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# Musculoskeletal disorders in dentistry

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# MUSCULOSKELETAL DISORDERS IN DENTISTRY

A Thesis

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Master of Science in Industrial Engineering

in

The Department of Industrial Engineering

by:

Frank Maurice Pitts

Bachelor of Science in Mechanical Engineering, Southern University, 1993  
December 2005

*This is dedicated to my Grandmother; Agnes Guidry, who encouraged me with education and armed my entire family with the values necessary to succeed in life.*

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## ABSTRACT

Because of the common occurrence of pain experienced by dental professionals during the course of a workday and throughout their career, an epidemiological and a field study were performed in an effort to contribute to the prevention of musculoskeletal disorders in dentistry. The aim of the thesis is two fold: to assess the perception of occupational pain and discomfort felt by dentists through a perception based survey and to assess the muscle behavior of dentists during isotonic postures while performing various dental procedures on their first and last patients in a given work day. One hundred (100) dentists participated in the survey and ten (10) dentists out of the same sample group participated in the field study. Eight (8) EMG measurements were taken per dentist (four measurements per area of the back during the course of the day): representing lower back and upper trapezius EMG during the first minute of the first patient's visit and lower back and upper trapezius EMG during the last minute of the first patient's visit. The results of the survey indicate that fifty-eight percent of all of the respondents reported that they experience or have experienced some form of pain in their lower back, shoulder or neck during their tenure as a practicing dentist. Sixty-nine percent stated that the pain is such a real issue that they work out regularly to avoid it. Forty-seven percent report that they find comfort and muscle relaxation through massages and massage therapy. The development of muscle fatigue was assessed by spectral analysis (median frequency). It was found that the median frequency decreased significantly in the upper trapezius muscle from the last minute of the first patient to both the first and last minutes of the last patients. Perception of pain was found to have a significant relationship with the change in EMG frequency recorded after both 4 and 8 hours of work.

# CHAPTER 1

## INTRODUCTION

### 1.1 Significance

In the dental profession, dentists and dental hygienists spend their work days in an awkward, static position performing extremely precise procedures in a 2”x 2½” workspace- the patient’s mouth. Because there is no room for error, a steady hand and a steady, awkward posture must be assumed and maintained. However, maintaining the steady hand and posture comes at a cost to the back, neck and shoulder area of the dentist. Occasional pains from irregular stances or positions are to be expected while they are performing static work. However, when the pain becomes a regular occurrence, cumulative damage could arise leading to debilitating injuries.

Several studies have indicated that back, neck and shoulder pain are a major problem among dentists. Six studies, in particular, polled respondents over a period of 1 to 5 years and found that over half of the participating dentists experienced musculoskeletal pain: Shugars, *et al.*(1987) reported 60%; Runderantz, *et al.* (1990) cited 72%; Auguston and Morken, (1996) reported 81%; Finsen, *et al.* (1997) reported 65%; and Chowanadisai, *et al.* (2000) reported 78%. (However, all of these studies focused primarily on the physiological effects of prolonged postures occurring in the neck and shoulder region.) When dentistry changed from a standing job to a sit down task, musculoskeletal pain in the neck and shoulder region became more prevalent. This may explain the eventual focus on these areas. However, musculoskeletal pain in the lower back, regardless of occupation, remains a constant cause of loss of work for dentists and should be equally examined. Because dentists spend long hours hunched over their patients with their arms raised and their hands positioned relative to their patients’ mouths, unsupported

stress is placed on the muscles of the lower back. A study by McGill *et al.*, (2000), explains how prolonged static contractions of the lumbar erector spine decreases oxygenation levels in the muscle. When this happens, lactic acid and metabolites accumulate and causes the pain that one feels.

The pain suffered by dentists may lead to reduced productivity in terms of missed time from work or reduced work hours and may also lead to inefficient movements while working, causing an increase in time spent per patient. Incidentally, Shugars *et al.*, (1987) report that dental professionals lose in excess of \$41 million annually because of musculoskeletal pain. The re-scheduling and/or canceling of appointments of 1.3 million patients was also due to pain and discomfort suffered by their dentist. Therefore, not only will those engaged in dentistry benefit from a reduction of the chronic trauma often associated with the profession, but society as a whole will reap benefits in terms of efficiency and reliability of dentists and their practices. `

The scope of this thesis is two-fold: A comprehensive survey and a field study. In order to assess the problems experienced by those in the dental field, a number of dentists were asked to complete a survey form designed to evaluate the level of discomfort routinely experienced during the course of a working day. Using the results of these surveys, an assessment of the types of problems was made, and the relationships between pain experienced and a number of factors thought to be related to that pain were explored.

The field study consisted of observing, video taping, and taking electromyographic (EMG) measurements of back muscles from eight dentists performing actual procedures such as cleanings and checkups in an effort to analyze muscle fatigue. These recordings are a graphical representation of the electrical manifestation of muscle activity that proves very useful when measuring muscle fatigue levels. There are several different techniques for processing EMG;

however, the development of fatigue is best observed by amplitude and spectral analysis of EMG readings (Hagberg, 1981). The time-dependent shift in the median frequency of EMG signals to lower frequencies during the fatigue process is a proven and well established phenomenon and; therefore, it is the method of choice for this undertaking. The measurements were taken during the course of a full working day starting with the first patient at 8:00 a.m. and ending with the last patient at 4:00 p.m. Repeated measures analysis was used to determine if fatigue occurred in the upper or lower back muscles over time. Participants were asked a number of questions designed to evaluate the level of discomfort routinely experienced during the course of their day. Using the results of these practical surveys and EMG measurements, an assessment of the types of problems was made and possible solutions explored.

## CHAPTER 2

### BACKGROUND AND LITERATURE REVIEW

#### 2.1 Introduction to Literature on Musculoskeletal Pain Experienced by Dentists

There are many studies regarding musculoskeletal disorders experienced by persons working in the dental field that have used surveys to assess pain perception. Although they vary in scope and objective, a targeted look at the upper back, neck, shoulders and wrists is common in all of the studies. Each study has an epidemiological component which is of particular interest to this study because it allows for the examination of a comparable return rate for questionnaires.

In a study comparing Swedish and Australian dentists (Ylipaa *et al.*, 2002) regarding working conditions and their mental well being, 376 dentists were polled with a response rate of 86% in Sweden and 71% in Australia. Correlations were made based on age, number of years working and residence. Work-family overload, scaling procedures, work relations, practicing in Australia, and being under 42 years of age were associated with more musculoskeletal disorders. The percentage of the total sample that reported the following complaints were: Physical fatigue- 18%, Mental fatigue- 15%, Headaches- 16% and Anxiety- 13%.

In a similar study using a multidisciplinary approach (Lehto *et al.*, 1991), 131 professionally active dentists were studied. Forty-two percent of the dentists had experienced pain and disability (interference with daily activities) from neck and shoulder problems during the preceding year. Another study used telephone interviews to determine the prevalence of neck, shoulder, arm, and hand discomfort in dentists and pharmacists (Milerad and Ekenvallm,1990). Fifty-one percent of dentists compared to 23% of pharmacists reported shoulder symptoms, and 44% of dentists and 26% of pharmacists suffered from neck pain. This indicates that shoulder-neck discomfort is more of a problem among dentists than pharmacists.

These results lend support for further research regarding the postures commonly assumed by those working in the field of dentistry.

It is certainly plausible that the difficult work positions demand of dentists, including large cervical flexion and rotation, abducted arms, and repetitive precision-demanding handgrips, in comparison to pharmacists, could lead to the high levels of shoulder-neck discomfort reported.

