Analogue Scales identical to those completed in Groups 1 and 2. The material selected for that day was presented, mainly through lecture with graphs, charts, and models utilized as necessary. Some modelling was done by the trainer. The modelling was specific on how to position the hands correctly while lifting, the position of the back during lifting, and how to correctly mirror chronic repetitive actions. Discussion was encouraged and questions emphasized.

Session 10 was similar to sessions 2 to 9 in that the subject completed the Visual Analogue Scales. After that he/she was given 10 minutes to complete a 10 question multiple choice questionnaire. This questionnaire was designed by the author, with the 10 questions representing the content of the course. A score of 7 or better was considered as evidence of learning. The remainder of the session was spent discussing the test results and reviewing the course.

The subject was then advised to apply what they had learned during the follow-up period.

TABLE 3

Course Outline

Session #	Content
1	Orientation
2	Anatomy and Physiology
3	Muscles, balance, and posture
4	Lifting, moving and mirroring
5	Exercise
6	Depression
7	Stress
8	Stress Management
9	Handy Dandy Tips
10	Test and Review

Measures

Independent Variable

In the study of muscle activity the use of EMG techniques would appear to adequately reflect the contraction of the muscle. As Basmajian (1967) states "electromyography is unique in revealing what a muscle actually does at any moment during movement and postures. Moreover, it reveals objectively the fine interplay or coordination of muscles; this is patently impossible by any other means" (p. 22). Electrical impulses arriving at the muscle cause contraction of the muscle and "the electrical result ... is an electrical discharge with a median duration of 9 msec and a total amplitude measured in microvolts (mv) (or millionths of a volt)" (Basmajian, 1967, p. 22). Microvolts are thought to correlate with the generated force of the muscle at $r = .9$ (Basmajian, 1967; Bouisset, 1973; Lippold, 1952; Vredenbregt & Rau, 1973).

As a discipline psychology employs the criteria of validity and reliability as the determinants as to scientific acceptability. The validity of EMG techniques may be established by determination of face and concurrent validity. Face validity is established by rigid adherence to standarized procedures when applying surface electrodes (Basmajian & Blumenstein, 1983: Cram, 1988). These procedures include (a) application along the belly of the muscle, (b) monitoring striated muscles which are close enough to the surface to permit pick-up of the signal, (c) avoidance of adipose and thick tissue, (d) utilization of a standard sized electrode and inter-electrode distance, (e) a universal reference, and (f) correct abrasion, application of gel, and good firm adherence. Bouisset and Maton (1973) compared surface electrodes to wire electrodes inserted in the right biceps brachii. While performing an isometric contraction they found a relationship of $r = .98$. The authors concluded that surface electrodes are at least as representive as needle electrodes of the electrical field of the muscle. Anderson, Jonsson, and Ortengren (1974) compared the myoelectric activity recorded by surface electrodes to that from wire electrodes while studying the erector spinae at the L1, L3, and L5 levels with the subjects in numerous positions. The results showed a strong congruence in the amplitudes recorded, but the wire electrodes displayed a higher standard deviation. Based on these results the authors concluded that each type of electrode adequately sampled the myoelectrical activity, but surface electrodes were more precise in their sampling of the activity.

Reliability of EMG scores have been established by various authors in test-retest studies. Jonsson and Komi (1973), utilizing the brachioradialis, compared surface to needle electrodes at 10-minute and at 3-day intervals under various isometric load conditions (20 - 100 units of tension). Studying 12 subjects, the authors found that the reliability coefficient for the surface electrodes for the 10-minute interval was r =.88 and .69 for the 3-day interval. Komi and Buskirk (1970) studied the test-retest reliabilites of surface electrodes assessing isometric and isotonic contractions. They found the coefficients for 3 and 55 days ranged from .91 to .97. Cram (1986) studied 12 chronic pain patients examining 11 different muscle sites. Using post electrodes with a filter range of 100 to 200 Hz and no abrade/electrode paste conditions, he found a median coefficient of r = .83 for all sites. Coefficients of r = .80 and r = .66 for the left side T10 paraspinals during sitting and standing respectively, and r = .57 and r = .84 for the right side are reported. Results for the lumbar (L3) paraspinals showed a similar pattern (r = .99 and r = .57 for the left side, and r = .77 and r = .78 for the right side respectively). Cram (1986) concludes "the test-retest correlations should be considered fairly good, and approximately in the same ball park as those seen with test-retest of attached electrodes" (p. 85).

In summary, EMG values appear to adequately represent the amount of force generated by the muscle. Test-retest studies (Cram, 1986; Jonsson & Komi, 1973; Komi & Buskirk, 1970) suggest the EMG as a measure is reliable, while concurrent validity was established by Bouisset and Maton (1973) and Anderson, Jonsson, and Ortengren (1974). Face validity may be established by careful adherence to standard operational procedures (Basmajian & Blumenstein, 1983).

The independent variable in this study is the muscle activity of the lower thoracic and lumbar paraspinal processes (T10 to L5) as measured in microvolts. The muscle activity was measured as the subject lay, sat, stood, and moved about producing four levels of the variable. The pain-spasm-pain model predicts that the higher reading of the two would be associated with the pain, while the biomechanical model predicts that the bilateral difference would be associated with the pain. Both the bilateral difference (d) and the higher amplitude (a) were treated as the independent variable as these measures may be related.

Dependent Variables

A review of the literature reveals that the assessment of chronic pain has become multifaceted in nature. Keefe (1982), Keefe et al. (1982), Melzack and Wall (1982), Naliboff et al. (1985), Turk et al. (1983), and Turk and Flor (1984) all report that the assessment of chronic pain should involve measures of pain, personality, behavior, and physiology. The dependent variables chosen for this study reflect the current thinking.

Measures of Pain .

McGill-Melzack Pain Questionnaire.

The McGill-Melzack Pain Questionnaire (MPQ) is presently one of the most commonly utilized instruments in the study of pain. The checklist consists of 102 adjectives divided into 20 categories that describe three aspects of pain (sensory, affective, and evaluative). The test gives three types of measures:

(a) a pain rating index (PRI-T) which is based on the rank order values of the words, (b) the number of words chosen, and (c) the present pain intensity. Melzack (1983) states:

> Each type of data represents a quantitative index of pain and can also be used to indicate the extent of change in pain quality and intensity as a result of some manipulative procedure. The questionnaire is administered before and after the procedure, and the difference can be expressed as a percentage change from the initial value. (p. 45)

Numerous studies have indicated the validity of the MPQ. Reading (1983) suggested that the instrument has "performed favorably, displaying acceptable reliability and face, construct, discriminant and concurrent validity" (p. 59). Reading (1983) reports a consistency index of 75% (range 35 to 90%) between weekly administrations on cancer patients. These findings are consistent with those of Melzack (1975) who reported a consistency index of 70.3% from 10 cancer patients over a three day period. Reading (1983) suggests that the MPQ's face validity is established by the number of studies in which it is utilized as a dependent measure. Construct validity has been established by various authors (Atkinson, Kremer, & Ignelzi, 1982; Byrne et al., 1982; Kremer, Atkinson, & Ignelzi, 1981, 1982; Kremer, Atkinson & Kremer, 1983; Kremer, Block, & Atkinson, 1983; Reading, Hand, & Sledmere, 1983) with the results suggesting that four main factors (sensory, affective, evaluative, and sensory-affective) account for the variance. The MPQ has been compared to the Visual Analogue Scale (Gaston-Johansson, 1984), analgesic requirements (Reading, 1982), and ratings of headache intensity (Hunter & Philips, 1981) to establish the concurrent validity. Turk, Rudy, and Salovey (1985) studied the MPQ responses of two groups of chronic pain patients (a diversified pain group n = 70 and a low back pain group n = 98). In attempting to cross validate the independence of the three subscales they found the average between subclass correlations to be larger than the within subgroup correlations. The authors concluded that the MPQ does not demonstrate discriminant validity but offers a "measure of general pain severity" (p. 395).

The MPQ has been particularly utilized in the study of chronic pain. When acute pain patients are compared to chronic pain patients, the chronic pain patients report higher scores due to a loading on the affective components of the scale (Bradley, 1983; Kremer et al., 1982; Kremer, Block, et al., 1983; McCreary, Turner, & Dawson, 1981; Reading, 1982; Sedlak, 1985).

A problem with the MPQ is that the words are difficult to understand for some people with reading difficulties or divergent ethnic backgrounds. This restricts the type of populace to which the test may be administered. In an effort to counteract this, the words may be read to the subject. While there appears to be a slight difference in results (the subjects, when read to, produce slightly higher scores), Melzack (1983) suggests that either method is acceptable when applied consistantly. The nature of the data lends itself to problems, for when used as a measure of change the difference in scores between administrations is converted to a percentage. Thus a change from 4 to 2 is as significant as a change from 40 to 20. Various methods have been proposed as alternatives, however none as yet are sufficently standardized (Melzack, 1983). Lodge and Tursky (1981) criticize the MPQ on the basis that it induces a response bias by imposing response constraints.

Despite these problems the MPQ appears to have adequate reliability and validity, plus it is sensitive to changes in pain making it an effective measurement for the study of treatment effects. Utilization of the MPQ PRI-T score appears to give a good measure of general pain severity.

The subjects were instructed to pick the words that "best describe your present pain. Leave out any word group that is not suitable. Use only a single word in each appropriate group-the one that applies best." (McGill Comprehensive Pain Questionnaire Interviewer Guide, p. 12A). The pain rating index (PRI) was obtained by totalling the rank values for the words chosen from each box (i.e., the first word in each box received a score of one, the second a score of two, etc.) (Melzack, 1983). Turk et al. (1985), in reviewing the relationship of the three components (sensory, affective, and evaluative) found that the scores were highly interrelated and recommended that only the total score be utilized in pain assessment. In view of the results of Turk et al. (1985) only the total rank score of the PRI was employed from each administration.

Visual Analogue Scale.

The Visual Analogue Scale (VAS) "is a line, usually 10 cm in length, the extremes of which are taken to represent the limits of the pain experience; one end is therefore defined as 'no pain' and the other as 'severe pain'" (Huskisson, 1983, p. 33). The VAS yields an unidimensional estimate of pain intensity. It has been utilized extensively in the study of pain generally for the purpose of establishing the efficacy of treatment.

Huskisson (1983) reports that visual analogue scales are easily understood, the distribution of results is uniform in an unselected population making it sensitive to change, and the results have a good correlation with verbal descriptive scales. Scott and Huskisson (1979) report test-retest correlations of .99 on successive administrations. Carlsson (1983) suggests the instrument is valid as it is responsive to changes in chronic pain when used in pharmacological studies.

The major difficulty with the scale is that it is undimensonal reducing the complex nature of chronic pain into a single dimension labelled intensity (Carlsson 1983, 1984; Lodge & Tursky, 1981). In addition, the limitation imposed by the ends of the scale may lead to distortion of the response. If an individual utilizes the end of the scale, then changes further in that direction, it is not possible to indicate that change. Change relief scales were designed in an effort to account for this problem. However Carlsson (1983), in comparing an absolute to a comparative scale, found the absolute scale to be less sensitive to bias than the comparative scale and therefore it is preferable for general clinical use. The advantage of the comparative type scale is all subjects start from the same point and consequently the scale is easier to use. Finally, the data produced by the scales is assumed to be equal in interval and treated statistically in this manner

(Carlsson, 1983).

Despite these limitations the VAS enjoys popularity as a tool in chronic pain research. Its ease of administration, sensitivity as a measure, and reliability make it suited for the study of treatment effects.

The assessor read the instructions as printed on the form to the subject. These were as follows:

> Below is a line 10 cm long. We would like you to draw a mark on this line at the point which best indicates how severe your pain is. The left end of the scale will indicate no pain, the right end will indicate the worst possible pain. There is no right or wrong answer, only the amount that you feel.

The subjects then were asked to make a mark on the line which best represented the amount of pain they were in at that moment. This was recorded as the VAS-General score. After the subject completed the supine part of the EMG assessment, they were given the same VAS form previously used and asked to make a mark on the line which represented the amount of pain they were in during that part of the assessment. This was recorded as the VAS-lying score. This process was repeated for the sitting, standing, and movement parts of the iEMG assessment, with the scores recorded as the VAS-sit, VAS-stand, and VAS-move scores respectively.

Two Visual Analogue Scales were also employed during treatment in order to document the rate of change and protect the subject in case any treatment procedures caused an increase in pain. The two scales employed were absolute and comparative in type (Carlsson 1983). These were administered by the trainer each day prior to treatment except for the first day. The directions for the absolute scale were the same as those listed above for the VAS-general. For the comparative scale, the subject was read the instructions as follows:

> Below is a line 10 cm long. We would like you to draw a mark on this line that represents the percent change in your pain since the last appointment. The middle of the line represents no change; to the left of centre represents the pain getting worse (increasing); to the right of centre represents the pain getting better (decreasing). Please remember there is no right or wrong answer, only the change you feel since your last appointment.

Any questions were answered, with the scale then completed. The scores for the 9 days were recorded as VAS-intensity and VAS-change.

<u>Measures of Personality</u> .

MMPI.

The MMPI is one of the oldest and most commonly used psychological tests today. Developed by Hathaway and McKinley (1951) the test was intended as an objective aid in psychiatric diagnosis. Since that time the MMPI has been employed in the assessment of numerous dysfunctions. For example, Trief and Yuan (1983) and

Keefe et al. (1982) suggest that the MMPI is the only objective test that predicts the response to medical or surgical treatment. Due to the extensive amount of literature, the following discussion is limited to the use of the MMPI in chronic pain assessment and treatment.

The recognition that CLBP patients feel depressed, anxious and have numerous physical problems (Keefe, 1982) led to the utilization of the MMPI for the assessment of personality variables (i.e., traits which were thought to cause pain). However, the results of numerous descriptive, diagnostic, and predictive studies are not consistent (Keefe, 1982). Keefe goes on to suggest that the "major problem with the MMPI research on chronic pain is that it has tended to rely on univariate statistical comparisons of composite groups of patients. This approach has fostered the 'illusion of homogeneity':..." (p. 901). Recent research (Bradley et al., 1978; Costello et al., 1987; Grubman, 1984; McGill et al., 1983; Schmidt & Wallace, 1982) suggests that CLBP patients (a) do not form a homogeneous group, (b) that sub-groups may be identified, and (c) these subgroups have distinct behavioral correlates (Keefe, 1982).

Of the 10 clinical scales the Hypochondriasis scale

(#1), Depression scale (#2), and Hysteria scale (#3) are most commonly referred to in the study of CLBP. Keefe et al. (1982) in reviewing the literature suggest that CLBP patients are likely to have elevated #1, 2, and 3 scales. The authors suggest that this elevation is known as the 'neurotic triad' with the pattern suggesting a high degree of depression, denial of emotional conflicts, and the expression of needs through somatic symptoms. Hendler (1982) suggests the #1 and 3 scales become elevated during the subacute phase (2 to 6 months) with the #2 scale becoming elevated during the chronic phase (6 months to 8 years). Kleinke and Stephenson (1988) when studying 42 CLBP patients report that scores on the #2 and 3 scales were associated with the greatest admission to discharge improvement. Barnes, Smith, Gatchel and Mayer (1989) utilized the MMPI to discriminate patients who successfully completed a back rehabilitation program versus those who failed, versus those who dropped out. Based upon a sample of 150 patients it was found that the average scores for three MMPI scales were all above 70 with the two negative outcome groups significantly ($p < .05$) higher. Employing these three scales, Timmermans and Sternbach (1976) showed that chronic pain patients of greater than 6 months duration showed significant (a T score greater than 70) elevations. These elevations were reversed with successful alleviation of the pain by various treatments. Melzack and Wall (1982), in reviewing the results from Timmermans and Sternbach, suggest that chronic pain is usually the cause rather than the result of neurotic patterns with decreases in the three scales evident after successful treatment.

Scale #1 (Hypochondriasis scale) was designed to assess a neurotic concern over bodily functioning employing 33 items which are mainly focused on the abdomen and back. A person who is actually physically ill obtains a moderate score (a T score of 60 - 65). T scores above this range are assumed to reflect character features in addition to the physical factors (Carson, 1969; Graham, 1987; Greene, 1980). Using multiple regression techniques, Naliboff et al. (1982) found scale #1 T scores correlated ($r = .31$) to the Functional Limitation Scale (a subjective measure of the ability to perform ordinary daily tasks) for 74 CLBP subjects, suggesting (as the authors state) this scale is related to the perceived limitations that the pain imposes.

For scale #1 test-retest reliability coefficents range from .79 to .86 for a two-week interval and .38 to .65 for a one-year interval (Dahlstrom, Welsh, & Dahlstrom, 1975).

Scale #2 (Depression) contains 60 items designed to measure a general attitude characterized by poor morale, lack of hope, and apathy (Carson, 1969; Graham, 1987; Greene, 1980). Thought to be a measure of reactive or exogenous depression, scale #2 scores are expected to fluctuate as the mood changes. Watson (1982), using item analysis, found the scale to reflect a considerable amount of depressive symptomatology (sleep disturbance, poor self-esteem, apathy, helplessness, anxiety, and dissatisfaction) rather than personality traits. Using multiple regression techniques Naliboff et al. (1982) found a relationship ($r = .20$) between this scale and the Functional Limitation Scale.

Reliability coefficients for 30-day intervals of .80 to .90 are reported by Dahlstrom et al. (1975).

Scale #3 (Hysteria) consists of 60 items designed to measure specific somatic complaints and social adjustment. While the relationship between these factors in well adjusted individuals is weak, in chronic pain patients the factors may interact, producing conversion-type symptoms used as a means of resolving conflicts and avoiding responsibility. A score of 70 and above suggests that these individuals convert stress into physical complaints (Graham, 1987; Greene, 1980). Using multiple regression techniques, Naliboff et al.

(1982) found this scale related to the physical limitations of the dysfunction (r = .30) rather than the reported level of pain.

Test-retest reliability coefficients range from .63 to .84 for two-week intervals and .36 to .72 for one-year intervals (Dahlstrom et al., 1975).

In summary, scales # 1, 2 and 3 appear to measure personality factors associated with CLBP, have been extensively studied, and appear to be reactive to changes in treatment (Hendler, 1982; Melzack & Wall, 1982; Timmermans & Sternbach, 1976).

The subjects were given a MMPI test booklet (University of Minnesota Press, 1982) and asked to read the instructions as listed on the inside cover. Upon completion of this they were asked if they had any questions, which were answered by the assessor. The booklet and answer sheet were completed at home by the subject and returned to experimenter. The raw scores were converted into T scores using Insite MMPI Software, IBM version. The T scores were utilized for data analysis.

<u>Behavioral Measures</u> .

Behavior Checklist.

Since the works by Fordyce (1976), much interest in the behavioral correlates of CLBP has emerged. By utilizing behavior measures Fordyce, Roberts, and Sternbach (1985) suggest that the level of disability and expression of suffering is measured. Numerous behaviors have been monitored. Turk, Wack, and Kerns (1985), in reviewing the behavioral constructs utilized by psychologists and physicians, found four factors which account for most behaviors. These were (a) distorted ambulation or posture, (b) negative affect, (c) facial/audible expressions of distress, and (d) avoidance of activity. One factor labelled as avoidance of activity reflects a decrease in physical activity and increase in down time (i.e., rest). Fordyce et al. (1985), Haley et al. (1985), Linton (1985), Waddell (1987), and Wilson (1981) found that the activity levels of CLBP patients were not proportional to the reported pain, with the activity level generally lower than what would be expected. The authors concluded that other factors (e.g., functional disability) in addition to pain may contribute to the decrease in activity, but presently research in this field is lacking.

One method of behavioral assessment is to have the subject record the amount of activity. These observation techniques are widely utilized because they are (a) inexpensive, (b) may be carried out in various settings allowing for long term assessments, and (c) may lead to increased self-awareness of the targetted behaviors (Keefe et al., 1982). Philips and Jahanshani (1986) examined the reliability of the Pain Behavior Checklist over a one week period. Data collected from 25 headache sufferers indicated a test-retest coefficient of r = .72 for the total score. Factor analysis of the test's 49 items suggested that six factors all related to avoidance behaviors accounted for 42.6% of the total variance. The authors suggest that avoidance behavior is a crucial consequence of chronic pain.

Developed by Turk et al. (1983), the Behavior Checklist (BCL) is a menu-driven scale consisting of 30 activities (e.g., do some physical exercise) commonly affected by CLBP. Visual inspection suggests that the items may be grouped into four categories: (a) household activities, (b) social activities, (c) exercise, and (d) leisure activities. A six point scale was employed with the subject indicating his/her perception of how much he/she engages in each activity. A further category of "not applicable" was also available for items which did not apply due to season or lifestyle. Communication with the authors (December, 1987) indicated that the studies concerning the test-retest reliability of this measure were progressing but no data were yet available.

As the 30 items appeared to reflect activities common to much of the population, the six point scale allowed for the reporting of the lack of activity (avoidance of activity) and for changes to be reported (necessary in repeated measures), and the not applicable category appeared to increase validity by discarding those activities which were not individually relevant, it was decided to utilize this test.

The subject was presented the BCL and instructed as previously outlined.

The average score for all the activities was calculated by totalling the scores for the activities and dividing this by the number of scored activities. Linton (1985) indicates that activity and pain levels are related when global scores are utilized. Thus, the average score for each subject was utilized as the dependent variable.

Postural Measure.

The avoidance of pain is a very strong stimulus leading to the adoption of postures which will minimize the pain. The straightness of the spine is maintained by the activity of the ligaments and paraspinal processes. Most subjects standing in a relaxed position show little muscular activity with an equilibrium across the spine (Basmajian, 1976). Hoogmartens and Basmajian

(1976) found that idiopathic scoliosis was caused by an asymmetrical pattern of muscle activity, with increased activity found on the side of the curve. Various authors (Cram, 1986; Cram & Engstrom, 1986; Jones & Wolf, 1980; Wilson & Schneider, 1985; Wolf et al., 1982) indicated that incorrect posture is reflected in asymmetrical activity of the paraspinal muscles. Correction of the asymmetry should lead to a change in the posture.

The Posture Evaluation Kit is a clear plastic posture grid 63.5 x 122 cm (25 x 48 inches) which is suspended from a ceiling or wall. The chart is sub-divided into grids forming rectangles 5 x 14 cm in size, 21 from top to bottom and four from side to side. Perfect vertical was achieved by a plumb-bob suspended from the middle of the top of the chart to which the chart is centered. The subject was asked to stand behind the chart, facing away from the examiner. A clear plastic flexible tube was given to the subject with the instructions to tie the tube around the hips so the tube rested on top of the hips (crest of the ilium). The subject was then asked to stand still in a normal comfortable position with the arms at their side. The examiner marked on the chart the following points: (a) the top of the hips as represented by the belt, (b) the midline of the back, (c) the apex of the shoulders, (d) the mid line of the neck, and (e) the tip of the lobe of the ears.

Scoring of the chart was completed after the subject had left the room. For the hips the distance from the nearest horizontal grid line for each hip was measured. If the hips were equal distance from the grid line or within 1/2 inch of equal distance (representing symmetry) then a mark of 10 was given. Nigl (1984) indicates that a difference of less than 1/2 inch does not significantly affect the muscle activity. If the difference was 1/2 to 1.0 inch a score of 5 was assigned. If the deviation was over 1 inch then a score of 0 was given. This process was repeated for the shoulders and the lobes of the ears. The deviation of the spine from the vertical was calculated by drawing a straight line from the lower mid back mark to the mark from the neck. The deviation from the vertical was then calculated with no deviation to 1/2 inch scored as a 10, 1/2 inch to 1 inch a 5, and over 1 inch a 0. These scores were then totalled to give a total posture score.

As the scoring of the chart was novel in its approach, validity of the procedure was established by comparing the examiner to a known standard (a physiotherapist). Following the above procedure, both assessors screened 5 randomly selected CLBP pain subjects. The results showed a correlation of $r = .67$. Although more research should be conducted, the results indicate that the examiner's assessment is consistent with acceptable professional standards.

Summary

The assessment of CLBP involves a number of variables all of which contribute to the cause and maintenance of the pain pattern. Numerous authors (Fordyce et al., 1985; Keefe, 1982; Keefe et al., 1982; Melzack and Wall, 1983; Naliboff et al., 1982; Turk & Flor, 1984; Turk et al., 1983; Waddell, 1987; Waddell et al., 1984) indicated that (a) the perception of pain, (b) personality variables, and (c) behavior correlates need to be studied if a thorough understanding of this complex phenomenon is to be achieved.

Statistical Analysis

The basic statistical analysis employed was a 3 x 3 repeated measures analysis of variance where one factor was group (biofeedback, relaxation, education) and the other was time (pre, post, follow-up). Because there was more than one dependent measure, in order to protect against inflated Type I error rates, multivariate analysis of variance was used, as appropriate. The procedures recommended by Leary and Altmaier (1980) were followed. These authors suggest performing MANOVAs on homogeneous subsets of variables. The utilization of MANOVAs in this restricted fashion reduces the risk of obtaining significant results by chance (Type I errors) as may be the case when ANOVAs are repeatedly utilized, and also allows for examination of significant differences which may be confined to one or two variables (the homogeneous subset) which might otherwise be lost in the midst of other nonsignificant variables, thereby reducing the risk of Type II errors. When significant results are found from these analyses, univariate procedures are then employed to test for the significance of the individual measures. Hummel and Sligo (cited in Leary and Altmaier, 1980) argue that using the multivariate-univariate combination in this manner results in an experimental error rate that is consistent regardless of the number of comparisons made.

Inspection of the dependent variables indicated that (a) the measures of the general levels of pain would be grouped together (i.e., MPQ and VAS-General), as could (b) the three MMPI measures. The VAS pain scores for the four assessment positions were considered to be components of the VAS-General score and were therefore not combined into a composite via MANOVA. (The two VAS which monitored the intensity of and change in pain daily during treatment were considered separately.) The data from the BCL and Posture assessment were considered to be measuring factors different from the other data and consequently not grouped in a subset.

Subset #1 included the data from the MPQ and VAS-General as both of these measures were designed to assess the subject's perception of his/her pain in general. Personality measures were grouped together forming a second subset (Subset #2) and consisted of the scores from the three scales of the MMPI. These subsets were then analyzed employing a two-way MANOVA (group by time) producing a 3 x 3 mixed between-within design. Pillai's criterion was selected as the criterion for statistical inference in view of its robustness with a smaller sample (Tabachnick & Fidell, 1983, p. 249). When significant results were obtained the measures were then individually studied utilizing a two-way ANOVA (Hinkle, Wiersma, & Jurs, 1979).

For those measures that were considered different from each other [VAS scales (except for the General score), the BCL data, and the scores from the Posture analysis] two-way ANOVAs were utilized to analyze the data. This allowed for the examination of main effects [(group - 3 levels) and (time - 3 levels)] and the interaction between them (group by time) producing a 3 x 3 mixed between-within ANOVA. The two daily treatment VAS scores were each aggregated into three scores representing the averages for days 2 - 4, 5 - 7, 8 - 10. These average scores for each VAS were then analyzed using two-way ANOVAs as outlined above.

The change in the magnitude of the independent variable (EMG scores) was studied by utilizing two-way ANOVAs. Benjamin (1983) recommended the use of covariate techniques in analyzing psychophysiological data because of the effect of the Law of Initial Values. This law suggests that the size of the response to an experimental stimulus is related to the prestimulus value. However, using initial or prestimulus data as a covariate conceals any trends that may be present from pretreatment to post treatment. Furthermore, when examination of the prestimulus data shows no significant between groups differences the effect of the Law of Initial Values is not relevant. Utilization of a two-way ANOVA (group by time) was employed for the EMG values rather than ANCOVA as there were no significant pretreatment differences found (see Chapter Five) and the rate of change between pretreatment and post treatment was considered an important area of study.

The EMG pretreatment data were also analyzed correlating these values with the MPQ and VAS scores. Their relationship to the MPQ was established with Pearson product-moment coefficients which were derived by correlating the individual average EMG scores of amplitude and bilateral difference (five and four respectively) to the total score from the MPQ. Multiple regression procedures were then utilized combining the EMG scores in various ways to determine the greatest multiple correlations. This procedure was then repeated for the VAS scores.

Finally, the EMG scores were themselves intercorrelated, and so were all the dependent variables.

In summary, for the dependent variables when they were considered conceptually to be measuring the same factor two-way MANOVAs were performed. When significant multivariate F ratios were obtained univariate analyses of the measures were then performed. In those cases where the variables were considered conceptually to be measuring different factors two-way ANOVAs were conducted. Two-way ANOVAs were also utilized in the analyses of the independent variable (EMG) to verify that it had been effectively manipulated. (N.B. In these analyses the EMG became the <u>dependent</u> variable.)

CHAPTER FOUR

Results

Demographic Data

Data was gathered on 36 subjects through interview by the author and examination by the physician. This information was subdivided into four categories; (a) descriptive data, (b) type and nature of pain, (c) history of treatment, and (d) medical findings.

Descriptive Data

The descriptive data revealed that there was an almost equal number of males and females (n = 17 and 19 respectively), who on the average were 38.0 years old (SD = 7.5 years with a range from 24 - 54 years). A one-way ANOVA performed on age showed no significant differences between the three groups, although the F ratio approached significance [$F(2,33) = 3.057$, $p < .06$], with the biofeedback group (M = 42.2, SD = 7.1) approximately 6 years older than the relaxation group (M = 35.8, SD = 6.5) and the education group (M = 36.1, SD = 7.7). All subjects were employed in the same occupation for an average of 8.8 years (SD = 6.9).

Nature and Type of Pain

Data as to the nature and type of pain revealed that pain was most commonly experienced in the lumbar region at the L3 level with the other lumbar levels also highly painful (see Table 4 for details). On the average, the subjects reported being in pain for 83.44 months (SD = 80.33 months with a range of 72 - 360 months). A one-way between groups ANOVA showed no significant differences [$F(2,33) = 2.19$]. The biofeedback group was in pain for an average of 110.82 months (SD = 100.02), the relaxation group 55.00 months (SD = 42.73) and the education group 75.33 months (SD = 78.23). Although the biofeedback group's average duration of pain was twice that of the relaxation group, the variability was also considerably greater. The pain was reported as occurring daily, varying in intensity (owing to fatigue, posture, and activity), with at least one other muscle group (usually the neck) sore. Twenty-six subjects reported stiffness upon rising in the morning. Trauma (usually a motor vehicle accident) was the cause of the pain in 21 cases, with 9 others caused by lifting. Lifting exacerbated the pain in 24 subjects. Half the subjects (18) reported a parent or sibling as having experienced CLBP. Discussion with the 18 subjects revealed 5 were in a similar occupation to the injured family member. Table 4 summarizes the nature and type of pain.