Conventional wisdom suggests that by switching from stand-up dentistry to a seated practice with an assistant, one would experience fewer incidences of lower back pain and more occurrences of neck and shoulder discomfort. Thus, the focus of most studies seemed to concentrate on the upper trapezius area when lower back pain and discomfort were prevalent. In a study by Biller (1946), 65% of dentists surveyed experienced and complained of back pain. A study by McGill *et al.*, (2000) conducted fifty-four years later showed that 81% of dentists surveyed experienced and complained of neck, shoulder, wrist and back pain. These examples show how switching to a seated position has made little to no difference in the frequency of pain experienced by dentists in the lower back region (Figure 2.1).

In a study by Basset (1983), 465 Canadian dentists were surveyed and 62% of the respondents reported lower back pain. Seventy percent of those reporting lower back pain sought professional treatment for their discomfort, and 50% used exercise as a preventative tool and a means of relief. Thirty percent of those reporting lower back pain had missed days from work due to pain and discomfort. Diakow and Cassidy (1984) found that 57% of their surveyed dentists suffered from back pain and this pain may be more prolonged than that experienced by the general population. They also indicated that the highest frequency of lower back pain was experienced by the 30-40-year-old age group.

Even more to the point of the study at hand is an experiment by Finsen *et al.*, (1997) conducted to identify risk factors in dentistry contributing to musculoskeletal disorders. A survey was used to identify the incidence of disorders over a one-year period. The study gave the following results: of 115 dentists surveyed, 65% reported shoulder-neck problems, while 59% experienced lower back discomfort. A field study was also conducted to measure EMG activity during the three most common tasks performed by dentists in order to determine if one position would require less muscle activity than the other and, therefore, lead to reduced discomfort levels. Those tasks were found to be dental examinations, tooth cleanings and dental filling procedures. However, the results of this study indicate no differences regarding muscle activity or frequency of movement between the three most common postures and that the variations between those postures does not significantly reduce the musculoskeletal load on the neck and shoulders.

Finally, an electromyographic study by Milerad *et al.*, (1991) identifies the muscles placed under the most stress by routine dental work to be the shoulder, neck and arm muscles. Of these muscles investigated in the study, the trapezius muscles on each side of the body had the highest mean amplitude (expressed in % maximal reference contraction). The right trapezius mean was 9.0%, while the left was 7.6%.

## **2.2 Anatomy and Physiology of the Back**

To examine muscle activity in the lower and upper back regions, it is important to understand the function of the vertebrae and the muscles supporting the vertebrae. There are three vertebral groups that comprise this twenty-four bone structure: the neck (7 cervical vertebrae), the middle back (12 thoracic vertebrae), and the lower back (5 lumbar vertebrae).



The muscles that connect the upper extremity to the vertebrae column and are of relevance to this study are the latissimus dorsi and the trapezius muscles.

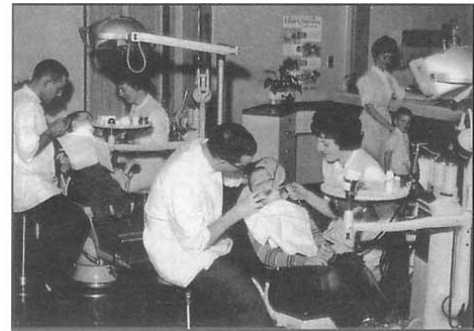
The trapezius is a flat, triangular muscle, covering the upper and back part of the neck and shoulders. It arises from the external occipital protuberance and the medial third of the superior nuchal line of the occipital bone, from the ligamentum nuchae, the spinous process of the seventh cervical, and the spinous processes of all the thoracic vertebrae, and from the corresponding portion of the supraspinal ligament (Gray, 2000). The angles of the trapezius fibers provide pull in three different directions: up, down, and in toward the center line of the body. The descending part of the right and left trapezius muscle and the latissimus dorsi are a common site of symptomatic pain in dentists (Murtomaa, 1982; Milerad and Ekenvall, 1990). The latissimus dorsi is a triangular, flat muscle which covers the lumbar region and the lower half of the thoracic region, and is gradually contracted into a narrow fasciculus at its insertion into the humerus. It arises by tendinous fibers from the spinous processes of the lower six thoracic vertebrae and from the posterior layer of the lumbodorsal fascia by which it is attached to the spines of the lumbar and sacral vertebrae, to the supraspinal ligament, and to the posterior part of the crest of the ilium (Gray, 2000). It rises no higher in point of origin than the first lumbar spine.

The postures in which dentists sit require over half of the body's muscles to work to hold the body motionless while resisting gravity. The static forces resulting from these postures have been shown to be more taxing than dynamic forces (Ratzon, *et al.*, 2000). Therefore, when the supporting muscles begin to reflect fatigue, a process of pain and discomfort begins and could very well lead to musculoskeletal injury. An article by Valachi and Valachi (2003) cited a

flowchart of muscle activity and pain leading to a musculoskeletal disorder: Prolonged Static Posture→ Muscle Fatigue and Muscle Imbalance→ Muscle Ischemia/Necrosis, Trigger Points and Muscle Substitution→ Pain→ Protective Muscle Contraction→ Nerve Compression, Spinal Disk Degeneration→ Musculoskeletal Disorder. Muscle imbalances could result from an awkward posture similar to that in Figure 2.1.C.



**A. Upright Posture (Biller, 1946)**



**B. Sit Down Posture (McGill, 2000)**



**C. Field Study Posture**

**Figure 2.1. Various Dental Work Postures**

The steady posture assumed in Figure 2.1.C shows a slight forward bend with the neck and head tilted in an effort to get a better view, while the arms are elevated and unsupported. As this posture becomes the normal working position, the muscles responsible for supporting the working posture become stronger and shorter while the contrasting muscle group becomes

weaker and elongated. The stress shortened muscles can then become ischemic and painful. Muscle imbalances in the lower back can also occur when the dentist leans forward repeatedly, causing strain in the low back extensors while making the transverses abdominus weaker. Over time, the body can adapt to these imbalances and this abnormal posture could ultimately follow Valachi and Valachi's (2003) illustration of prolonged postures leading up to musculoskeletal disorders.

### **2.3 Electromyography (EMG)**

Electromyography (EMG) is the study of muscle function through analysis of electrical signals emanated during muscular contractions (Acierno *et al.*, 1995). These signals represent the electrical activity associated with contracting muscles and, therefore, can be affected by anatomical and physiological muscle properties. Because of this effect, a basic understanding of muscle function is explained in section 2.2. Another factor effecting EMG signals is the EMG instrumentation itself. Surface electrodes were used in this study as they provided a general representation of muscle activity as well as the most comfort and accessibility. Since they are the direct site of connection between the body and the collection system, special care and handling was given to this equipment. Along with electrodes, components such as amplifiers, filters and the information gathering device itself complete the makeup of the EMG collection system.

The study of fatigue has often been relegated to using the force output of a muscle as the index of muscle fatigue. When the force output decreases sharply, the muscle is said to have reached its fatigue point. This concept implies that fatigue occurs at a specific point in time and that philosophy is not the approach accepted by some researchers. In a paper by De Luca (1997) three factors are listed that gives reason to the disadvantages of this approach.

- 1) During a voluntary contraction, the force of an individual muscle is not often directly accessible, and the monitored torque may not faithfully represent the force of the muscle of interest.
- 2) During a submaximal contraction, it is possible to maintain the torque acceptably constant, in a macroscopic sense, but there are time-dependent physiological and biochemical processes that microscopically alter the means for generating force during a sustained contraction. These processes include: a) motor units may be recruited and derecruited; b) the firing rates of most motor units decrease; c) the force twitches of motor units increase in amplitude during sustained contractions.
- 3) The failure point is a function of both physiological and psychological factors and it is difficult to know accurately the causal relationship of each to the failure point. The preferable approach is to exploit the well known spectral modification property of the EMG signal detected during a sustained contraction. Means for monitoring and quantifying the spectral changes during sustained contractions provide fatigue indices that describe the time course of the fatigue-related physiological and biomechanical processes. The two disadvantages of this approach is:
  - a. Contractile force can only be conveniently measured by monitoring the torque about a joint to which more than one muscle can contribute. In contrast, the EMG signal can be detected from individual muscles; thus, the spectral variable fatigue index can be used to describe the performance of individual muscles.
  - b. The spectral modification progresses continuously from the onset of contraction, thus providing an indication of the rate of the fatigue process early in contraction.

Contractile fatigue, as currently measured, requires the expenditure of considerable effort prior to being measurable (De Luca, 1997).

A diagrammatic explanation of the spectral modification occurring during a sustained contraction using a three-point digital filter is shown in Figure 2.2. Points of consideration when using spectral fatigue indexes are:

1. Electrode configuration
2. Electrode location
3. Electrode orientation
4. Crosstalk
5. Subcutaneous tissue
6. Fiber diameter
7. Signal stability

Electrode configuration, location and orientation are important in that the EMG signal is representative of the summation of MUAPs (motor unit action potentials) and it is difficult to know which motor units contribute to it. This gives way to muscle recruitment and derecruitment. In fatigued motor units, firing rates decrease while contraction time increases. When this occurs, the muscle tries to compensate for fatigue by recruiting new motor units. This produces more synchronous firing and a lower frequency bias in the composite EMG signal from the fatigued muscle. Therefore, the muscle fatigue index is represented by the median frequency of the spectrum.

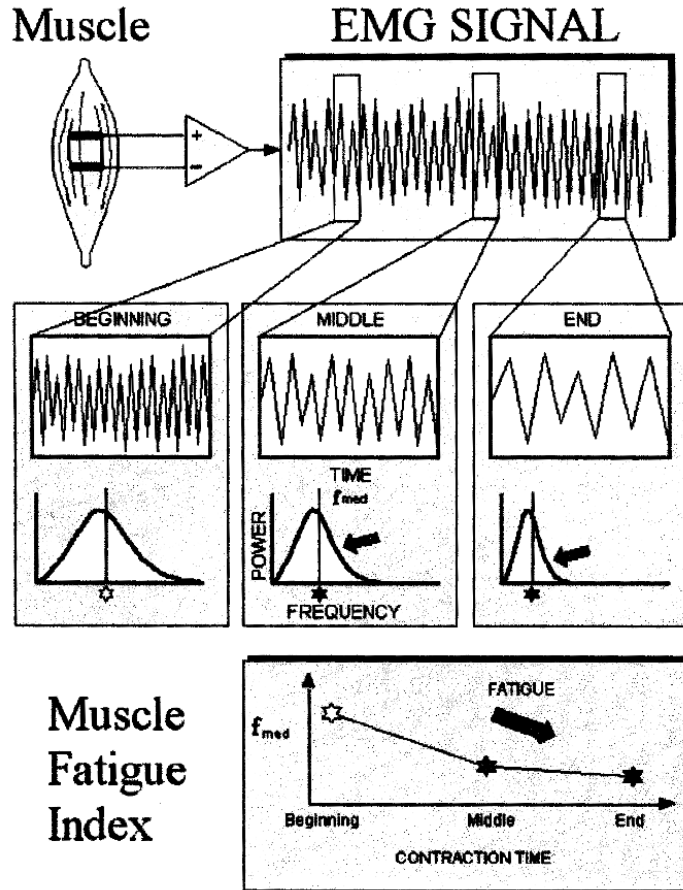


Figure 2.2. Muscle Fatigue Index.

## 2.4 Rationale

There are a small number of survey-based studies with a direct objective of targeting the most vulnerable stress areas and assessing fatigue levels through electromyography (EMG). In the most similar study, over 50% of dentists surveyed report a high frequency of musculoskeletal troubles because they have prolonged work postures and high static load in the neck and shoulder region (Finsen *et al.*, 1997). In sit-down dentistry, the work area is higher than elbow height which causes an elevation of the shoulder girdle. The static elevation of the shoulders may cause chronic myalgia in the descending part of the trapezius muscle, often referred to as

tension neck syndrome (Milred and Ekenvall, 1990). Also, several of these working positions require the cervical spine to not only be bent but also turned, which increases the load. Though Finsen's study is similar in scope, it does not address the lower back region.

In a study by Milerad *et al.* (1991), high muscular activity during dentistry work was recorded from the trapezius muscles since this working posture is such where the arms are unsupported, abducted and flexed. The same study revealed that the infraspinatus muscle showed a low activity level. The infraspinatus muscle is an important stabilizer of the glenohumeral joint and its activation increases with arm elevation (De Luca and Forrest, 1973). Again, the EMG methodology was not used on the lower back region and a survey was not done in conjunction with an EMG field study.

## **2.5 Research Objectives**

The goal of this study is to:

- Evaluate the perception of pain and discomfort felt by dentists due to the rigors of dental work through the use of a survey.
- Examine muscle activity associated with dental work in the upper and lower back of dentists through EMG measurements.
- Identify muscle fatigue in high-stress areas and explore comparisons of time spent working and the perceived amount of pain.
- Examine the association between selected demographic variable and the level of discomfort that people experience
- Determine if preventative techniques like exercise and massage have any effect on the prevention of pain associated with dental work.

## CHAPTER 3

### METHODS AND PROCEDURES

#### 3.1 Experimental Design

##### 3.1.1 Perception Measurement

The method used to measure the perception of pain and discomfort in the workplace was to randomly sample 100 dental professionals in Louisiana. A close-ended questionnaire was used to measure the target sets' perception of pain and discomfort in the workplace and the effectiveness of the activities to alleviate the pain caused by workplace conditions (see Appendix C). Effectiveness questions were divided to rank the following outcome indicators:

- How many respondents experienced lower back pain
- How many respondents experienced severe shoulder pain
- How many respondents experienced severe neck stiffness
- What steps does one take to alleviate such conditions
- When does the pain occur (after how many hours of work)
- General demographic information

##### 3.1.2 Statistical Analysis of Survey Data

A pain index was created from the survey to quantify the perceived pain. For any question (of the first 3 questions) that was answered “yes” one point was noted on the “pain index.” For example, if they had lower back pain, severe shoulder pain, and were forced to stand up and stretch because of severe back tightness, three points were assigned. If they only had shoulder pain, only one point was assigned. If they didn't experience any pain during the day, zero points were assigned.



### 3.1.3 Data Collection

Data was collected from public and private dentistry's statewide. The following return results were achieved.

**Table 3.1. Survey Response Rates**

Questionnaires		Response Rate (%)
Random Sample Target		100
	Returned	72
	Complete	64
	Incomplete	8
	Not Returned	28

### 3.1.4 Data Reliability and Validity

The reliability of the data was tested by measuring its stability and answerability over time. One hundred dentists were asked to participate in this survey and sixty-four of them completed and returned the survey. The ten surveys belonging to the corresponding dentists that agreed to participate in the EMG field study were set aside for further comparison. Upon arrival to perform the EMG field study, each dentist was asked to complete another survey- the same survey as completed previously. All of the responses were the same in terms of a general perception of pain. The Licert scale format of answers/choices allows for one to "strongly agree," "agree," "have no opinion," "disagree" or "strongly disagree." The only differences in the second survey answers were, for example, where one answered "strongly agree" in the first survey, he or she may have answered "agree" in the latter survey. This does not affect the overall perception of pain and therefore, the data collected were deemed reliable.