TABLE 4

Nature and Type of Pain

Location	Frequency
T10	5
T11	6
T12	4
L1	15
L2	22
L3	25
L4	23
L5	17
S1	9
Duration	M = 83.4 months SD = 80.3 months
Frequency of Occurrence	Daily
Intensity	Varied
(Factors)	(fatigue, position, activity)
Pain reported in one or more other muscles	36
Stiffness reported after sleep	26
Positive neurological history	none
Trauma caused pain	21
Lifting caused onset of pain	9
Lifting made pain worse	24
Family history of pain	18

<u>History of Treatment</u>

Examination of the history of previous treatments (related to the back pain) indicated that on the average the subjects had received 1.7 courses of physiotherapy, and received 1.5 different types of medication (no subjects were presently on medication). Twenty-five subjects had received chiropractic treatments but the duration and frequency was so variable so as to render analysis meaningless. Six subjects had been hospitalized for their back pain, 8 had had abdominal surgery and 13 had worn a cast on a limb.

Medical Findings

Generally, the medical findings were not significant. This was to be expected, for evidence of neurological dysfunction was reason for exclusion from the study. The physician was able to detect muscle spasm in approximately half the subjects. Examination of the range of motion (ROM) data indicated that on the average the subjects could come within 7.55 cm of touching the floor. The biofeedback group showed a mean of 10.28 cm (SD = 9.12), the relaxation group 4.38 cm (SD = 7.78), and the education group 8.00 cm (SD = 10.67), with a one-way ANOVA showing no significant between group differences [$F(2,33) = 1.25$]. Schober's test of Skin Distraction was within normal limits (Moll & Wright, 1976). The mean scores were 6.96 (SD = 1.54), 6.33 (SD = 1.69), 7.00 (SD = 2.03) for the biofeedback, relaxation, and education groups respectively. Between groups ANOVA performed on the Schober's test scores showed no significant differences [$F(2,33) = 0.55$]. With one exception, the CBCs were not significant suggesting that infection was not prevalent. The one positive CBC was related to a disease which did not affect the study (Dr. E. Gingrich, personal communication, January 20, 1989). Not all subjects had X-rays, but those who did were diagnosed as normal.

Table 5 summarizes the medical findings.

Table 5

Medical Findings

Procedure	Outcome
Gait Analysis	33 normal, 3 guarded
Spinal Curvature	30 normal, 6 absent
Muscle Spasm	21 present
Range of Motion	M = 7.2 cm SD = 9.1 cm
Schober's Skin Distraction	M = 6.6 cm SD = 2.0 cm
Spinal Tenderness	22 present
Pain with leg raise > 70 degrees	31 normal, 5 pain
Plantar Reflexes	32 normal, 4 weakened
Heel Walk	35 normal, 1 pain
Toe Walk	35 normal, 1 pain
Squat	34 normal, 2 pain
Sit Up	31 normal, 5 pain
Patellar Reflexes	36 normal
Achilles Reflexes	36 normal
Babinski Reflexes	36 normal
CBC	35 normal, 1 abnormal
X-Rays	22 available - normal

<u>Summary</u>

In summary, the typical subject was 38.0 years old, employed in the same vocation for the last 8 years. The pain was most commonly located at the L3 level, starting 83.8 months previously, occurring daily to the point of interfering with activity, and varying in intensity. Pain in one other muscle group (usually the neck) was noted, as was stiffness upon rising. Trauma (e.g., motor vehicle accident) was the most common precipitating factor of the pain, while lifting intensified it. A positive family history was noted in half the subjects. Previous treatments included physiotherapy, chiropractic therapy, the use of medications, and some hospitalization. Unlike Wilson and Schneider's (1985) sample, the majority of subjects had not worn a cast.

The sample could best be described as the "walking wounded". They continued to function and work but experienced pain which affected their lives on a daily basis.

Independent Variable - Electromyographic Data

Two measures of electromyographic activity (the amplitude and the bilateral difference) were examined in terms of (a) the variance before and after treatment and at follow-up, and (b) their relationship to the reported pain measures for the four assessment conditions (lying, sitting, standing, and movement).

Amplitude was utilized as one measure, as the pain-spasm-pain model predicts that the pain would be proportional to the amount of muscle tension measured. For the lying, sitting, and standing parts of the assessment the amplitude was determined by obtaining an average score for the 6 minute sample for both sides (left and right) at the pain site, then selecting the higher score as the indicator of muscle tension. For movement the muscle firing pattern was examined and the point of maximum contraction for the entire pattern was determined. This maximum score was employed as one set of data (labelled as movement-high). The score of the side opposite to the maximum contraction was also examined and labelled as movement-low. In total, five sets of data for the amplitude were examined.

The <u>bilateral difference</u> was utilized as a second measure as the biomechanical model predicts that this score is related to pain. The bilateral difference (d) for the lying, sitting, and standing parts of the assessment was determined by calculating the difference between the average higher reading minus the average lower reading for each condition. The d score for movement was determined by subtracting the corresponding lower score from the maximum contraction higher score. This produced four sets of data for analysis.

<u>Pretreatment EMG Scores</u>

Pretreatment EMG readings were obtained for each assessment condition and analyzed as to differences utilizing a between groups ANOVA. The results showed no significant differences between groups for any condition as outlined in Table 6.

Table 6

Pretest EMG Data and F Ratios

Condition		Group			F(2,33)	p
		Biof.	Relax.	Educ.		
	Amplitude					
lying	M	3.14	1.30	2.86	1.63	.21
	SD	2.69	0.53	3.79		
sitting	M	6.13	3.77	3.73	1.16	.32
	SD	5.71	4.17	2.97		
standing	M	8.20	6.04	7.44	0.57	NS
	SD	6.35	4.64	3.68		
movement						
(high)	M	49.00	42.78	47.28	0.18	NS
	SD	30.33	28.01	18.56		
(low)	M	39.33	35.08	34.95	0.20	NS
	SD	18.34	25.53	10.65		
	Bilateral Difference					
lying	M	1.96	0.70	1.50	2.69	.08
	SD	2.05	0.56	0.99		
sitting	M	2.29	1.80	1.58	0.44	NS
	SD	1.98	2.34	1.28		
standing	M	2.13	2.34	3.16	0.66	NS
	SD	1.86	1.95	2.96		
movement	M	9.73	8.50	12.33	0.20	NS
	SD	21.82	7.70	12.34		

Note: N.S. indicates the value was over .50, biof. = biofeedback, relax. = relaxation, educ. = education groups, respectively.

Analysis of EMG Scores

EMG Amplitude Scores Over Time .

The means and standard deviations of the amplitude scores were calculated for each group for each assessent. Examination of the scores over time revealed that for the biofeedback group the means decreased over time for all conditions. The relaxation group scores increased in average amplitude for the lying, sitting, standing, and movement-low conditions, and decreased in the movement-high condition. The education group decreased in average amplitude for lying, sitting, and standing conditions, with increases in both movement scores. These results are listed in Table 7.

Table 7

EMG Amplitude Scores over Time for Each Condition

Condition	Group		Time		
			Pre	Post	Follow-up
Lying	Biof.	M	3.14	2.04	2.37
		SD	2.69	0.97	2.36
	Relax.	M	1.30	1.87	2.93
		SD	0.53	1.13	5.49
	Educ.	M	2.86	2.17	1.82
		SD	3.79	0.85	1.15
Sitting	Biof.	M	<u>6.13</u>	<u>4.27</u>	<u>3.08</u>
		SD	5.71	2.97	2.27
	Relax.	M	<u>3.77</u>	<u>4.83</u>	<u>6.22</u>
		SD	4.17	4.19	7.03
	Educ.	M	<u>3.73</u>	<u>5.60</u>	<u>3.45</u>
		SD	2.97	4.33	3.16
Standing	Biof.	M	8.20	7.76	6.15
		SD	6.35	7.58	3.63
	Relax.	M	6.04	5.86	6.11
		SD	4.64	4.10	6.14
	Educ.	M	7.44	7.02	6.55
		SD	3.68	3.09	4.47
Movement (high)	Biof.	M	49.01	57.61	43.00
		SD	30.33	31.15	20.90
	Relax	M	42.78	47.99	44.33
		SD	28.01	21.91	21.97
	Educ.	M	47.28	49.02	48.65
		SD	18.56	17.13	25.35
(low)	Biof.	M	39.33	44.26	38.98
		SD	18.34	25.98	19.88
	Relax.	M	35.08	41.01	37.05
		SD	25.53	18.71	18.62
	Educ.	M	34.95	40.65	41.37
		SD	10.65	14.66	22.56

Note: Underlined scores indicates significant differences, pre = pretreatment, post = post treatment, respectively.

The scores for each condition and group were subjected to a two-way ANOVA (group by time). No significant results were obtained except for the groups by time interaction for sitting [F(4,103) = 3.00, p = .02] and over time for movement-low [F(4,103) = 3.04, p = .05]. The sitting data were then examined for simple main effects at pre, post and follow-up. The analyses showed no significant differences [F(2,33) = 1.16, 0.36 and 2.18] for the three assessments, respectively. All F scores are reported in Table 8.

Table 8

Group by Time ANOVAs of EMG Amplitude Scores

Condition	Source	df	F	p
lying	group	2,105	0.28	NS
	time	2,105	0.33	NS
	group x time	4,103	1.15	.34
sitting	group	2,105	0.12	NS
	time	2,105	0.39	NS
	group x time	4,103	3.00	.02
standing	group	2,105	0.33	NS
	time	2,105	0.78	NS
	group x time	4,103	0.37	NS
movement (high)	group	2,105	0.16	NS
	time	2,105	2.17	.12
	group x time	4,103	0.94	NS
(low)	group	2,105	0.09	NS
	time	2,105	3.04	.05
	group x time	4,103	0.49	NS

EMG Bilateral Difference Over Time .

The means and standard deviations of the bilateral difference scores were calculated and analyzed in a manner identical to that of the amplitude. The results showed a decrease in mean scores for all conditions for the biofeedback and education groups. The relaxation group showed increased bilateral differences for lying, sitting, and standing with a slight decrease for movement. Table 9 summarizes this data.

Table 9

EMG Bilateral Difference Scores Over Time for Each Condition

Condition	Group		Time		
			Pre	Post	Follow-up
Lying	Biof.	M	1.96	1.70	0.96
		SD	2.05	1.94	1.09
	Relax.	M	0.70	1.09	2.02
		SD	0.55	1.00	5.18
	Educ.	M	1.50	1.53	0.82
		SD	0.99	0.91	0.95
Sitting	Biof.	M	2.29	1.94	0.90
		SD	1.98	1.51	0.61
	Relax	M	1.80	2.04	3.35
		SD	2.34	2.65	5.82
	Educ.	M	1.58	2.19	0.75
		SD	1.28	1.36	0.59
Standing	Biof.	M	2.13	3.46	1.61
		SD	1.86	4.35	1.76
	Relax.	M	2.34	1.95	2.87
		SD	1.95	1.96	5.62
	Educ.	M	3.16	2.47	1.80
		SD	2.96	1.94	1.86
Movement	Biof.	M	9.73	13.27	4.03
		SD	21.82	13.40	5.04
	Relax.	M	8.50	6.98	7.23
		SD	7.70	5.43	7.31
	Educ.	M	12.33	8.12	7.31
		SD	12.34	8.56	8.86

The scores for each condition and group were then subjected to a two-way ANOVA (group by time). No significant results were obtained although the groups by time analysis for sitting approached significance [F(4,103) = 2.26, p = .07]. The F scores and p values are reported in Table 10.

Table 10

Group by Time ANOVAs of EMG Bilateral Difference Scores

Condition	Source	df	F	p
lying	group	2,105	0.20	NS
	time	2,105	0.06	NS
	group x time	4,103	1.16	.33
sitting	group	2,105	0.77	NS
	time	2,105	0.33	NS
	group x time	4,103	2.26	.07
standing	group	2,105	0.01	NS
	time	2,105	0.44	NS
	group x time	4,103	1.20	.32
movement	group	2,105	0.20	NS
	time	2,105	1.43	.25
	group x time	4,103	0.85	NS

<u>Summary of EMG Changes</u> .

Although statistical significance was not obtained (except for sitting and movement-low [amplitude]), there were a number of trends evident in the above data. To clarify these trends the differences between the pretreatment and follow-up scores were calculated for each group and condition and are reported in Table 11. The biofeedback group showed the expected decrease in amplitude and bilateral difference for all conditions. The relaxation scores increased for all conditions and measures except for the bilateral difference measure for movement-high which decreased. Amplitude scores in the education group did not follow a consistent pattern with lying, sitting, and standing decreasing, and both movement scores increasing. However, the bilateral difference scores decreased for all conditions.

Table 11

EMG Score Changes Over Time for Each Group and Condition

Condition	Group					
	Biofeedback		Relaxation		Education	
	amp.	bil.dif.	amp.	bil.dif.	amp.	bil.dif.
lying	-0.8	-1.0	+1.6	+1.4	-1.2	-0.7
sitting	-3.0	-1.4	+2.5	+1.6	-0.3	-0.8
standing	-2.0	-0.5	+0.1	+0.6	-0.9	-1.4
movement						
(high)	-6.0	-5.7	+1.6	-1.3	+1.4	-5.0
(low)	-0.4	NA	+2.0	NA	+11.9	NA

LEGEND
- \- decrease in activity
- \+ increase in activity
- 0 no change
- NA not applicable

Summary

Two EMG values (amplitude and bilateral difference) were studied over time (pretreatment, post treatment and at 3 months follow-up) and between groups (biofeedback, relaxation, and education). These values were studied for lying, sitting, standing, and movement (high and low) conditions. Analysis of the mean scores showed a decrease in readings for the biofeedback group for all conditions. The relaxation group scores tended to increase, while the education results were mixed for amplitude but decreased for all conditions for bilateral differences. Results of analyses (two-way ANOVAs) of the data were not significant except for the amplitude scores for sitting (group by time effect) and movement-low (time effect). However, analyses of the data for simple main effects for sitting did not indicate significant differences between the three groups at pre, post, or follow-up times. The biofeedback group showed the expected decrease in EMG values for all recordings, the relaxation group generally increased, while the education group decreased except for the amplitude of the movement scores.

Relationship of EMG Measures to Reported Pain

The nature of the relationship between EMG values and standard measures of pain was studied. If the pain-spasm-pain model is accurate then the amplitude should be related to the pain. If the biomechanical model is accurate then the bilateral difference should be related to the reported pain. Finally, if there is an interaction between these models, (i.e., high amplitude and large bilateral difference) then combining these scores should be predictive of pain.

The EMG scores utilized were those for all 36 subjects from the pretreatment assessment. First, the amplitudes and the bilateral differences for each condition were correlated with the MPQ and VAS scores. Second, the amplitude scores for all conditions were simultaneously regressed against the pain scores. This was then completed for the bilateral differences.

Finally, the amplitude and bilateral difference scores for each assessment condition (e.g., lying) were combined for that condition, and regressed against the pain scores. The pain scores utilized varied for each test as explained below.

Relationship to the MPQ .

As the subjects often reported the pain as varying depending upon position, the total score (PRI-T) of the MPQ was first correlated with the EMG scores for each condition (lying, sitting, standing, and movement [high and low]). The results of this assessment revealed a range from $r = .04$ to $.33$ as outlined in Table 12 below, with the correlation between the movement-low score and the MPQ score significant ($r = .33$, $p < .05$).

Table 12

Correlation of EMG Amplitude and Bilateral Difference Scores for Assessment Conditions to MPQ Scores

Condition	Amplitude r	Bilateral Difference r
lying	.04	.05
sitting	.12	.08
standing	.18	.18
movement-high	.17	.10
movement-low	.33	-.10

Note: critical value r (2 tail, $p < .05 = .33$)

As chronic pain often is reported in a vague and undifferentiated manner the EMG scores (all amplitude scores and then all bilateral difference scores) were regressed against the PRI-T score of the MPQ utilizing a simultaneous regression procedure. The results for the amplitude scores showed a multiple correlation, $R = .49$ with the movement-low regression coefficient significant ($p = .02$). The results for the bilateral differences revealed a multiple correlation, $R = .26$ with no regression coefficients significant. These results for both EMG measurements are outlined in Table 13.

Table 13

Regression Analyses of EMG Amplitude and Bilateral Difference Scores to the MPQ Total Score

Amplitude

Source	df	SS	MS	F(5,30)	p
Regression	5	1599.02	319.80	1.88	.13
Residual	30	5093.87	169.80		
Total	35	6692.89			

$R = .49$ $R^2 = .24$ Adjusted $R^2 = .11$

Variable	b	t	S.E.	p
Movement-low	-.50	-2.36	.21	.02
Movement-high	.15	.92	.16	.15
Standing	.74	1.30	.57	.20
Sitting	.28	.41	.68	NS
Lying	.11	.13	.81	NS
Constant	32.60			

Bilateral Difference

Source	df	SS	MS	F(4,31)	p
Regression	4	450.39	112.60	.56	NS
Residual	31	6242.50	201.38		
Total	35	6692.90			

$R = .26$ $R^2 = .07$ Adjusted $R^2 = .0001$

Variable	b	t	S.E.	p
Movement	.13	.68	.19	NS
Standing	1.03	.95	1.09	NS
Sitting	-1.46	-.97	1.51	NS
Lying	1.19	.65	1.83	NS
Constant	28.67			

Finally, as the reported pain may result as an interaction between the amplitude and bilateral difference, these scores for each condition and then all conditions were simultaneously regressed against the MPQ total score (PRI-T). The results as reported in Table 14 below showed no statistically significant interactions, although both movement analyses approached significance.

Table 14

Regression Analyses of the Interaction between EMG Measures for Each Assessment Condition and MPQ Scores

Condition	df	F	p	R	R^2	Adj. R^2
Movement						
low	2,33	2.66	.08	.37	.14	.09
high	2,33	2.40	.10	.36	.13	.07
Standing	2,33	0.69	NS	.20	.04	NS
Sitting	2,33	0.98	NS	.24	.06	NS
Lying	2,33	0.04	NS	.05	.003	NS
All	9,26	1.21	NS	.54	.30	.05

The above results indicate that the correlation between the EMG scores and the MPQ total score varied, with only the movement-low coefficient showing statistical significance. Combining the amplitude scores increased the correlation, but not to a statistically significant level, and had little effect on the bilateral difference scores. Combining the amplitude and bilateral difference scores for each condition increased the correlations, but not to statistically significant levels.

Relationship To The VAS .

The relationship of the EMG values to scores obtained on a Visual Analogue Scale (VAS) were studied in a manner almost identical to those above. There was no difference in procedures or data analysis. The only difference occurred in the pain scores utilized. For the specific conditions (e.g., lying) the EMG score was correlated with the score specific for that condition (e.g., the lying EMG value was compared to the VAS score for the lying condition). When more than one measure was used (e.g., combined condition) the EMG scores were simultaneously regressed against a VAS score reflecting the general level of pain.

The individual EMG score for each assessment condition was correlated to the comparable score from the VAS. The results as seen in Table 15 indicated that the amplitude scores for sitting, movement-high, and movement-low were significantly ($p < .05$) correlated with the appropriate VAS score, as was the bilateral difference score for movement.

Table 15

Correlations of EMG Measures to VAS Scores for Each Condition

Condition	Amplitude r	Bilateral Difference r
lying	.01	.09
sitting	.37	.24
standing	.10	.01
movement-high	.60	.39
movement-low	.53	-.39

Note: critical value r (2 tail, p < .05 = .33)

The EMG scores for (a) amplitude and (b) bilateral difference respectively were then simultaneously regressed against the VAS general score in a manner identical to the procedure utilized for the MPQ score. The analyses showed no statistically significant results as outlined in Table 16.

Table 16

Regression Analyses of EMG Amplitude and Bilateral Difference Scores to VAS General Scores

Amplitude					
Source	df	SS	MS	F(5,30)	p
Regression	5	40.36	8.07	1.76	.15
Residual	30	137.31	4.58		
Total	35	177.68			

$R = .48$ $R^2 = .23$ Adjusted $R^2 = .10$

Variable	b	t	SE	p
Movement-low	.02	.52	.03	NS
Movement-high	-.02	-.86	.03	NS
Standing	.04	.46	.09	NS
Sitting	-.19	-1.71	.11	.09
Lying	.22	1.64	.13	.10
Constant	3.12			

Bilateral Difference					
Source	df	SS	MS	F(4,31)	p
Regression	4	24.82	6.21	1.26	.31
Residual	31	152.85	4.93		
Total	35	177.68			

$R = .38$ $R^2 = .14$ Adjusted $R^2 = .03$

Variable	b	t	SE	p
Movement	-.01	-.49	.03	NS
Standing	-.03	-.15	.17	NS
Sitting	-.40	-1.68	.24	.10
Lying	.36	1.25	.29	.22
Constant	3.18			

Finally, the interaction between the amplitude and bilateral difference was studied in a manner similar to the MPQ analysis. The EMG scores for each condition were regressed against the VAS score for that condition. Then, all the scores were regressed against the VAS general score. The results indicated that both scores (high and low) for movement were similar in outcome and significantly correlated (R = .61, $p < .01$; R = .61, $p < .01$ respectively) to the VAS score. No other outcomes were significant. These results are reported in Table 17.

Table 17

Regression Analyses of the Interaction between EMG Measures for Each Assessment Condition and the Respective VAS Scores

Condition	df	F	p	R	R^2	Adj. R^2
Movement						
(low)	2,33	9.67	< .01	.61	.37	.33
(high)	2,33	9.55	< .01	.61	.37	.33
Standing	2,33	0.29	NS	.13	.02	.00
Sitting	2,33	2.57	.09	.37	.14	.08
Lying	2,33	0.36	NS	.15	.02	.00
All	9,26	1.35	NS	.56	.32	.08

In the cases where the analysis of the interaction was significant, the results were further studied for contributions of each variable. The results revealed that the regression coefficients for amplitude were significant in both movement analyses but the regression coefficient for bilateral difference was significant for movement-low only. These results are noted in Table 18.

Table 18

Simultaneous Regression of Amplitude and Bilateral Difference of Assessment Conditions Showing Significant Results

Condition	Variable	b	t	SE	p
movement (low)	amplitude	-.06	-3.36	.02	.002
	bil. diff.	-.05	-2.21	.02	.03
movement (high)	amplitude	-.06	-3.33	.02	.002
	bil. diff.	.01	.32	.03	NS

The above results indiciate that the correlations between the amplitude scores and the associated VAS scores are generally higher than those noted for the MPQ. Statistically significant correlations were observed for amplitude for both movement scores and sitting, and for the bilateral difference for movement. Combining the scores in the various manners increased the correlations slightly, but not significantly so.

Summary

The above results suggest that the correlation between EMG data and the MPQ vary as per the assessment condition, and range from very low to moderate. Only one of the correlations (amplitude of the movement-low side) was significant. The correlations between the VAS scores and the EMG measures also vary as per condition but are much stronger ranging from low to moderately high, with sitting and movement-low and movement-high showing significant results. In particular the relationship between the EMG movement scores and the intensity of pain (as measured by the VAS) appears to be strong and significant. Amplitude appears to be more highly correlated to the pain measures than does the bilateral difference. Combining the scores in various ways appears to increase the correlations, but not to statistically significant levels.

Dependent Variables

Pretest Assessment of Data

In order to determine whether the groups differed prior to treatment, the pretreatment data for all dependent variables were subjected to one-way ANOVAs. No significant group differences were found for any variables. Table 19 lists the means and standard deviations for the three groups for each assessment and variable and the related F scores.

Table 19

Pretest Scores and Between Group ANOVAs for the Dependent Variables

Measure		Group Biof	Relax	Educ	F(2,33)	p
MPQ	M	28.75	31.08	34.50	0.51	NS
	SD	15.11	12.39	14.43		
VAS General	M	2.23	2.51	3.85	0.95	NS
	SD	1.59	2.17	2.70		
Lying	M	1.98	2.96	2.18	0.67	NS
	SD	1.90	2.61	1.95		
Sitting	M	1.68	2.34	3.12	1.76	.19
	SD	1.54	2.01	2.03		
Standing	M	2.08	2.74	2.78	0.45	NS
	SD	1.77	2.36	1.99		
Movement	M	3.33	3.74	2.80	0.43	NS
	SD	2.43	2.66	2.40		
MMPI Hypo	M	60.42	62.50	61.67	0.26	NS
	SD	9.57	7.94	8.26		
Dep	M	63.08	64.00	59.25	0.33	NS
	SD	11.86	13.72	9.51		
Hyst	M	63.75	59.00	58.75	0.89	NS
	SD	8.88	8.77	11.17		
Posture	M	31.25	27.92	35.00	1.76	.19
	SD	12.27	8.65	5.64		
BCL	M	2.49	2.52	2.56	0.09	NS
	SD	0.42	0.44	0.27		

The above data, when analyzed for all subjects, also adds to the information about the subjects. The overall average MPQ score of 31.44 (the three group scores averaged) places this sample slightly higher in reported pain as compared to other studies. For example Melzack (1975) reports scores of 26.3 for back pain, 26.0 for cancer, 25.0 for phantom limb pain, 22.6 for post herpetic pain, 19.5 for dental pain, and 18.8 for arthritic pain. The overall average scores for the MMPI scales (Hypochondriasis, Depression, and Hysteria) were 61.53 (SD = 8.59), 62.11 (SD = 11.70), and 60.50 (SD = 9.61) respectively, matching those reported by Swenson, Pearson, and Osborne (1973). On a sample of 50,000 medical outpatients, Swenson et al. (1973) reported a mean of 61.18 (SD = 12.30), 60.19 (SD = 12.23), and 61.00 (SD = 10.61) for the Hypochondriasis, Depression, and Hysteria scores respectively. Utilizing the classification system by Costello et al. (1987), this sample would be classified in the N type group. Costello et al. (1987) reports this group as usually the best educated, most often employed; and moderate in their claims of ill health, emotional instability, intensity of pain, and impact of the pain upon their daily functioning. They tend not to use medication and are very responsive to treatment. The authors report that approximately 25% of all chronic pain patients fall into this category.

In summary, the subjects discussed above reported pain slightly higher than other back pain samples, with an MMPI profile that is characteristic of outpatient medical patients who demonstrate objective organic findings. While it is suggested by Costello et al. (1987) that subjects of this sort should respond well to treatment, it is interesting to note that the various treatments previously attempted (e.g., medication, physiotherapy) had not worked and in fact these subjects had remained in pain on the average 83.4 months (almost 7 years).

Subset #1 - General Pain Measures - MANOVA Results .

Two measures utilized in this study were considered to reflect the subject's perception of the general level of pain. These were the total score (PRI-T) of the MPQ and average score from the VAS General. These data were analyzed utilizing an two-way MANOVA with Pillai's criterion selected as the criterion for statistical inference. Results of this analysis revealed significant results for the effect of time [$F(4,30) = 8.62$, $p < .001$], and the interaction of group by time [$F(8,62) = 2.12$, $p < .05$], but not for the effect of group [$F(4,66) = 1.83$, $p < .13$]. These results are summarized in Table 20.

Table 20

Results of MANOVA for Subset #1 - Pain Measures General

Effect	Pillai's Value	F	Multi F	p
Group	.20	(4,66)	1.83	= .13
Time	.53	(4,30)	8.62	< .001
Group x time	.43	(8,62)	2.12	= .05

MPQ scores and ANOVA Results .

In view of the significant results obtained for the MANOVA the total scores (PRI-T) of the McGill Melzack

Pain Questionnaire (MPQ) were then examined pretreatment, post treatment, and at follow-up and between groups (biofeedback, relaxation and education). The overall effects (group, time, and group by time) were studied using a two-way repeated measures ANOVA. Results of this analysis as outlined in Table 21 revealed a significant reduction in reported pain for all groups over time [$F(2,105) = 7.30$, $p < .01$], and for groups by time [$F(4,103) = 2.60$, $p < .05$]. None of the tests for homogeneity of variance was significant.

A test for simple main effects was then conducted, employing a one-way (between groups) ANOVA at each time level. The results showed no significant group differences [$F(2,33) = 0.51$] at pretreatment. Post treatment results revealed a trend towards significance [$F(2,33) = 2.72$, $p < .08$] with means of 16.08 (SD = 14.99), 27.67 (SD = 12.63) and 28.58 (SD = 16.07) for the biofeedback, relaxation, and education groups, respectively. The results of the follow-up analysis showed significant results [$F(2,33) = 3.53$, $p < .04$] with means of 15.33 (SD = 15.66), 32.33 (SD = 11.31) and 20.08 (SD = 20.28) for the biofeedback, relaxation and education groups, respectively. Post hoc analysis utilizing the Tukey HSD procedure revealed that at the biofeedback group mean was significantly ($p < .05$) lower than the relaxation group. The education group did not significantly differ from either group.

Inspection of the group means in Table 21 reveals that the biofeedback group reported by far the greatest decrease in pain at post treatment, which was sustained at follow-up. The relaxation group showed little change over time, while the education group displayed a substantial decrease in pain between post treatment and follow-up.

Table 21

MPQ Scores by Group over Time and Two-way ANOVA Results

		Group Means		
Group		Pretreatment	Post treatment	Follow-up
Biofeedback	M	28.75	16.08	15.33
	SD	15.11	14.98	15.66
Relaxation	M	31.08	27.67	32.33
	SD	12.39	12.63	11.31
Education	M	34.50	28.58	20.08
	SD	14.43	16.07	20.28
Overall Effects				
Group			$F(2,105) = 2.29$	$p = .12$
Time			$F(2,105) = 7.30$	$p < .01$
Group x time			$F(4,103) = 2.60$	$p = .04$

VAS General Scores and ANOVA Results .

The VAS General scores were analyzed in a manner identical to that for the MPQ scores. The average scores were studied over time and between groups utilizing a two-way ANOVA. The results as outlined in Table 22 showed no significant differences between groups [F(2,105) = 1.81, p < .18], or for the group by time interaction [F(4,103) = 1.22, p < .31], with a significant difference noted for time [F(2,105) = 9.32, p < .01]. Tests for homogeneity of variance were not significant.

Table 22

VAS General Scores and Results of Two-way ANOVA

Group		Assessment		
		Pretreat	Post treat	Follow-up
Biofeedback	M	2.23	1.26	0.72
	SD	1.59	1.57	1.32
Relaxation	M	2.51	1.90	1.78
	SD	2.17	1.27	1.31
Education	M	3.48	2.47	0.87
	SD	2.83	1.76	1.26
Overall Effects				
Group		F(2,105) =	1.81	p = .18
Time		F(2,105) =	9.32	p < .01
Group x time		F(4,103) =	1.22	p = .31

A one-way repeated measures ANOVA for time revealed the biofeedback group significantly [F(2,33) = 5.50, p < .01] decreased between pretreatment and post treatment assessments, maintaining this decrease at follow-up, the relaxation group decreased but not to a significant level [F(2,33) = 1.11, $p < .35$], while the education group significantly [F(2,33) = 5.76, $p < .01$] decreased between post treatment and follow-up.