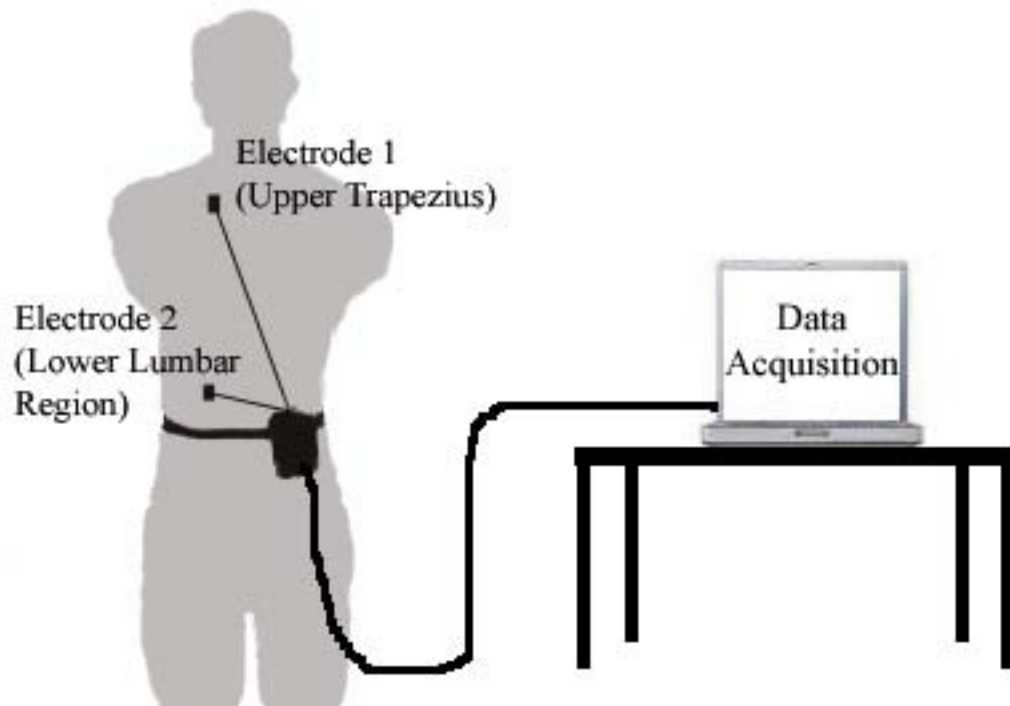
The validity of the survey was addressed by its construct, content and criterion. Its construct validity was measured by its association with the general theory that any human muscle under a sustained contraction will, at some point, exhibit fatigue over time. In this case, fatigue

is associated with muscle strain and muscle substitution that will ultimately produce pain in the afflicted area. Also, people are more likely to take some type of immediate action when their body is at risk of injury and/or experiencing pain and discomfort. This action can come in many different forms- pain medicine, massage, heat pads, exercise, etc. The survey was designed to identify specific areas of pain and fatigue as well as to designate a time period of more discomfort after so many working hours. Content validity was addressed by collaborating with a practicing dentist in an effort to authenticate the issues of pain and discomfort in specific areas and to develop identifiable questions that would resonate with the reader. Criterion validity with its subtype of predictive validity was based on its challenge of the literature review. Several, if not all, of this manuscript's referenced studies on musculoskeletal disorders in dentistry, have an epidemiological component that includes a survey involving the polling of respondents about their propensity to experience pain and discomfort. In aggregate, all of the studies yielded a return rate where over 50% of the respondents polled experienced back, neck and shoulder pain. The outcome of this survey is characteristically in line with those reviewed for this study.

The validity of the field study was addressed by taking an inventory of procedures that the dentists performed on the day of their participation. Each list was quantified and compared in an effort to qualify each workload as sufficient and/or equal and comparable in task. Table 4.5 was designed in an effort to quantify the amount of work performed by the participating dentist on the day that the EMG measurements were taken. A detailed quantification procedure and analysis was not warranted because we just wanted to show that each dentist performed actual procedures in the patient's mouth with the arms abducted and unsupported.

### 3.2 EMG Measurement

In examining the amount of muscle activity associated with dental work, 10 dentists out of the sample group that participated in the survey segment of this study were asked to participate. These 10 dentists agreed to allow EMG data to be recorded during the dental treatments of their first and last patients of the day. Electrodes were placed on the upper trapezius muscle and the latissimus dorsi muscle (shown in Figure 3.1) of each dentist and EMG data were recorded during the first and last minute of the morning treatment (the first patient) and during the first and last minute of the afternoon treatment (the last patient).



**Figure 3.1. Electrode Placement.**

This study is unique in that EMG measurements throughout the course of a dentist's workday have not been analyzed in previous work. Also, this study is very specific in that isotonic

postures focusing on two localized areas, upper and lower back, was studied. Milerad *et al.*, (1991) and Finsen *et al.*, (1997) focused on the neck, shoulder and arm muscles.

In order to identify muscle fatigue in high-stress areas, the participating dentists were observed during the course of their normal duties in the static positions in which they spend most of their time. Digital pictures of the participants in various positions were taken from several angles, for the purpose that, in aggregate, they would provide a means of documenting the back, neck, and shoulder angles for analysis using software that shows forces and moments acting on the body in depicted postures.

One consideration that must be mentioned is the potential for invasion of privacy of the patients on whom the dentists involved in the experiment were working on at the time the video and photographs were taken. By necessity, these patients become passive participants. Therefore, their permission was obtained before any photographs were taken, and efforts were made to exclude them from photographs and video where feasible. Fortunately, as it is the dentists' back, neck, and shoulders that were the primary focus of the study, it was rarely necessary for the patients to be included in the shots. However, concern expressed by some dentists on the patients' behalf was somewhat of a problem in recruiting participants.

### **3.2.1 EMG Apparatus**

EMG data acquisition and analysis were done by the use of the Delsys Inc.'s Bagnoli-2 EMG System (650 Beacon St., Boston MA. 02215, [www.DelSys.com](http://www.DelSys.com)). Its active electrodes are specifically devised to optimally detect EMG signals in the skin surface, rejecting common noise signals such as motion and cable artifacts and yielding an excellent signal-to-noise ratio. A gain of 1000 was selected for acquisition.



**Figure 3.2. Bagnoli EMG System.**

### **3.2.2 EMG Analysis**

*EMG* data was processed using the median frequency of the signal. A moving average was performed to see how the *EMG* signal changes with time over the contraction. A comparison was made with the normalized data. The median frequency (MDF) was also calculated in an effort to interpret the firing behavior of the motor units by calculating data in three steps. First, a Fast Fourier Transform (FFT) was calculated for the data within the window. The Power Spectrum Density (PSD) was then determined by squaring the FFT and determining the magnitude. Finally, the Median Frequency was calculated by determining the frequency that divides the PSD in two regions having the same amount of power.

De Luca (1997) reported overall spectral shifts in the surface *EMG*. These shifts are attributed to the type of muscle fibers activated and may therefore be used for characterization of motor unit recruitment and muscle composition. Investigation of these shifts have been limited to changes in the median frequency of the power spectrum derived using windowed FFT.

### **3.2.3 Statistical Analysis of EMG Data**

Eight *EMG* measurements were taken per dentist (four measurements: 2 per area of the back) during the first and the last minute of the morning patient's visit where " $\mu_{1Lower}$ " represents the latissimus dorsi *EMG* and " $\mu_{1Upper}$ " represents the upper trapezius *EMG*. During the last minute of the first patient's visit, " $\mu_{2Lower}$ " represents the latissimus dorsi *EMG* and " $\mu_{2Upper}$ "

represents the upper trapezius EMG. Because the experiment repeated the same procedure during the afternoon visit, “ $\mu_{3Lower}$  and  $\mu_{4Lower}$ ” represent the latissimus dorsi EMG measurements for the first and the last minute of the last patient’s procedure and “ $\mu_{3Upper}$  and  $\mu_{4Upper}$ ” represent the upper trapezius EMG during the first and the last minute of the last patient’s visit. The independent variables in this model are dentist and time of day, and the dependent variable is the EMG measurement, which is considered to be a repeated measure over time for each dentist, (with correlation between measurements decreasing as distance in time increases).