VAS Scores for Each Position and ANOVA Results .

Four VAS scales (lying, sitting, standing, and movement) utilized in the assessments were analyzed using two-way ANOVAs as these scales were conceptualized as representing distinct components of the VAS-General scale. The means and ANOVAs for each scale are reported in Tables 23 - 26 respectively. In no cases were significant group or group by time results obtained, although the results for time alone were significant as the means of all three groups decreased over time. Tests for the homogeneity of variance were not significant. Examination of the scores revealed a tendency for the biofeedback group means to decrease most between the pretreatment and post treatment assessments, maintaining these levels at follow-up. The relaxation group showed a tendency to decrease between pretreatment and post treatment assessments with follow-up showing no consistent pattern. The education group showed most of its decreases between post treatment and follow-up, with less of a change between the first two assessments.

Table 23

VAS Lying Scores and Results of Two-way ANOVA

Group		Assessment		
		Pretreat	Post treat	Follow-up
Biofeedback	M	1.98	1.09	1.13
	SD	1.90	1.19	1.54
Relaxation	M	2.96	2.55	2.11
	SD	2.61	2.32	1.82
Education	M	2.18	2.18	1.01
	SD	1.95	1.69	1.34
Overall Effects				
Group		F(2,105) =	1.88	p = .17
Time		F(2,105) =	4.14	p < .02
Group x time		F(4,103) =	0.60	p = NS

Table 24

VAS Sitting Scores and Results of Two-way ANOVA

Group		Assessment		
		Pretreat	Post treat	Follow-up
Biofeedback	M	1.68	1.07	0.93
	SD	1.54	0.87	1.32
Relaxation	M	2.34	2.20	2.01
	SD	2.01	2.18	1.47
Education	M	3.12	1.91	0.95
	SD	2.03	1.88	1.31
Overall Effects				
Group		F(2,105) =	1.83	p = .17
Time		F(2,105) =	6.47	p < .01
Group x time		F(4,103) =	1.70	p = .16

Table 25

VAS Standing Scores and Results of Two-way ANOVA

Group		Assessment		
		Pretreat	Post treat	Follow-up
Biofeedback	M	2.08	0.87	0.97
	SD	1.77	1.05	1.44
Relaxation	M	2.74	2.19	2.63
	SD	2.36	1.94	2.00
Education	M	2.78	2.10	1.01
	SD	2.99	2.01	1.36
Overall Effects				
Group		F(2,105) =	2.07	p = .14
Time		F(2,105) =	6.06	p < .01
Group x time		F(4,103) =	1.76	p = .15

Table 26

VAS Movement Scores and Results of Two-way ANOVA

Group		Assessment		
		Pretreat	Post treat	Follow-up
Biofeedback	M	3.33	1.25	1.05
	SD	2.43	1.20	1.40
Relaxation	M	3.74	2.86	3.08
	SD	2.66	2.37	2.58
Education	M	2.80	2.60	1.10
	SD	2.40	2.06	1.37
Overall Effects				
Group		F(2,105) =	2.04	p = .14
Time		F(2,105) =	9.82	p < .01
Group x time		F(4,103) =	2.07	p = .09

The significant results for time for each position were then analyzed using a one-way repeated measures ANOVA. The results as listed in Table 27 showed significance for the biofeedback group for standing and movement, no significant results for the relaxation group, and significant results for sitting, standing and moving for the education group.

TABLE 27

One-way ANOVA Results for Time for Each Position

Position		Group		
		Biofeedback	Relaxation	Education
lying	(F2,33)	1.51	1.52	2.13
	p	NS	NS	NS
sitting	(F2,33)	1.91	0.26	5.28
	p	NS	NS	= .02
standing	(F2,33)	3.67	0.79	4.27
	p	= .05	NS	= .04
movement	(F2,33)	8.48	1.70	3.31
	p	< .01	NS	= .05

<u>VAS Daily Treatment Scores and ANOVA Results</u> .

In a effort to monitor immediate treatment effects, two Visual Analogue Scales were administered from the 2nd day to the 10th day of treatment. One scale reflected the intensity of the pain, while the other scale reflected the perceived change in pain from day to day. Nine scores for each scale were obtained for every subject. For each scale, this data was then condensed into three scores per group by totalling the scores for days 2 to 4, 5 to 7, and 8 to 10 and calculating the mean and standard deviation for each of these aggregate scores. Analyses utilizing a two-way ANOVA (group by time) revealed no significant interaction effect. The results showed a decrease in intensity and a perception of improvement over time for the biofeedback group, and a slight improvement for the relaxation and education groups. Table 28 shows the means and standard deviations for each group and the results of the analysis of variance for these scales.

Table 28

Condensed VAS Daily Treatment Scores and ANOVA Results

Intensity

		Average Scores		
Group		Days 2-4	Days 5-7	Days 8-10
Biofeedback	M	2.63	2.26	1.41
	SD	1.86	1.09	1.47
Relaxation	M	2.33	2.14	1.89
	SD	1.68	1.16	1.19
Education	M	2.23	2.39	2.12
	SD	0.66	1.67	1.69
Overall Effects				
Group		F(2,105)	= 0.05	p = NS
Time		F(2,105)	= 1.84	p < .08
Group x time		F(4,103)	= 0.95	p = NS

Change*

		Days 2-4	Days 5-7	Days 8-10
Group				
Biofeedback	M	0.06	0.48	1.40
	SD	0.91	0.71	1.05
Relaxation	M	-0.22	0.21	0.28
	SD	0.65	0.56	0.72
Education	M	0.24	0.39	0.71
	SD	0.98	1.50	1.25
Overall Effects				
Group		F(2,105)	= 1.81	p = .18
Time		F(2,105)	= 2.86	p < .01
Group x time		F(4,103)	= 0.71	p = NS

* a zero score indicates no change; a negative score, increased pain; a positive score, decreased pain (range from -5 to +5).

Subset #2 - Emotional Factors - MANOVA Results .

The K corrected scores from the three MMPI scales were subjected to a two-way MANOVA utilizing Pillai's criterion for statistical inference. The results of this analysis revealed no significant results between groups [F(6,64) = 0.58, p < .74], and for group by time

[F(12,58) = 0.82, p < .63]. However, significant results were noted for time [F(6,28) = 4.54, p < .01]. These results are outlined in Table 29.

Table 29

Results of MANOVA for Subset #2 - Emotional Factors

Effect	Pillai's Value	F	Multi F	p
Group	.10	(6,64)	0.58	= .74
Time	.49	(6,28)	4.53	< .01
Group x time	.29	(12,58)	0.82	= .63

<u>MMPI Hypochondriasis Scale (#1) and ANOVA Results</u>.

In view of the significant results obtained with the MANOVA the K corrected T scores from the three MMPI scales were then individually subjected to a two-way analysis (ANOVA) of variance (group, time, and group by time). The mean scores for the biofeedback group on the Hypochondriasis scale were 60.42 (SD = 9.56), 57.50 (SD = 10.43), and 56.08 (SD = 10.05) for the three assessments (pretreatment, post treatment, and follow-up) respectively. The relaxation group scores were 62.50 (SD = 7.94), 55.42 (SD = 10.19), and 56.17 (SD = 9.42), respectively, and 61.68 (SD = 8.26), 58.25 (SD = 9.36) and 59.58 (SD = 8.67) for the education group. Results of the ANOVA indicated a significant change in scores for time [F(2,105) = 11.02, p < .01], but not for group [F(2,105) = 0.18], or group by time [F(4,103) = 1.14]. A repeated measures (for time) ANOVA for each group showed the biofeedback group [$F(2,33) = 4.15$, $p < .05$] and relaxation group [$F(2,33) = 6.21$, $p < .01$] decreased significantly but not the education group [$F(2,33) = 1.88$]. Tests for homogeneity of variance were not significant.

<u>MMPI Depression Scale (#2) and ANOVA Results</u> .

The average pretreatment K corrected T scores for the Depression scale of the MMPI were 63.08 (SD = 11.86), 64.00 (SD = 13.72) and 59.25 (SD = 9.51) for the biofeedback, relaxation, and education groups, respectively. Post treatment scores were 57.00 (SD = 6.65), 57.67 (SD = 13.68), and 58.75 (SD = 11.07) and at follow-up 58.25 (SD = 8.27), 58.83 (SD = 13.18) and 61.25 (SD = 12.23) for the respective groups. Analysis of this data employing a two-way ANOVA (group by time) showed a significant change in scores over time [$F(2,105) = 7.28$, $p < .01$], no significant differences between groups [$F(2,105) = 0.01$], with group by time approaching significance [$F(4,103) = 2.38$, $p < .06$]. A repeated measures (for time) ANOVA for each group revealed the biofeedback group [$F(2,33) = 3.84$, $p < .04$] and the relaxation group [$F(2,33) = 6.58$, $p < .01$] decreased significantly, while the education group [$F(2,33) = 0.75$] did not. Tests for homogeneity of variance were not significant.

MMPI Hysteria Scale (#3) and ANOVA Results .

Analysis of the data (group mean K corrected T scores) from the Hysteria scale of the MMPI employing a two-way analysis of variance (ANOVA) revealed no significant differences between groups [$F(2,105) = 1.04$], for time [$F(2,105) = 2.92$, $p < .06$], or for group by time [$F(4,103) = 0.73$]. Group mean scores of 63.75 (SD = 8.88), 62.17 (SD = 9.91) and 60.58 (SD = 9.21) were obtained for the three assessments for the biofeedback group. The relaxation group scores were 59.00 (SD = 8.77), 56.42 (SD = 8.88), and 56.58 (SD = 8.64), respectively, while the education group scores were 58.75 (SD = 11.17), 56.83 (SD = 9.57) and 58.66 (SD = 9.31). Test for homogeneity of variance were not significant.

Behavior Checklist Scores and ANOVA Results .

Means for each group were tabulated for the treatment conditions (pretreatment, post treatment and follow-up) and then subjected to a two-way ANOVA (group by time). Pretreatment scores of 2.50 (SD = 0.42), 2.52 (SD = 0.44), and 2.56 (SD = 0.27) were obtained for the biofeedback, relaxation, and education groups, respectively, with post treatment scores of 2.59 (SD = 0.45), 2.60 (SD = 0.46), and 2.49 (SD = 0.23), respectively, and follow-up scores of 2.53 (SD = 0.37), 2.63 (SD = 0.49), and 2.43 (SD = 0.38) respectively.

The results of the two-way ANOVA showed no significant differences for any of the effects: groups [F(2,105) = 0.18], time [F(2,105) = 0.37], and groups by time [F(4,103) = 1.33].

Posture Scores and ANOVA Results .

The data from the posture assessment was analyzed in a manner identical to that of the Behavior Checklist. Means were obtained for each group and examined over time for each assessment (pretreatment, post treatment, and at follow-up) employing a two-way ANOVA. The means for the biofeedback group were 31.25 (SD = 12.27), 30.42 (SD = 8.65) and 33.75 (SD = 8.56) for the three assessments. The relaxation group showed scores of 27.92 (SD = 8.65), 30.42 (SD = 9.88) and 32.08 (SD = 5.82), while those of the education group were 35.00 (SD = 5.64), 35.42 (SD = 7.22) and 35.42 (SD = 5.42). The results of the ANOVAs showed no significant differences between groups [F(2,105) = 1.53], over time [F(2,105) = 2.41] and for groups by time [F(4,103) = 0.83].

Summary

Following the suggestions of Leary and Altmaier (1980) the measures were analyzed utilizing two-way MANOVAs on two subsets of data; a) pain measures general, and b) emotional factors. The results for subset #1(pain measures) showed a significant decrease for time ($p < .01$) and group by time ($p < .05$).

Univariate analysis showed the MPQ significantly decreased for the group by time interaction, with the biofeedback group significantly ($p < .05$) lower than the relaxation group at follow-up. The VAS-General score showed a significant decrease over time ($p < .01$) for all groups. Results of ANOVAs for all four conditions showed significant ($p < .02$) decreases over time, with the biofeedback group showing the greatest change from pretreatment to post treatment. This change was maintained at follow-up. The relaxation group VAS pattern was inconsistent, while the education group displayed the greatest change between post treatment and follow-up. Results of the MANOVA performed on the emotional factors subset (the three MMPI scales) showed significant ($p < .02$) decreases over time. Scales # 1 and 2 decreased singificantly over time ($p < .01$) for the biofeedback and relaxation groups when examined with ANOVAs. Univariate analyses (two-way ANOVAs) conducted on the BCL and Posture scores showed no significant results.

Correlations

Independent Measures

The relationships amongst the EMG scores (amplitude and bilateral difference) for each assessment condition (lying, sitting, standing, and movement-high and low) were examined using correlational analysis. The results revealed significant correlations between amplitude scores for sitting and standing ($r = .56$), amplitude scores for sitting and movement-high and low ($r = .47$ and $.38$ respectively), amplitude scores for movement-high and low ($r = .82$), bilateral difference scores for sitting and lying ($r = .37$), bilateral difference for sitting and movement ($r = .39$), and between amplitude movement-high and low and bilateral difference sitting ($r = .59$ and $.44$ respectively). Each condition also showed significant correlations between the amplitude and bilateral difference (lying $r = .81$, sitting $r = .59$, standing $r = .65$, movement $r = .71$). Table 30 outlines these results.

Table 30

Correlations Amongst EMG Scores

	1	2	3	4	5	6	7	8
1								
2	.03							
3	.01	.56						
4	-.01	.47	.25					
5	-.03	.38	.31	.82				
6	.81	.09	.13	.12	.06			
7	.14	.59	.22	.59	.43	.37		
8	-.19	.15	.65	.27	.25	-.07	.07	
9	-.01	.30	.02	.71	.18	.08	.39	.24

Legend: 1 amplitude - lying
2 amplitude - sitting
3 amplitude - standing
4 amplitude - movement-high
5 amplitude - movement-low
6 bilateral difference - lying
7 bilateral difference - sitting
8 bilateral difference - standing
9 bilateral difference - movement

Note: Critical value r (2-tail, $p < .05 = .33$)

Dependent Measures

Commonality amongst the dependent variables was examined by means of correlational analyses. Of the seven dependent variables, three (posture, MPQ, and VAS) showed no significant correlations with any other measures. The Hypochondriasis scale of the MMPI correlated significantly with the Depression and Hysteria MMPI scales ($r = .42$ and $.58$ respectively) but with no other measures. The Hysteria scale also showed a significant negative correlation ($r = -.33$) with the scores from the Behavior Checklist. All other correlations for the various scales were not significant. Table 31 summarizes the significant correlations.

Table 31

Correlations Amongst Dependent Variables

	Pos	MPQ	VASG	Hypo	Dep	Hys
Pos						
MPQ	-.08					
VASG	.02	.08				
Hypo	-.01	.07	-.09			
Dep	-.15	-.01	-.32	.42		
Hys	.19	-.15	-.26	.58	.29	
BCL	.16	.10	-.18	.03	-.33	-.03

Note: Critical value r (2-tail, p < .05 = .33)

The above results reveal significant intercorrelations amongst the MMPI scales. This is not surprising as these scales are referred to as the "neurotic triad" by Carson (1969) and have been shown (Timmermans & Sternbach, 1976) to be reactive to pain. The negative correlation between the scores of the Behavior Checklist and the Hysteria scale is not surprising as the measured activity should increase as hysteria decreases.

As it was expected that the scores on the various parts of the VAS assessment reflected the same phenomenon (intensity of pain), the relationships amongst the VAS scores (general, lying, sitting, standing, and movement) were also subjected to correlation analysis. The results were as predicted and showed significant correlations for all conditions. These results are reported in Table 32.

Table 32

Correlations Amongst VAS Scores

VAS Scores	General	Lying	Sitting	Standing
General				
Lying	.37			
Sitting	.40	.67		
Standing	.54	.53	.57	
Movement	.35	.78	.58	.53

Note: Critical value r (1-tail, $p < .05$) = +.28

Melzack (1983) suggested the MPQ scores are divided into sensory, affective and evaluative components. As the VAS is considered a sensory measure only, a comparison was conducted between the sensory scores of the MPQ and the general scores from the VAS using a Pearson's correlation. The results showed a negligible correlation (r= .07) between the two measures.

In view of the difference in group means for age (biofeedback = 42.2, relaxation = 35.8, and education = 36.1), age was correlated with outcome on the MPQ and VAS using a Pearson's correlation. The results showed little relationship (r= -.14 and .30) between age and the MPQ and VAS respectively.

<u>Summary</u>

Examination of the relationships amongst the independent variables (EMG scores) revealed a significant correlation between the amplitude scores for sitting, standing and movement-high. The amplitude and bilateral difference scores for each condition were significantly related. Finally, a significant correlation was noted for amplitude (movement-high) with the bilateral difference for sitting.

Correlations amongst the dependent variables were consistent with previous research for the MMPI scales. In addition, the Hysteria scale correlated with the Behavior Checklist. Finally, the VAS scales showed significant intercorrelations amongst all the subscales.

Learning

Shellenberger and Green (1986) state that "it was for good reasons that early pioneers emphasized the fact that criteria to demonstrate significant learning must be established before making claims about the treatment effect, or before correlating the treatment effect with biofeedback training" (p. 31). The critical question is to what level should subjects train? This principle may be applied in clinical health psychology to any situation in which learning is the active component of treatment. A review of the literature reveals a lack of studies which address the question, particularly in regard to the treatments utilized in this study.

In view of the lack of firmly established criteria, the author arbitarily established criteria based upon information from the available literature. The criteria varied from group to group as outlined below. For all subjects, the assessment of learning was conducted at the end of treatment during day 10.

In order to demonstrate control (the ability to increase then decrease the muscle activity upon command), the biofeedback group was required to meet the criteria for single motor unit (SMU) training as established by Johnson (1976). SMU training criteria was selected in view of the well documented research supporting the efficacy of SMU training, the use of these standards as accepted standards, and the lack of comparable research for muscle groups (Yates, 1980). Johnson (1976) examined several measures of degree of control of SMUs including: (a) the maintenance of electrical silence, (b) maintenance of a "picket-fence" pattern (increased activity then silent periods occurring at regular intervals), (c) demonstration of frequency control, (d) demonstration of on-off control (activate SMU on cue, then stop and maintain silence), and (e) demonstration of control of rhythm (fire SMU at specified rate, maintaining silence between individual firings). Employing multiple regression techniques he found that (a) on-off control, (b) rhythm control, and (c) SMU isolation control (maintenance of the "picket fence pattern) were the best predictors of success.

Following Johnson's (1976) criteria, the biofeedback subjects were required to demonstrate the ability to increase and decrease the activity of the targetted muscle. As the ability to demonstrate this activity just once may be by chance, and to more closely meet Johnson's (1976) criteria, it was decided to require the subjects to demonstrate this learning six times at the rate of once a minute for 6 minutes. Furthermore, as six contractions in a row fatigue a muscle (personal observation), completion of this task was considered to demonstrate improved muscle strength. In order to allow some margin for failure, the subjects were allowed a second attempt at obtaining the six contraction criterion if they failed on any of the first six. Visual inspection of the computer generated graphs indicated that based upon this criterion, 11 of the 12 subjects demonstrated learning on the first set of trials. The 12th subject met the criterion on the second set. Thus all subjects were considered to have demonstrated learning.

The literature does not offer much in the way of criteria when utilizing cross-body EMG values for the demonstration of learning for relaxation training. Only one article was found that listed any EMG values as criteria. In this article Johnson and Hockersmith (1983), listed the following criterion as indications of relaxation. A microvolt reading of 9.1 or greater was utilized as the criterion for learning at what was called level 1. Readings between 5.2 - 9.0 mv indicated obtaining a level 2 score, 4.0 - 5.1 mv a level 3 score, and 3.9 mv and below a level 4 score. The subject was required to obtain a level 4 score for at least 45 minutes in various positions before being considered relaxed. The average length of training was 55 sessions. This criterion was apparently developed in their clinic on 510 CLBP sufferers over a 7-year period by correlating the EMG values to a seven point pain rating scale. The criterion was modified slightly for this study in that the subject was assessed only in the reclined position and only for a 6 minute interval. Of the 12 subjects, 7 met the criterion of a level 1 score, 0 a level 2 score, while 2 subjects obtained level 3 scores, and 2 subjects met level 4 criterion. The 12th subject's score actually increased over time suggesting increased muscle tension and a poor ability to relax.

As random fluctuation in psychophysiological states may suggest a change where none exists, Shellenberger and Green (1986) suggest the use of the standard error of measurement as a estimate of stability over time. By applying the formula of $Se = Sx\sqrt{1-rxx}$ (where Sx is the standard deviation, and rxx is the reliability), confidence limits of change may be established. As the length of time between pretreatment and follow-up (90 days) for this study was most similar to the length of time (55 days) used in the Komi and Buskirk (1970) study, the reliability coefficient for concentric contractions ($r = .97$) from the Komi and Buskirk study was utilized. The means utilized were those from the first assessment on the first day of treatment and the last assessment on the last day of assessment. The standard deviation utilized was that from the first assessment on the first treatment day. Comparison of the first day mean to the last day mean using the above formula indicated that 11 of the 12 subjects' EMG readings decreased over time exceeding the 95% confidence level. The 12th subject showed an increase in EMG readings over time and did not meet the criteria for the demonstration of change.

Based upon the above criteria it was concluded that 11 of the 12 subjects demonstrated a change in EMG readings that was not due to random fluctuation. This change was in the expected direction approaching or meeting the criterion as outlined by Johnson and Hockersmith (1983) suggesting that the relaxation training was effective and learning had occurred for 11 of the 12 subjects.

The education group's knowledge was assessed by administration of a questionnaire during the 10th session. This method was chosen as written tests are universally employed as a measure of knowledge. The test, constructed by the author, was a 10 question multiple choice exam with one mark given for each correct answer. The questions were based upon the course's content and followed the course outline. In an effort to examine the validity of the test, the test was administered to a) a group of school teachers, and b) a group of laborers. These results were then compared to those obtained from the education group. The results from the educational group (12 subjects) revealed a group mean score of 8.85, with 4 subjects scoring 10, 4 scoring 9, 2 scoring 8, and 2 scoring 7. The teachers' group showed an average of 8.1, while the laborers group average was 6.2. While there does appear to be an effect due to educational status, it would appear that the test did discriminate between groups and so it was concluded that the education group demonstrated learning.

<u>Summary</u>

Based upon the above results it is concluded that all groups demonstrated learning: (a) the biofeedback group developed control of the muscle group, (b) the relaxation group lowered upper body muscle activity, and (c) the education group gained knowledge relevant to reducing CLBP.

Summary of Chapter

Data collected on 36 CLBP subjects (17 males, 19 females) indicated that this sample was similar to other samples as reported in the literature. The subjects' average age was 38.0 years (SD = 7.5), they were all employed, and reported daily pain lasting for the last 83.4 months (SD = 80.3). Pain was most commonly reported at the L3 level with all subjects having tried previous types of treatments. The reported level of pain was slightly higher than that of other back pain studies, while the MMPI scores were characteristic of medical patients with objective organic findings. Three methods of treatment (biofeedback, relaxation, and education) were employed with EMG measures utilized as the independent variable. Two-way ANOVAs showed the EMG scores for sitting significantly ($p < .05$) decreased over time and between groups for the biofeedback group. Only the biofeedback group demonstrated the expected decrease in EMG scores for all measures. Correlations between the EMG scores and reported pain varied with the method of assessment, producing a range of low ($r = .04$ and .01) to moderate ($r = .51$ and .61) with the MPQ and VAS, respectively. The high correlations were produced mainly during movement while measuring amplitude. Correlations amongst the EMG scores showed the amplitude score for sitting correlated highly with most other EMG scores. A high correlation was also noted between the amplitude and bilateral difference for each assessment condition. The dependent measures were grouped into subsets where appropriate and analyzed using a two-way MANOVA. Where significant results were obtained two-way ANOVAs were utilized to study the individual effects. For two variables (Posture and BCL) univariate analyses (two-way ANOVAs) were employed as these variables did not fit into the subset definitions. The results of the two ANOVAs showed no significant differences between groups over time for posture, and activity as measured by the Behavior Checklist. Results of the MANOVAs revealed significant ($p < .05$) results for subset #1 (pain measures general) for time and group by time, and for subset #2 (emotional factors) for time. Analyses of the MPQ using a two-way ANOVA produced significant ($p < .05$) group by time differences on the MPQ total scores. Post hoc analysis (Tukey HSD) showed the biofeedback group significantly ($p < .05$) lower than the relaxation group at follow-up. The VAS-General scores showed a significant ($p < .01$) decrease over time but not between groups and for groups by time. For both pain measures the biofeedback group showed the greatest decrease between pre and post treatments, while the education group showed the greatest decrease between post treatment and follow-up. Two-way ANOVAs of the VAS scores (subset #2) showed a significant ($p < .02$) decrease over time for all conditions, but no significant between group or group by time differences were noted. Similar results were also found for the Hypochondriasis and Depression scales of the MMPI (subset #2), while the Hysteria results showed no significant differences ($p < .06$). Correlations amongst the dependent variables showed the expected associations amongst the MMPI scales and between the Hysteria scale and activity measured on the BCL. Correlations amongst the subscales of the VAS were high, suggesting a common factor was being measured. Learning was demonstrated for all groups.

CHAPTER FIVE

Discussion

The purpose of this study was to examine the efficacy of three types of treatment upon CLBP. In particular, the activity of the erector spinae muscles were modified in an effort to establish if (a) increasing muscle activity through EMG biofeedback (SMU protocol) training, (b) decreasing muscle activity through modified progressive muscle relaxation training, or (c) didactic instruction, was more effective in reducing pain. By establishing the most efficacious method of treatment the mechanism(s) of pain would also be elaborated.

It was found that the three treatments affected the subjects in differing ways. The biofeedback training produced the expected changes in EMG measures and reduced the reported pain and emotional components, the relaxation training produced changes on one pain measure and reduced the emotional elements, while the didactic instruction reduced the reported pain and most of the EMG measures. These results are discussed in more detail below.

Dependent Measures

MPQ

The results of this study indicated the biofeedback training was significantly ($p < .05$) more effective than the relaxation training in reducing pain at follow-up as measured by the McGill-Melzack Pain Questionnaire (MPQ). The biofeedback group displayed a marked reduction of pain during and immediately after treatment. This reduction was maintained at follow-up and is similar to that reported by Wolf et al. (1982). The education group showed its greatest decrease in reported pain over the 90 days between post treatment and follow-up, while the relaxation group changes followed no consistent pattern. As the MPQ has been shown to have acceptable psychometric properties (Reading, 1983), it is concluded that the change in reported pain was reliable. For this measure the null hypothesis is rejected. The possible mechanisms of change are discussed below in the independent measure section.

VAS

The pain ratings from all VAS scales also changed over time in a manner similar to the MPQ, but did not show a significant groups by time difference. The patterns of scores for the biofeedback and education groups were similar to those from the MPQ, while the relaxation group showed slight but consistent decreases over time.

The difference in outcome may be attributable to the differences in type of pain measure. The MPQ scores reflect sensory, affective, and evaluative factors (Melzack, 1983), while the VAS is considered to reflect the intensity of the pain (Carlsson, 1983). It appears that all the treatments affected the intensity of the pain, but the biofeedback and education treatments affected other factors as well. For this measure the null hypothesis is accepted. Further discussion of this outcome may be found in the independent measure and MMPI sections.

<u>Posture</u>

The posture scores showed no statistically significant changes over time or between groups. The scores did tend to slightly improve over time for all three groups. However, there is a defined upper limit for these scores making attainment of between groups differences at a statistically significant level difficult. It appears that this "ceiling effect" may have contributed to the lack of attainment of significant between group differences. Furthermore, the instrument may not have been sensitive to minute changes in posture. Although Nigl (1984) indicates that 1/2 inch difference in symmetry is significant, there is little evidence otherwise to support this position. Until further research and standardized measures become available this area remains speculative, and it is concluded for this study that the null hypothesis is accepted.

Activity

The activity level as measured by the BCL showed very little change over time for any of the groups. It is suggested that there may be a number of factors contributing to this outcome. The validity and reliability of behavior checklists are at best questionable (Keefe et al., 1982). Several authors (i.e., Linton, 1985; Wilson, 1981) found a weak relationship between the reported pain and level of activity. This sample of CLBP sufferers were all working, showed little evidence of depression, and reported a moderate pretreatment level of activity. This result is consistent with that reported by Nagi, Riley, and Newby (1973) who found that 85% of CLBP patients had little-to-moderate limitations of activity. It may have been unreasonable to expect this sample to further increase their level of activity, as they appear to have adapted to their pain. Thus, it is concluded that these factors contributed to the lack of change in the BCL scores and the null hypothesis is accepted.

MMPI Scales

It was expected that the three MMPI scales would show little change, as the pretreatment scores were within normal T score limits, suggesting little emotional involvement in the pain (Costello et al., 1987). However, two of the three scales (Hypochondriasis and Depression) showed significant decreases over time for the biofeedback and relaxation groups, with the Hysteria scale approaching significance. It is concluded that the biofeedback and relaxation treatments were more effective than the educational group in reducing the emotional involvement with the pain, although statistical significance was not obtained. On the basis of these results the null hypothesis is accepted.

Much debate exists in the literature as to the nature of the relationship between the emotional and physical factors involved in pain. Various theorists (e.g., Sarno, 1976) suggest that the pain is caused by emotional factors. However, this position is weakened by the lack of controlled research. Other researchers support the position that the pain causes an emotional reaction which varies as the pain varies. Timmermans and Sternbach (1976) and Hendler (1982) suggested that the three MMPI scales are reactive to pain and should decrease with a decrease in pain. This present study concurs with these findings. (The rationale for this statement is discussed in conjunction with the outcomes from the independent measures for each group.)

The Hysteria scale consists of 60 items organized about two dimensions: (a) specific somatic complaints, and (b) denial of emotional or interpersonal difficulty (Carson, 1969). In "normal" subjects these two dimensions show no tendency to interact, with significant elevations occurring only with an interaction between the two factors. As this group of subjects started from a relatively low T score, little interaction between the factors would be expected, making further decreases difficult.

Independent Measure - Electromyographic Activity Biofeedback Group

As noted in Table 11, the amplitude and bilateral difference scores for all conditions for all measurements decreased over time for the biofeedback group. As the biofeedback group demonstrated learning (the ability to increase then decrease activity of the movement-low side muscle), it is concluded that this training effectively reduced the amplitude and bilateral difference scores. As the pain scores (reported by the

MPQ and VAS) decreased over time for all conditions for this group, and in view of the noted correlations between EMG scores and pain for this study and other studies (i.e., Cobb et al., 1975; Cram & Engstrom,1986), it is concluded that the biofeedback training effectively reduced pain.