Examining the amount of muscle activity associated with dental work and determining if fatigue is reached at the end of a patient’s procedure or at the end of the day was done by using a repeated measures mixed model analysis with a five percent level of statistical significance. The following hypotheses were tested:

- 1.)  $H_0 : \mu_{1Lower} = \mu_{2Lower}$
- 2.)  $H_0 : \mu_{1Upper} = \mu_{2Upper}$
- 3.)  $H_0 : \mu_{3Lower} = \mu_{4Lower}$
- 4.)  $H_0 : \mu_{3Upper} = \mu_{4Upper}$
- 5.)  $H_0 : \mu_{1Lower} = \mu_{3Lower}$
- 6.)  $H_0 : \mu_{1Upper} = \mu_{3Upper}$
- 7.)  $H_0 : \mu_{2Lower} = \mu_{4Lower}$
- 8.)  $H_0 : \mu_{2Upper} = \mu_{4Upper}$
- 9.)  $H_0 : \mu_{1Lower} = \mu_{4Lower}$
- 10.)  $H_0 : \mu_{1Upper} = \mu_{4Upper}$
- 11.)  $H_0 : \mu_{2Lower} = \mu_{3Lower}$

12.)  $H_0 : \mu_{2Upper} = \mu_{3Upper}$

$\mu_1 =$	Mean MDF electrical activity in the muscle at the beginning of the first patient's procedure
$\mu_2 =$	Mean MDF electrical activity in the muscle at the end of the first patient's procedure
$\mu_3 =$	Mean MDF electrical activity in the muscle at the beginning of the last patient's procedure
$\mu_4 =$	Mean MDF electrical activity in the muscle at the end of the last patient's procedure

### 3.3 Pilot Study

In an effort to test the procedure of the EMG field experiment, a volunteer was asked to simulate an isotonic posture and replicate some hand movements that dentists make while attending to a patient. These simulated movements included reaching for tools, turning the torso as if to examine something and pretending to intricately work on a tooth. The electrodes were placed on the right upper trapezius muscle and just to the right of the latissimus dorsi region (see Figure 3.3). This prototyping procedure was relegated to what would be one patient's visit, averaging 23 minutes (based on polled dentists' approximation), because simulation of an entire work day was not possible. However, the realization of this fact raised questions of validity that will be answered in the Data Reliability and Validity section of this thesis. The questions involve qualifying and quantifying what takes place during the typical day of a dentist and how this study will qualify and compare these procedures as common indicators between EMG measurements. For example, one dentist may examine x-rays and give patient consultations on certain days while another could perform tooth extractions and cleanings.



**Figure 3.3. Electrode Placement- Pilot Study.**



**Figure 3.4. Isotonic Posture with Arms Unsupported.**

This pilot procedure was also helpful in streamlining the data collection process and improving the data analysis method by transferring the data to Microsoft Excel. The EMG data analysis software does not lend itself to the mathematical and graphical exploits that Excel offers and, therefore, a transfer to Excel through the tools drop-down menu labeled ‘Export to CSV’ was encouraged. The MDF was calculated by EMGWorks and the average MDF was calculated in Excel. These data points were used as determinants of fatigue.



## CHAPTER 4

### RESULTS AND DISCUSSION

#### 4.1 Survey Results

##### 4.1.1 Demographics

Table 4.1 summarized the demographic data of the surveyed dentists. Forty-four percent of the respondents ranged in age from 20 to 40 years old and fifty percent had been practicing between 1 and 15 years. An additional forty-four percent of the respondents ranged in age from 41 to 50 years old and most of these had been practicing between 10 and 25 years. Thirteen percent of the respondents polled were 51 years old or older and had been practicing from 21 to 25 years. Eighty-one percent worked an average of 7 to 9 hours per day; of these, forty -six percent worked 3 or 4 days per week while fifty-four percent worked 5 or 6 days per week. Fifty percent of all respondents weighed between 151 and 180 lbs and stood 5'6" to 6' in height, but these were not all the same respondents. Seven percent of the respondents weighed between 120 and 150 lbs, and thirty one percent weighed between 180 and 220lbs. Six percent of the respondents were between 4'6" and 5' in height. Thirty one percent were between 5'1" and 5'5" and twelve percent were over 6' (Table 4.1).

##### 4.1.2 Population Summary

Overall survey responses were tabulated individually by question, and estimates of population percentages along with 95% confidence intervals were calculated for each level of response using the Surveymeans procedure of SAS® Version 9.1.3 statistical software. These confidence intervals reflect the overall population size of dentists (896 dentists in southern Louisiana) from which the sample was drawn. For each response level, the estimated population percentage is

simply the sample percentage, and the confidence interval reflects the uncertainty inherent in making that estimate based on the sample values. These results are summarized in Table 4.2.

**Table 4.1. Cross-Tabulation of Height and Weight of Survey Respondents.**

Height	Weight			Total	
	120-150 pounds	151-180 pounds	181-220 pounds		
4 ft, 6 in. to 5 feet	Number of Respondents	4	0	0	4
	Percent	6.25	0.00	0.00	6.25
5 ft, 1 in. to 5 ft., 5 in.	Number of Respondents	8	12	0	20
	Percent	12.50	18.75	0.00	31.25
5 ft, 6 in. to 6 feet	Number of Respondents	0	20	12	32
	Percent	0.00	31.25	18.75	50.00
6 feet to 7 feet	Number of Respondents	0	0	8	8
	Percent	0.00	0.00	12.50	12.50
Total	Number of Respondents	12	32	20	64
	Percent	18.75	50.00	31.25	100.0

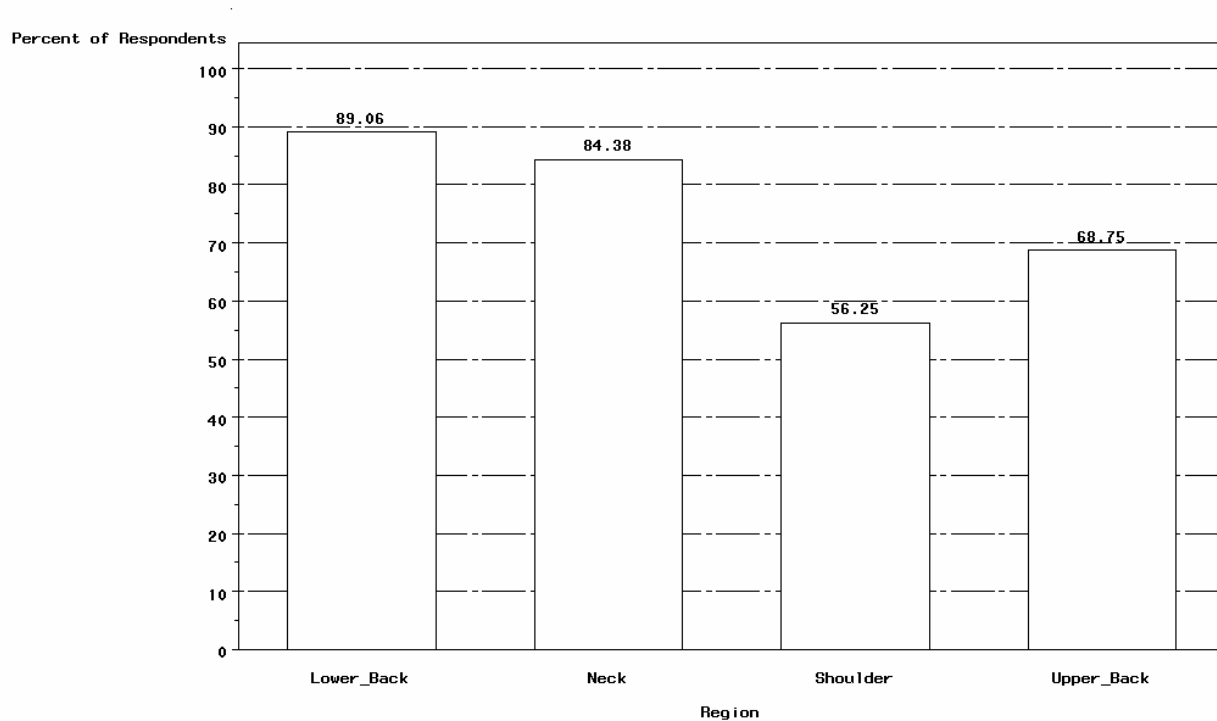
**Table 4.2. Summary of Survey Results and Confidence Intervals.**