The VAS daily scores indicated that the reduction of pain occurred early in treatment and was maintained over time. Examination of the VAS scores also showed a reduction in pain for all conditions, particularly for sitting. It is concluded that the training reduced pain quickly and generalized to all positions. Although the training methods differed, these results are consistent with the findings of Wolf et al. (1982).

The training site was the side which showed the lower EMG reading during movement. As the EMG reflects the amount of force generated by a muscle, it is possible to conceptualize this muscle group as generating <u>less</u> force than its agonist. Muscles when put in a stretched position generate less EMG activity than in a non-stretch position (de Vries, 1966). It is possible to conceptualize the low EMG readings as reflecting a muscle in a chronically stretched position. Control of muscles in a stretch position is through a reflex which prevents it from being overstretched, involving the stretch receptors in the muscles and tendons, and the activity of the gamma motor circuit (Patton, Sundsten, Crill, & Swanson, 1976). As the training meets the requirements for the establishment of learning (Shellenberger & Green, 1986; Meichenbaum, 1976) it is suggested that the training facilitated the reestablishment of motor control.

There are a number of possible explanations as to why the training of the low side reduced pain. These will obviously require further investigation but are suggested here. The nature of the training may have served to strengthen the weaker muscle thus reducing the load (particularly static) on the agonist allowing it to relax. This position is consistent with that proposed by de Vries (1968), who suggested that CLBP may be caused by muscle tone deficiency of the erector spinae. The strengthening may occur in several ways, two of which are listed here: (a) the contraction process itself may serve to strengthen the muscle much in the manner that exercise would, or (b) it may be that the signal generated by the gamma motor circuit is in error. The muscle fibre spindles and Gogli bodies of the tendons as part of the gamma motor circuit are responsible for the maintenance of the muscle's tension level (Guyton, 1971). These systems may be not functional so that the brain perceives the muscle state as relaxed (instead of stretched), leading to the reduced recruitment (reduced EMG readings) during movement. The training in a manner as yet unknown may have corrected this.

A second explanation as to why the treatment works involves another neurological process. In this type of movement the extensor muscle fibres generate a signal which inhibits the flexor activity on the side opposite. Basmajian (1967) notes that the normal role of reciprocal innervation is to modify the excitability levels of the appropriate neurons. Known as the cross extensor reflex (Hole, 1984), this mechanism may be strengthened. Third, the increased amplitude of the higher side may reflect a reflexive protective spasm, protective guarding, or bracing with the lower side acting as the trigger (Wolf & Basmajian, 1978; Wolf et al., 1982). The reestablishment of control may alleviate the need for this protection. Finally, the increasing and decreasing control process is similar to progressive muscle relaxation training procedures in that the muscles are tensed (increased activity) then relaxed (decreased activity). The training of the muscle may serve to reduce the opposite side muscle spasm in a manner which is presently unknown.

Regardless of which of the above is correct, all the above mechanisms have a commonality of serving to decrease the muscle activity on the side opposite to the training.

Brudney (1982) and Wolf et al. (1982) demonstrated that the retraining of muscles was possible using amplitude and temporal information to regain motor control. While the techniques utilized in this study differ from those used by Brudny and Wolf et al., it is suggested that a common factor may be operating to facilitate the retraining. Mulder and Hulstijn (1985b) demonstrated that the specificity of the information rather than other factors was important in establishing motor control. It is suggested that in the studies cited, and in this study, control was reestablished through the provision of specific information as to the nature of the muscle activity.

As mentioned previously, the biofeedback training was also effective in reducing the emotional components of the CLBP possibly accounting for the differences in outcomes between the MPQ and VAS scores. There are a number of possible mechanisms which could account for the changes. Timmermans and Sternbach (1976) suggested that the changes are due to the reduction in pain. This reduction in pain would break the "learned helplessness"

(Chapman & Brena, 1982; Seligman, 1975; Turk & Salovey, 1984) part of the depression. Naliboff et al. (1985) suggested that psychological dysfunction was more closely related to physical limitations than to the reported intensity of the pain. While it is possible that the biofeedback treatment reduced the physical limitations, the quick reduction in pain during treatment (as monitored by the VAS scores) would suggest that this process occurred before any improvement in physical functioning would occur. It is concluded that the biofeedback training was effective in quickly reducing the sensory components of the reported pain, which in turn reduced the emotional components producing the noted outcomes. These changes were maintained over time.

Relaxation Group

As noted in Table 11, except for the EMG movement-high amplitude and bilateral difference scores (decreased and no change respectively), all EMG scores increased over time, particularly for lying and sitting. The pain scores for the MPQ dropped from pre to post treatment, then increased at follow-up. The VAS scores decreased between each assessment for three of the conditions (lying, sitting, and general), and decreased then increased for standing and movement. There appears to be little correlation amongst the measures. Particularly the static assessments (lying and sitting) show a negative relationship to the reported pain. This is consistent with other published research (i.e., Nouwen & Solinger, 1979) and suggests that other variables (non-specific factors) may be affecting change.

Unlike the above results the daily treatment VAS and EMG scores demonstrate similar patterns. As outlined in the section on learning, 11 of the 12 subjects showed a decrease in EMG scores during treatment that could not be attributed to random fluctuation. The daily VAS pain intensity scores decreased over time from a day 2 mean of 2.13 (SD = 1.48) to a 10th day score of 1.68 (SD = 1.07). These results are similar and consistent with the majority of the studies in the literature which show positive outcomes (Lehrer & Woolfolk, 1984).

A possible explanation of this apparent contradiction between EMG readings lay in the site of EMG measurement. The assessments utilized the erector spinae for the EMG data, while the treatment sessions utilized the cross-body EMG sites. The progressive relaxation training did not focus specifically upon the erector spinae muscles of the back, but utilized a more general procedure. It would appear that the training facilitated generalized reductions in muscle activity, but did not serve to reduce the specific activity of the erector spinae. These results are consistent with the literature, in particular Linton and Gotestam (1985) and Philips (1977) who suggested that relaxation decreases the perceived pain even though the noxious stimulation was not changed. It is concluded that the reductions in the pain scores followed from general reductions in muscle activity and other non-specific factors, and not from a specific reduction in the activity of the erector spinae.

The results indicated a significant reduction in emotional factors occurred between assessments. The literature suggests that relaxation training affects pain through decreasing a number of physiological and emotional factors (Melzack & Wall, 1982). As a number of factors appeared to change simultaneously, it is difficult to determine if one or several of the factors are causal. Thus it cannot be concluded if the decrease in pain caused the decrease in emotional factors or other factors were involved.

Education Group

Table 11 shows that for all EMG measures except movement (high and low) amplitude there was a decrease in scores between pretreatment and follow-up. The pattern of the decreases showed a consistent decline in both sets of scores (amplitude and bilateral difference) over time, except for sitting where both scores increased between pre and post treatment, then decreased at follow-up. The movement scores increased over time for amplitude, but decreased for bilateral difference. The pain ratings from the MPQ and VAS decreased over time for all assessments and measures. It is concluded that the education program was effective in decreasing the EMG activity (except for movement), and by so doing served to reduce the reported pain.

Examination of the content of the education program revealed that four of the first five sessions concentrated on muscle activity including anatomy, symmetry, posture, lifting, mirroring, chronic repetitive actions, how the back gets out of symmetry, and how to correct same. The remaining five sessions focused on depression, stress, stress management, techniques on how to survive your back pain, and a review of the course. As evidence of learning was demonstrated at the end of treatment and based on the analysis of the course content, it is concluded that the course was effective in teaching the subjects about the physiology of the back and mechanisms of pain.

Examination of the pattern of reported pain scores showed that the greatest reduction in pain occurred between post treatment and follow-up. Based upon these results, it is concluded that the effect of the learning was not immediately evident, requiring time to be understood and to change behaviors which then affected the muscle activity of the back.

It was surprising that no significant changes in the MMPI scales were noted for this group, as part of the course focused specifically upon these areas. The change in the reported pain may have occurred late enough in the follow-up period that not enough time had occurred for the emotional changes to be affected. It may be that just providing information about the emotional factors does not change them, and more active interventions (e.g., cognitive behavior therapy) is needed for change. These results also suggest that the modification of the pain is more important than the teaching about the emotional factors.

The reduction in reported pain is consistent with that reported by Berguist-Ullman and Larson (1977). However, in this program not only knowledge of the physiology of the back was provided, but how to utilize this information in practical situations was provided. This knowledge may have helped the subjects challenge or understand their physical limitations in a manner consistent with the study of Naliboff et al. (1985). As Shellenberger and Green (1986) suggested, the provision of information is not adequate to cause change and instruction as how to effect change is necessary before change can be expected. Based upon this assumption, it is concluded that the effective component of change for the educational group was the information on how to apply the physiological information to overcome the pain and related physical limitations.

Factors Which Affected the Outcome

Non-specific Effects

In this study all groups received treatment as concern was raised as to the ethics of witholding treatment. The demographic data revealed that the subjects had been in pain on the average 83.4 months, had received 1.7 courses of physiotherapy, and had tried 1.5 different types of medication. In addition, various other forms of treatments (e.g., chiropractic) had been tried without success. There were also periods in the 83.4 months in which treatment(s) were not received. Based upon these facts it is difficult to conceive that non-specific factors (e.g., spontaneous recovery, maturation) would occur during this study.

The use of one therapist also helped to minimize non-specific therapist effects. Intangible factors like concern for the subjects, care, attention, and teaching style were presumably held constant.

In summary, it is difficult to account for the reported changes being the result of non-specific effects.

<u>Specific Effects</u>

It would appear that the three treatment programs varied in their effects upon the muscle activity of the erector spinae. The biofeedback group learned control quickly within the first few sessions, worked directly upon the affected muscles, and proceeded to reduce their pain by the time of the post treatment assessment, maintaining this at follow-up. The relaxation group learned how to reduce muscle activity generally throughout their body, but not specifically upon the erector spinae. This learning occurred in the latter two-thirds of the treatment. The education group learned the material, but appeared to need time to implement it, producing the pain reduction over the 90 days between the post treatment and follow-up assessments. Also, the education program was general in nature focusing upon all the muscles in the back. <u>It is concluded that the differences in rate of reduction of pain is due to (a) the specificity of the biofeedback</u>

training, and (b) the differences in the rate of implementation of learning.

Mechanisms of Pain

Examination of the EMG data from Table 11 clearly indicates a trend towards a reduction in both amplitude and bilateral difference for lying, sitting, and standing for the biofeedback and education groups. Conversely, the relaxation group shows an increase in these scores. The movement scores are not so consistent, with the biofeedback group decreasing for all scores and the education and relaxation groups increasing for amplitude and decreasing for bilateral difference.

Based upon these results it is suggested that neither the pain-spasm-pain model or the biomechanical model can account entirely for the reduction in pain, but that both of these models interact (as suggested by Dolce & Raczynski, 1985) to produce the pain. In the back the paraspinal muscles act in a synergistic manner to hold posture and produce movement (Basmajian, 1967). If one of these muscles produces less force than its partner, the partner is presumed to increase its activity to compensate for the weaker muscle producing the layered effect as described by Janda (1978). Over time the healthy muscle, in this chronic condition, becomes fatigued, producing spasm and the pain from trigger points as first suggested by Travell and Rinzler (1952). The greater the bilateral difference, the greater will be the biomechanical imbalance (Price et al., 1948), producing a greater demand upon the higher activity muscle. It is tentatively concluded that both models contribute to the development and maintenance of CLBP.

Correlations Between EMG Findings and Pain

The correlations between the EMG data and the reported pain as found in this study are in general agreement with those reported in the literature and summarized by Feuerstein et al. (1987). The correlations between pain and static assessment (lying, sitting, and standing) tend to be low. The sitting correlations tended to be higher reflecting the continued activity of the erector spinae when these muscles should be quiet. The correlations between the reported pain and movement readings are higher suggesting that movement analysis may be a more reliable method of assessment supporting the position of Ahern et al. (1988).

The pretreatment EMG values when averaged for the three groups (4.5 and 7.2 mv for sitting and standing respectively) are similar to those reported by Cram and

Engstrom (1986) for sitting and standing (mild elevations L3 level), supporting that work.

Limitations of the Study

This study was intended to be exploratory in nature for as Wolf (1983) noted, the need for between group studies which explore the effectiveness of increasing the activity of weakened muscles is great. The literature review showed no studies which addressed this need. As this is a first between group outcome study the results should be considered tentative in nature.

The results of this study can only be considered applicable for those subjects demonstrating similar medical and psychological profiles within the age range specified. It cannot be assumed that similar results would be found for subjects that demonstrate significant emotional problems. Furthermore, the sample was restricted to those individuals with no demonstrable medical problems (e.g., herniated disk, spinal stenosis, etc.). These results clearly cannot be applied to these individuals and biofeedback treatment may even be contraindicated. As muscle activity starts to change at approximately age 55 the patterns found in this study cannot be generalized to persons above that age.

All the techniques utilized in this study required an ability to learn. If the ability to learn was impaired (i.e., receptive aphasia) then as Brudny (1982) found the rate of implementing the learning would be slower making the outcome less predictable. Also, motivation would be a major factor. The techniques utilized in this study required the individual to be actively involved in the treatment. An individual not motivated to do so would not be expected to produce the same results as an individual who was motivated.

While every attempt was made to select subjects with only muscular problems, it cannot be unequivocally stated that other physical problems were not involved. Nachemson (1966) suggested that there is a very high correlation between intradisc pressure and pain. McKenzie (1973) suggests that most back pain is caused by disc problems. As the technology is not available that clearly defines when a disc is bulging or pressuring a nerve, this cause of pain cannot be ruled out.

The area of chronic pain still remains largely theoretical with little agreement as to the causes and correlates of pain. Other factors (e.g., locus of control) may have been involved which may have given differing results. Until a concensus can be arrived at, the assessment of CLBP will differ from study to study.

The area of the measurement of level of activity is extremely weak, for as Keefe et al. (1982) suggest the available instruments are psychometrically unreliable. This study was limited by the lack of a suitable measure of activity.

This study would be strengthened by demonstrating learning at follow-up. Further research should include this evaluation.

Suggestions for Future Research

As this study was exploratory in nature, it is recommended that further research replicate this study with a larger sample. There were several measures which approached statistical significance which may become significant with a larger sample.

Further investigation as to the nature of the relationship between EMG readings and reported pain is needed. In light of the high correlations, further study of this relationship may provide additional understanding of EMG readings during static and movement analysis, with the ultimate goal of demonstrating the presence of soft tissue injury. This of course would have implications for medicine and the assessment of whiplash injury for legal purposes.

Further investigation of the issue of bilateral difference, particularly focusing upon the lower side reading needs to be completed. If the lower side readings do prove to be evidence of a hyperextended (stretched) muscle, then the question as to why the muscle did not automatically return to the correct tension level needs to be answered.

Only three methods of treatment were compared in this study. Perhaps other methods (e.g., chiropractic adjustments) need to be compared and evaluated. In this era of cost effectiveness and accountability, examination of the various treatment techniques is needed. Perhaps there are better ways to teach what was utilized in this study. Perhaps the educational program would be more effectively taught in a group context, the relaxation training localized to the erector spinae muscles, or the biofeedback training reduced in length of treatment. All of these type of variables need to be examined and studied before the optimal procedures may be found.