Survey Question	Response	Estimated Population Percentage	StdErr	Lower 95% C.I.	Upper 95% C.I.
Lower Back Pain	No	0.5000	0.0607	0.3787	0.6213
	Yes	0.5000	0.0607	0.3787	0.6213
Severe Shoulder Pain	No	0.6250	0.0588	0.5075	0.7425
	Yes	0.3750	0.0588	0.2575	0.4925
Severe Neck Stiffness	No	0.5000	0.0607	0.3787	0.6213
	Yes	0.5000	0.0607	0.3787	0.6213
Stretching due to Severe Back Pain	No	0.7500	0.0526	0.6449	0.8551
	Yes	0.2500	0.0526	0.1449	0.3551
Breaks to avoid shoulder/neck pain	No	0.6875	0.0563	0.5750	0.8000
	Yes	0.3125	0.0563	0.2000	0.4250
Breaks to avoid Lower back pain	No	0.6250	0.0588	0.5075	0.7425
	Yes	0.3750	0.0588	0.2575	0.4925

Work out to avoid back pain	No	0.3125	0.0563	0.2000	0.4250
	Yes	0.6875	0.0563	0.5750	0.8000
Massages to avoid back pain	No	0.5625	0.0602	0.4421	0.6829
	Yes	0.4375	0.0602	0.3171	0.5579
Massages to avoid neck/shoulder stiffness	No	0.5625	0.0602	0.4421	0.6829
	Yes	0.4375	0.0602	0.3171	0.5579
Heating Pad for Back Pain	No	0.8125	0.0474	0.7178	0.9072
	Yes	0.1875	0.0474	0.0928	0.2822
Use of Muscle Relaxers for back pain	No	0.8125	0.0474	0.7178	0.9072
	Yes	0.1875	0.0474	0.0928	0.2822
Received Medical treatment for upper back pain	Strongly Agree	0.0625	0.0294	0.0038	0.1212
	Agree	0.3750	0.0588	0.2575	0.4925
	Disagree	0.3125	0.0563	0.2000	0.4250
	Strongly Disagree	0.2500	0.0526	0.1449	0.3551
Received Medical treatment for shoulder pain	Strongly Agree	0.1250	0.0402	0.0448	0.2052
	Agree	0.3125	0.0563	0.2000	0.4250
	No Opinion	0.1250	0.0402	0.0448	0.2052
	Disagree	0.1875	0.0474	0.0928	0.2822
	Strongly Disagree	0.2500	0.0526	0.1449	0.3551
Physical Therapist for muscle stiffness	Strongly Agree	0.1250	0.0402	0.0448	0.2052
	Agree	0.0625	0.0294	0.0038	0.1212
	No Opinion	0.1250	0.0402	0.0448	0.2052
	Disagree	0.4375	0.0602	0.3171	0.5579
Physical Therapist for muscle stiffness	Strongly Agree	0.1250	0.0402	0.0448	0.2052
	Agree	0.0625	0.0294	0.0038	0.1212
	No Opinion	0.0625	0.0294	0.0038	0.1212
	Disagree	0.1875	0.0474	0.0928	0.2822
	Strongly Disagree	0.2813	0.0546	0.1722	0.3903
Massages for muscle stiffness	Strongly Agree	0.1875	0.0474	0.0928	0.2822
	Agree	0.3125	0.0563	0.2000	0.4250
	No Opinion	0.1875	0.0474	0.0928	0.2822
	Disagree	0.0625	0.0294	0.0038	0.1212
	Strongly Disagree	0.2500	0.0526	0.1449	0.3551
Athletic trainer for muscle stiffness	Agree	0.0625	0.0294	0.0038	0.1212
	No Opinion	0.1875	0.0474	0.0928	0.2822
	Disagree	0.4375	0.0602	0.3171	0.5579
	Strongly Disagree	0.3125	0.0563	0.2000	0.4250
Medical Treatment for Lower Back Pain	Strongly Agree	0.1875	0.0474	0.0928	0.2822
	Agree	0.3125	0.0563	0.2000	0.4250
	Disagree	0.3125	0.0563	0.2000	0.4250
	Strongly Disagree	0.1875	0.0474	0.0928	0.2822
Medical Doctor for Muscle Stiffness	Strongly Agree	0.1250	0.0402	0.0448	0.2052
	Agree	0.1875	0.0474	0.0928	0.2822
	No Opinion	0.2500	0.0526	0.1449	0.3551
	Disagree	0.1250	0.0402	0.0448	0.2052
	Strongly Disagree	0.3125	0.0563	0.2000	0.4250