Of interest also is the need to study groups with differing psychological profiles and monitor their response to treatment. It would be fascinating to compare the outcome data from this study to that from the three other classification groups as outlined by Costello et al. (1987). Research of this type would allow for examination of the relative contribution of the various factors (sensory, emotional, behavioral) in the different groups. Differences in outcome would then be utilized to direct treatment in a more streamlined and efficacious manner.

There are a number of statistical procedures which may be utilized in future studies. Multivariate procedures would allow for the assessment of more than one dependent variable (Johnson & Lubin, 1972). For example, the interrelationship between muscle activity and intradisc pressure could be studied. The analysis of physiological data requires control for the prestimulus levels because of the Law of Initial Values. In situations where the pretreatment values are significantly different ANCOVAs or MANCOVAs should be utilized.

Finally these results bring into question the concept of secondary gain. The subjects in this study were, on the average, in pain for 7 years with some adjustment to the pain expected in this time period. If secondary gain factors were more powerful than the reduction in pain, then change would not be reported. As change was reported, it would appear that the secondary gain factors were not as powerful as the reduction in pain. The results from this study suggest that the concept of secondary gain as the reason for lack of recovery in the CLBP sufferer cannot be applied indiscriminantly to all persons who suffer from chronic low back pain. The work by Costello et al. (1987) indicates that CLBP sufferers do not form a homogenous group, but form subgroups. The relationship of secondary gain to these subgroups needs to be studied, as it may be more of a factor in certain subgroups (e.g., elevated profiles from the MMPI) than in others (e.g., normal limit profiles from the MMPI).

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Appendix A

Volunteers Required For Chronic Low Back Pain Study

Subjects are required to participate in a study of the effect of treatment techniques upon chronic low back pain. The study will involve approximately 20 hours spread over a three month period. The study is conducted under the authorization of the University of Calgary, and involves no risk or cost to the participants.

Criteria

1. Experience chronic low back pain in the area between the top of the buttocks and the bottom of your shoulder blades.

2. Have experienced this pain for one year.

3. Experience the pain regularly.

4. Between the ages of 18 and 55 years.

5. Not involved with long term disability or litigation.

Stuart Donaldson
Ph.D. Candidate
University of Calgary

Appendix B

CONSENT FORM

I ______________________________________have read the information sheet as provided by Stuart Donaldson. I am aware that I will be participating in a research study the purpose of which is to compare three forms of treatment for chronic low back. Furthermore, I am aware that at any time during the study I have the right to terminate my involvement. I am aware that for whatever reason my involvement in the study may be terminated by Stuart Donaldson. I am also aware that there is no cost for the study.

I am aware that all materials pertaining to this study, whether they be written, electronic or printed will be stored under double lock and key. Access to the material will be restricted to Stuart Donaldson. All materials will be number coded and no materials except this form will have my name on it. This form will be kept separate, from the data, in another office and destroyed upon completion of the study. At no time will any data concerning any subject be released.

Read at Calgary, the _________ day of __________, 198__

Signed ____________________

Witness ___________________

____

Appendix C

Date:____________________

____
____
____
____

Dear Dr. _______________:

Re: _________________________
____

the above named has volunteered to participate in a University of Calgary authorized research study of chronic back pain. This study has been approved by the Faculty of Education Conjoint Ethics Committee. This study will be conducted at the Calgary Pain Treatment Centre under the direction of the undersigned. The study will run until approximately June 1988.

As part of the study there is a medical screening process under the direction of Dr. E. Gingrich. As part of the screening process Dr. Gingrich needs to eliminate the possibility of a) infection and b) structural defects such as spondylosis. Attached is an information sheet we would ask that you complete if possible. Below is a signed authorization form permitting this.

Thanking you in advance for your cooperation. If I may provide you with any more information please do not hesitate to contact me at 255-5950.

Yours truly,

Stuart Donaldson
Ph.D. Candidate, University of Calgary

AUTHORIZATION

I _________________________ hereby authorize Dr. ____________________ to release to Dr. E. Gingrich such information as may be requested concerning my low back pain.

Signature ____________________

Witness ____________________

Date ____________________

SD/tr

Appendix C
Part 2

CHRONIC BACK PAIN STUDY

1) Has the subject had a recent CBC?

Yes ______ No ______ Date ____________________

Are all parts normal?

Yes ______ No ______

If no, what is abnormal?

____

2) Have x-rays ever been taken since the onset of the pain?

Yes ______ No ______

If they have are they normal?

Yes ______ No ______

Thank you for your help in this study.

Please return to:
Calgary Pain Treatment Centre
220, 5824 - 2nd Street S.W.
Calgary, Alberta
T2H 0H2

ATTN: Research Study

Appendix D

HISTORY & PHYSICAL EXAMINATION FORMS
(to be completed by a physician)

RESEARCH STUDY: THE EFFECT OF CORRECTING MUSCLE ASYMMETRY ON CHRONIC LOW BACK PAIN

BY: STUART DONALDSON
DEPARTMENT OF EDUCATIONAL PSYCHOLOGY
UNIVERSITY OF CALGARY

Name ______________________ Date ______________________

Subject # __________________ D.O.B. ____________________

Sex _______________________ Occupation ________________

Number of years in present occupation ____________________

HISTORY

1) Indicate the primary location of pain: T10 ___ T11 ___ T12 ___

L1 ___ L2 ___ L3 ___ L4 ___ L5 ___ Sacreal ___

NOTE: For purposes of this study the primary source of pain must be in one of these areas. If this condition is not met please discontinue the interview at this point.

2) How long have they been in pain? Years ____ Months ____

3) How frequently do they experience the pain?
Weekly ____ Daily ____ Hourly ____ Constant ____

4) Does the intensity of the pain vary? Yes ____ No ____ If yes are there obviously related factors? ______________________

5) Is there pain in other parts of the musculoskeletal system?
1) ______ 2) ______ 3) ______ 4) ______ 5) ______

6) Does the pain radiate from the primary site (see #1 above)?
Yes ______ No _____

7) Is the pain aggravated by? A) coughing _____ B) bending _____
C) sneezing _____ D) defecation___

8) Is relief obtained by? A) recumbency _____
B) local heat _____
C) local ice _____

9) Is there presence of morning stiffness? Yes _____ No _____

10) Is there a history of symptoms of neurological impairment?
A) bowel symptoms ________________________________
B) bladder symptoms ______________________________

11) Was the onset following lifting? Yes ____ No ____

12) Is (was) the condition aggravated by lifting? Yes____ No____

(2)

13) History of previous treatments:
A) Physiotherapy ________ Date(s) ____________________________

B) Medications (Indicate whether previously used or not)
A) simple analgesia _____
B) narcotic analgesia _____
C) non steriod anti-inflamatories _____
D) benzodiazepines _____
E) tricyclics _____
F) meprobromate _____
G) other _____

C) Surgery
Back _____ Dates _____________
Abdominal _____ Dates _____________

D) Hospitalizations (other than surgery) as related to the back.
Date(s) __________ __________ __________

E) Wearing a cast (for any reason)
Body ____ Arm ____ Leg ____

14) Is there a history of dyspareunia? Yes ____ No ____

15) (Males) Is there a history of impotence? Yes ____ No ____

16) Is there a family history of back pain? Yes ____ No ____
If yes indicate family member _______________
Was this family member absent from work due to back pain?
Yes ____ No ____

17) Is there a history of systemic diseases? Yes ____ No ____
If yes indicate which? ___________________________________

Appendix E

HISTORY & PHYSICAL EXAMINATION FORMS
(to be completed by a physician)

RESEARCH STUDY: THE EFFECT OF CORRECT MUSCLE ASYMMETRY
ON CHRONIC LOW BACK PAIN

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(3)

PHYSICAL EXAMINATION

Name ______________________ Date ______________________

Subject # __________________

1. Gait: Normal ____ Limp ____ Guarded ____

Spine: Normal curvatures Present ____ Absent ____
Abnormal curvature ____________________

Muscle Spasm: Present ____ Absent ____
Visible ____ Evident only by palpation ____
Area(s) ________________________________

2. Range of Motion:

A) Using a meter stick have the subject hold it upright with both hands one end touching the floor. Ask the subject to bend forward as far as is comfortable. Have the subject slide his or her hands down the meter stick as far as possible. Record the height from the floor. _______cm.

B) Schober Test
(Skin Distraction Test)
i) standing upright measurement ____cms
ii) forward flexion measurement _____cms

3. Spinal tenderness: (in prone position)
Present _____ Absent _____
Area(s) ____________________________

4. Straight leg raise:
pain induced _____ no pain _____
degree of elevation _____

5. Deep Tendon Reflexes:
A) Patellar Reflexes: LEFT LEG
Present ____ Decreased ____ Absent ____

RIGHT LEG
Present ____ Decreased ____ Absent ____

B) Achilles Reflex: LEFT LEG
Present ____ Decreased ____ Absent ____

RIGHT LEG
Present ____ Decreased ____ Absent ____

C) Babinski Test:

LEFT LEG
Positive _____ Negative _____

RIGHT LEG
Positive _____ Negative _____

6. Plantar Responses:
Present _____ Weakened _____ Absent _____

7. Heel Walking: Normal _____ Performed with Pain _____
Unable to perform _____
Toe Walking: Normal _____ Performed with Pain _____
Unable to perform _____
Squatting: Normal _____ Performed with Pain _____
Unable to perform _____

8. Performance of a sit up: able _____ unable _____ to perform

Medical Reports (obtained from routine care giver)

1. CBC (are all parts within normal limits)? Yes _____ No _____

2. X-rays (lateral/PA views are necessary and these need to have been taken since the onset of the pain)
(Note: a report of the X-ray results is acceptable in place of the actual pictures)

Are the X-rays normal _____ or abnormal _____

(4)

Admission to the program will by physicians assessment based on the following criteria. The subjects who are accepted will be generally described as suffering from musculigamentous backache. Exclusions from the program will be on the basis of physician's assessment that suggests that the subject belongs in a different diagnostic group.

Exclusion Criteria

1. History of back surgery.

2. Straight leg raise less than 70 degrees produces pain.

3. Loss of reflexes.

4. Weakness in lower limbs.

5. Severe scoliosis.

6. Gait abnormality which affects biomechanics of spine.

7. Any other significant disease.

This is to certify that the above named individual was personally examined by me on the date indicated on the first page and that he/she is a suitable candidate for the study.

Signed ______________________ M.D.

Appendix F

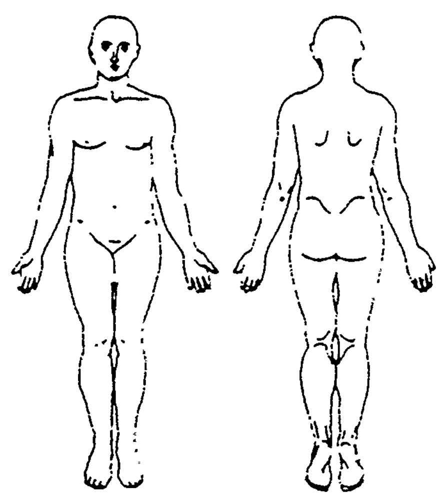
McGill Pain Questionnaire

Patient's Name ________________ Date __________ Time ________ am/pm

PRI: S ______ (1-10) A ______ (11-15) E ______ (16) M ______ (17-20) PRI(T) ______ (1-20) PPI ______

1	FLICKERING	11	TIRING
	QUIVERING		EXHAUSTING
	PULSING	12	SICKENING
	THROBBING		SUFFOCATING
	BEATING	13	FEARFUL
	POUNDING		FRIGHTFUL
2	JUMPING		TERRIFYING
	FLASHING	14	PUNISHING
	SHOOTING		GRUELLING
3	PRICKING		CRUEL
	BORING		VICIOUS
	DRILLING		KILLING
	STABBING	15	WRETCHED
	LANCINATING		BLINDING
4	SHARP	16	ANNOYING
	CUTTING		TROUBLESOME
	LACERATING		MISERABLE
5	PINCHING		INTENSE
	PRESSING		UNBEARABLE
	GNAWING	17	SPREADING
	CRAMPING		RADIATING
	CRUSHING		PENETRATING
6	TUGGING		PIERCING
	PULLING	18	TIGHT
	WRENCHING		NUMB
7	HOT		DRAWING
	BURNING		SQUEEZING
	SCALDING		TEARING
	SEARING	19	COOL
8	TINGLING		COLD
	ITCHY		FREEZING
	SMARTING	20	NAGGING
	STINGING		NAUSEATING
9	DULL		AGONIZING
	SORE		DREADFUL
	HURTING		TORTURING
	ACHING		PPI
	HEAVY	0	NO PAIN
10	TENDER	1	MILD
	TAUT	2	DISCOMFORTING
	RASPING	3	DISTRESSING
	SPLITTING	4	HORRIBLE
		5	EXCRUCIATING

BRIEF	RHYTHMIC	CONTINUOUS
MOMENTARY	PERIODIC	STEADY
TRANSIENT	INTERMITTENT	CONSTANT



E = EXTERNAL

I = INTERNAL

COMMENTS:

Appendix G

CALGARY PAIN TREATMENT CENTRE LTD.

VISUAL ANALOGUE SCALE

Below is a line 10 cm. long. We would like you to draw a mark on this line at the point which best indicates how severe your pain is. The left end of the scale will indicate no pain, the right end will indicate the worst possible pain. There is no right or wrong answer, only the amount that you feel.

no pain extreme pain

Name ______________________ Date ______________ Time ____________

Appendix H

CALGARY PAIN TREATMENT CENTRE LTD.

VISUAL ANALOGUE SCALE

Below is a line 10 cms long. We would like you to draw a mark on this line that represents the percent change in your pain since the last appointment. The middle of the line represents no change; to the left of centre represents the pain getting worse (increasing); to the right of centre represents the pain getting better (decreasing). Please remember there is no right or wrong answer, only the change you feel since your last appointment.

100% worse	no change	100% better

Name ______________________ Date ______________ Time ____________

Appendix I

Back to Balance Educational Program

1. Orientation
   - discuss the program
   - explain the nature of research
   - topics outline
   - the strategy of the program
     a) muscle spasm
     b) imbalance
     c) daily activity

2. Anatomy
   i) a) vertebrae
      b) facet joints
      c) discs
      e) muscles
   ii) the sources of pain
      a) fractures
      b) joint irritation
      c) nerve root entrapment
      d) muscular sprains/strains
   iii) symmetry/balance
      definition of muscular symmetry

3. Posture
   - its hip to be square
     (ideal posture)
     effects on muscles
   - causes of inequality
     leg length
     trauma
     chronic bad posture
     effects on muscles
     (1/2" difference is N.S.)
     weight distribution - knees and ankle

4. Causes of Muscle Imbalance
   i) Chronic Repetitive Actions
      a) opposing limb movement
         why exercise only half the back
      b) static loading
   ii) Lifting
      a) 10 degree tilt
      b) arm position
      c) leg position
      d) rotation

iii) When you just can't lift symmetrically
a) mirroring
b) stretching
c) exercise

5) Exercise
- when to exercise
- why exercise
M. Duffy's program

6) Depression
i) pain-anger-hopelessness-guilt
depression-isolation-withdrawal
decreased activity-pain cycle
ii) biomechanical changes
seretonin levels
neurotransmitters
nerve sensitivity
iii) medication

7) Stress
i) what is stress - definition
pain as a stressor
functionality
?/performance
ii) effects on muscles
decreased blood flow
increase of lactic acid

8) Stress Management
- breathing
- relaxation training
- exercise
- The Big C - Control
- Is It Worth Your Health

9) 25 tips

10) Review
Test