Lower Back After 4 Hours	Moderate Discomfort	0.4375	0.0602	0.3171	0.5579
	No Discomfort	0.5625	0.0602	0.4421	0.6829
Upper Back After 4 Hours	Moderate Discomfort	0.3125	0.0563	0.2000	0.4250
	No Discomfort	0.6875	0.0563	0.5750	0.8000
Shoulders After 4 Hours	Extreme Discomfort	0.1250	0.0402	0.0448	0.2052
	Moderate Discomfort	0.0625	0.0294	0.0038	0.1212
	No Discomfort	0.8125	0.0474	0.7178	0.9072
Neck After 4 Hours	Moderate Discomfort	0.4375	0.0602	0.3171	0.5579
	No Discomfort	0.5625	0.0602	0.4421	0.6829
Lower Back After 8 Hours	Extreme Discomfort	0.1250	0.0402	0.0448	0.2052
	Moderate Discomfort	0.7500	0.0526	0.6449	0.8551
	No Discomfort	0.1250	0.0402	0.0448	0.2052
Upper Back After 8 Hours	Extreme Discomfort	0.1250	0.0402	0.0448	0.2052
	Moderate Discomfort	0.5625	0.0602	0.4421	0.6829
	No Discomfort	0.3125	0.0563	0.2000	0.4250
Shoulders After 8 Hours	Extreme Discomfort	0.3906	0.0592	0.2723	0.5090
	Moderate Discomfort	0.1719	0.0458	0.0803	0.2634
	No Discomfort	0.4375	0.0602	0.3171	0.5579
Neck After 8 Hours	Extreme Discomfort	0.2500	0.0526	0.1449	0.3551
	Moderate Discomfort	0.5000	0.0607	0.3787	0.6213
	No Discomfort	0.2500	0.0526	0.1449	0.3551
Age in Years	20-30	0.1250	0.0402	0.0448	0.2052
	31-40	0.3125	0.0563	0.2000	0.4250
	41-50	0.4375	0.0602	0.3171	0.5579
	51+	0.1250	0.0402	0.0448	0.2052
Years in Profession	1-9	0.2500	0.0526	0.1449	0.3551
	10-15	0.2500	0.0526	0.1449	0.3551
	16-20	0.3750	0.0588	0.2575	0.4925
	21-25	0.1250	0.0402	0.0448	0.2052
Average Workday	10+ Hours	0.1250	0.0402	0.0448	0.2052
	4-6 Hours	0.0625	0.0294	0.0038	0.1212
	7-9 Hours	0.8125	0.0474	0.7178	0.9072
Average Work Week	3-4 Days	0.4375	0.0602	0.3171	0.5579
	5-6 Days	0.5625	0.0602	0.4421	0.6829
Average Age of Seating Equipment	1-5 Years	0.1250	0.0402	0.0448	0.2052
	6-10 Years	0.4531	0.0604	0.3324	0.5739
	11-15 Years	0.1250	0.0402	0.0448	0.2052
	16-20 Years	0.2500	0.0526	0.1449	0.3551
	21+ Years	0.0469	0.0257	0.0000	0.0982
Height	4 ft, 6 in. to 5 feet	0.0625	0.0294	0.0038	0.1212
	5 ft, 1 in. to 5 ft,5 in.	0.3125	0.0563	0.2000	0.4250
	5 ft, 6 in. to 6 feet	0.5000	0.0607	0.3787	0.6213
	6 feet to 7 feet	0.1250	0.0402	0.0448	0.2052
Weight	120-150 pounds	0.1875	0.0474	0.0928	0.2822
	151-180 pounds	0.5000	0.0607	0.3787	0.6213
	181-220 pounds	0.3125	0.0563	0.2000	0.4250

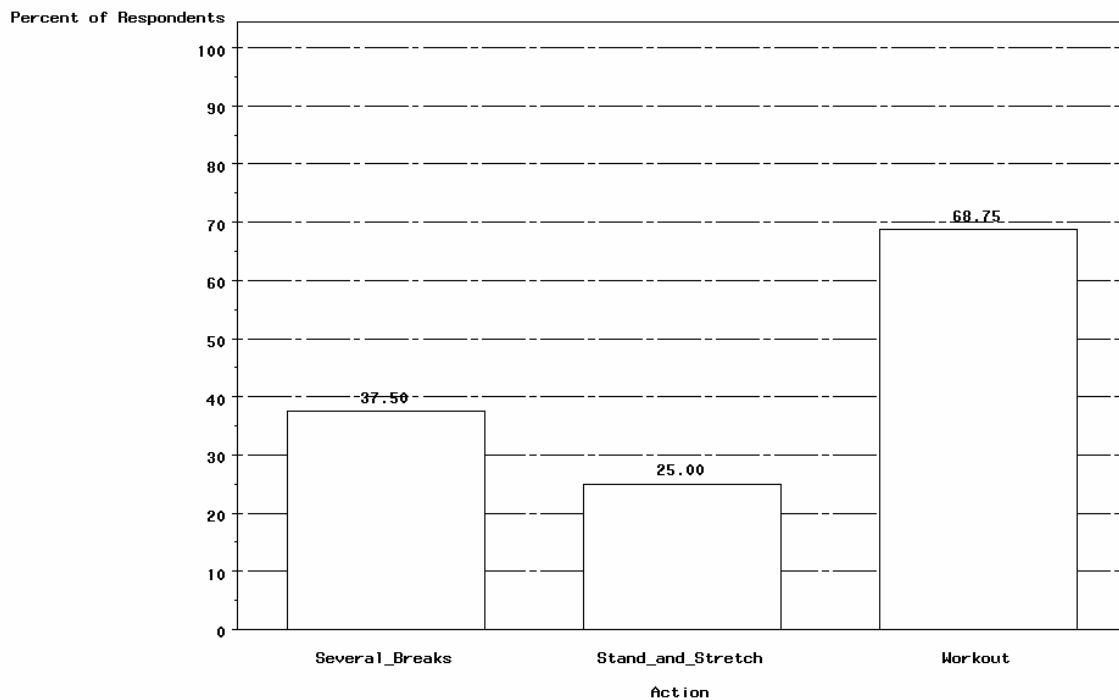
Forty-two percent of all of the respondents reported that they often experience some form of pain in their upper or lower back, shoulder or neck during their tenure as a practicing dentist. The percentages reporting pain in each of these regions is detailed in Figure 4.1 where the bar heights correspond to the percentage of survey respondents who reported experiencing some form of pain in the given area. Sixty-nine percent stated that the pain is such a real issue that they work out regularly to avoid it (Figure 4.2). In addition, fifty-three percent report that they find comfort and muscle relaxation through massages. Very few (nineteen percent) reported the use of muscle relaxers (Table 4.2). These statistics indicate an awareness of the perceived pain and identify a seemingly common preventative measure.



**Figure 4.1. Perception of Pain in Different Areas of the Body.**

The pain and discomfort felt by the participating respondents have not reached a level of any significance requiring prescription of medical treatment as evidenced by the low single and

composite percentages pertaining to the action. This is not an indication that lower back, shoulder and neck stiffness are not severe; however, it does indicate that the polled dentists are trying a more physiological approach before a chemical one. Figure 4.2 illustrates the percentage of respondents who reported that they managed pain by working out, by standing and stretching several times during the work day, and by taking several breaks while working. The bar heights represent the percent of respondents who reported using each action. These percentages are overall, meaning that a single respondent may have answered yes to as many as three of these questions.



**Figure 4.2. Actions Taken to Alleviate the Pain.**

### 4.1.3 Perception of Pain and Time

Every respondent reported moderate to extreme discomfort in either the lower back, shoulders or neck after eight hours of work. There was also discomfort after four hours of work but not as widespread or severe as reported after performing 8 hours of dental work. The differences in these perceptions of pain over time are detailed in Figures 4.3 and 4.4. These are overall percentages, and are meant to illustrate the differences between regions and hours worked rather than the interactions between regions. These graphs do not attempt to show whether an individual respondent reported different levels of pain in different regions. This question is addressed later via repeated measures analysis.

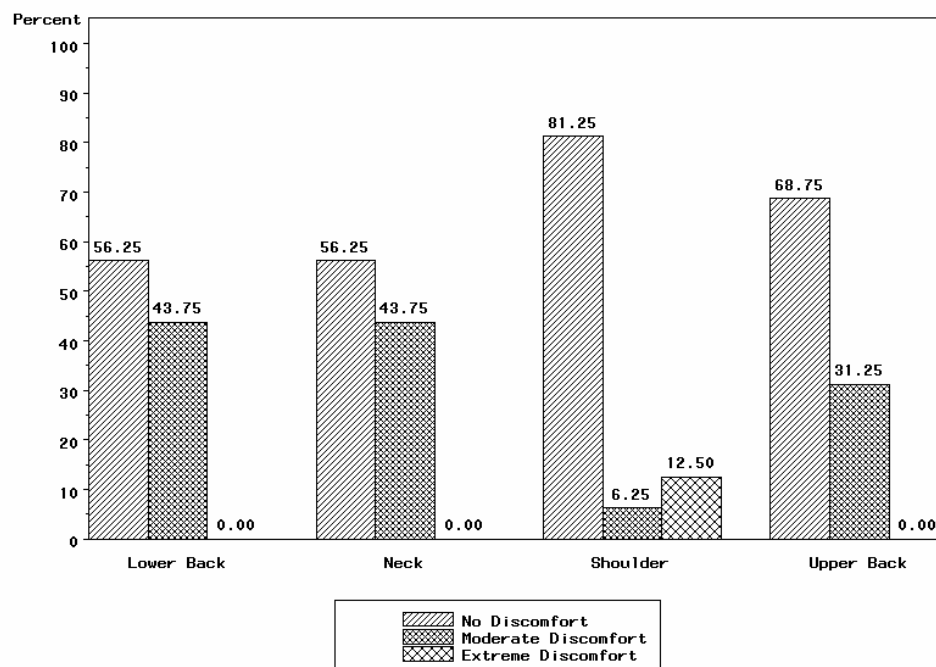
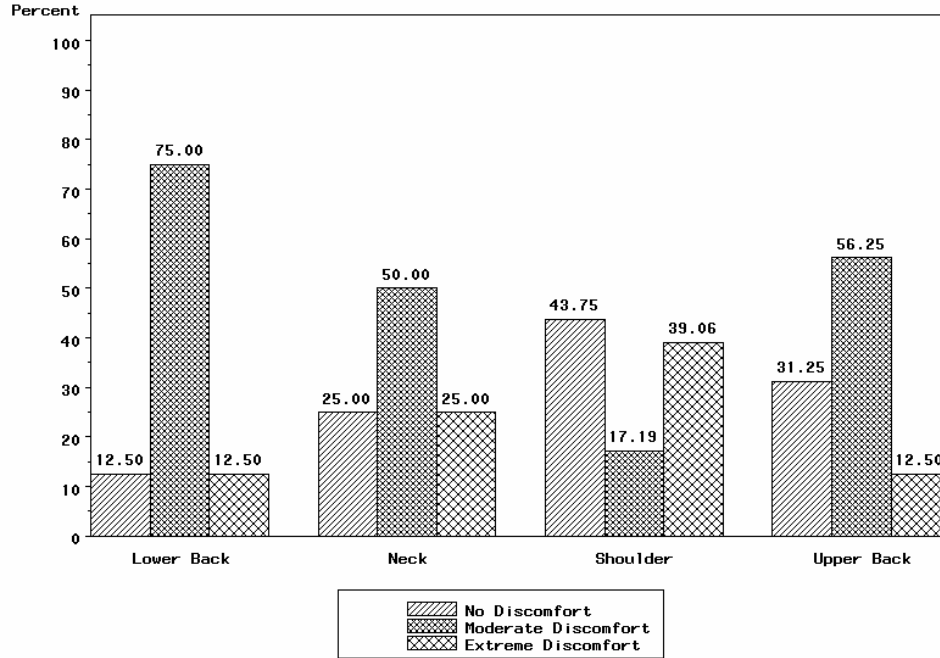


Figure 4.3. Perception of Pain in Each Region after 4 Hours of Work.

### 4.1.4 Results of Survey Statistical Analysis

A number of fixed effect analyses of variance were used to determine whether any of the



**Figure 4.4. Perception of Pain in Each Region after 8 Hours of Work.**

demographic factors or treatment methods had a significant effect on discomfort. Independent variables from the survey data included:

- Lower back discomfort after 4 hours
- Upper back discomfort after 4 hours
- Shoulder discomfort after 4 hours work
- Neck discomfort after 4 hours work
- Lower back discomfort after 8 hours
- Upper back discomfort after 8 hours
- Shoulder discomfort after 8 hours
- Neck discomfort after 8 hours



The survey questions that consistently had a significant effect on responses about discomfort were use of massage, seeking of treatment for muscle stiffness from both medical doctors and athletic trainers, and height of the dentist. Additionally, age and the number of days worked in the average week had a significant effect on shoulder discomfort after 4 hours of work. ANOVA results for significant survey questions are summarized in Table 4.3. The values in bold print are p-values for each significant effect at a 95% confidence level.

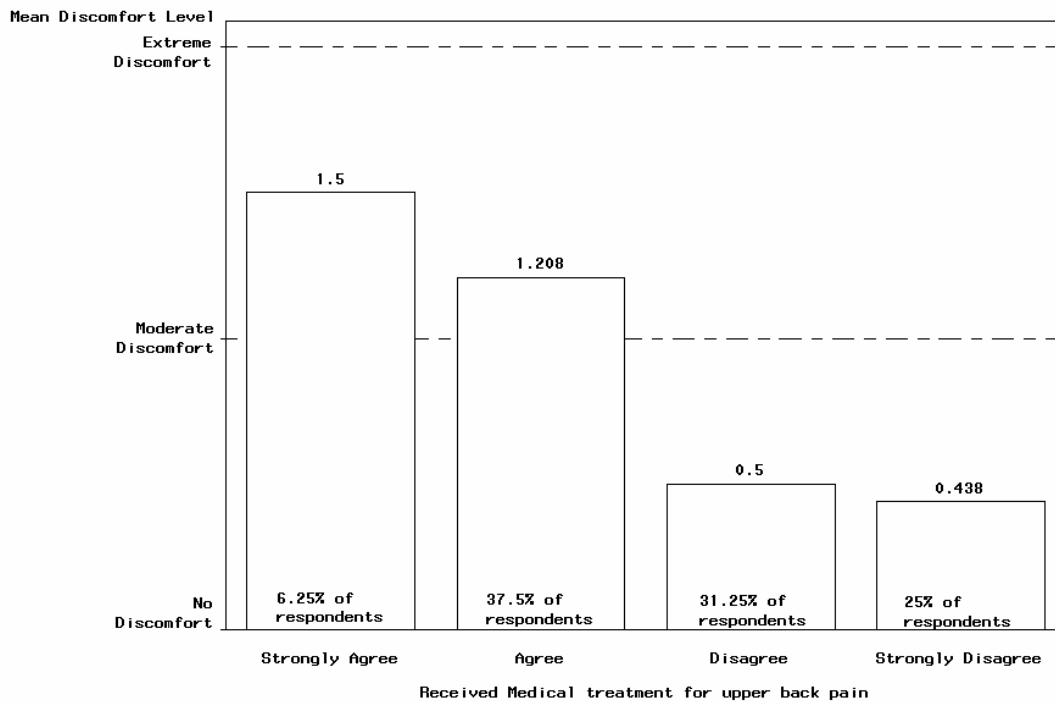
**Table 4.3. Summary of P-Values for Significant Survey Questions**

Effect	Lower Back After 4 Hours	Upper Back After 4 Hours	Shoulder After 4 Hours	Neck After 4 Hours	Lower Back After 8 Hours	Upper Back After 8 Hours	Shoulder After 8 Hours	Neck After 8 Hours
Massage	0.000003	.000192717	0.048366	.000054	0.000832	0.006859	Not Sig.	Not Sig.
Upper Back (Q12)	Not Sig.	Not Sig.	Not Sig.	Not Sig.	0.020770	0.012754	Not Sig.	Not Sig.
Athletic Trainer (Q17)	Not Sig.	Not Sig.	0.000569	Not Sig.	Not Sig.	0.007866	Not Sig.	Not Sig.
MD for Muscle Stiffness (Q19)	0.018794	.000569128	0.049410	.004299	Not Sig.	0.047936	Not Sig.	Not Sig.
Age	Not Sig.	Not Sig.	0.002368	Not Sig.	Not Sig.	Not Sig.	Not Sig.	Not Sig.
Work Days / Week	Not Sig.	Not Sig.	0.001538	Not Sig.	Not Sig.	0.003673	Not Sig.	Not Sig.
Height	0.012809	.000268348	0.000000	.001220	0.035784	0.000001	0.002630	.000338596
Work-outs	Not Sig.	Not Sig.	Not Sig.	Not Sig.	0.049053	Not Sig.	Not Sig.	Not Sig.

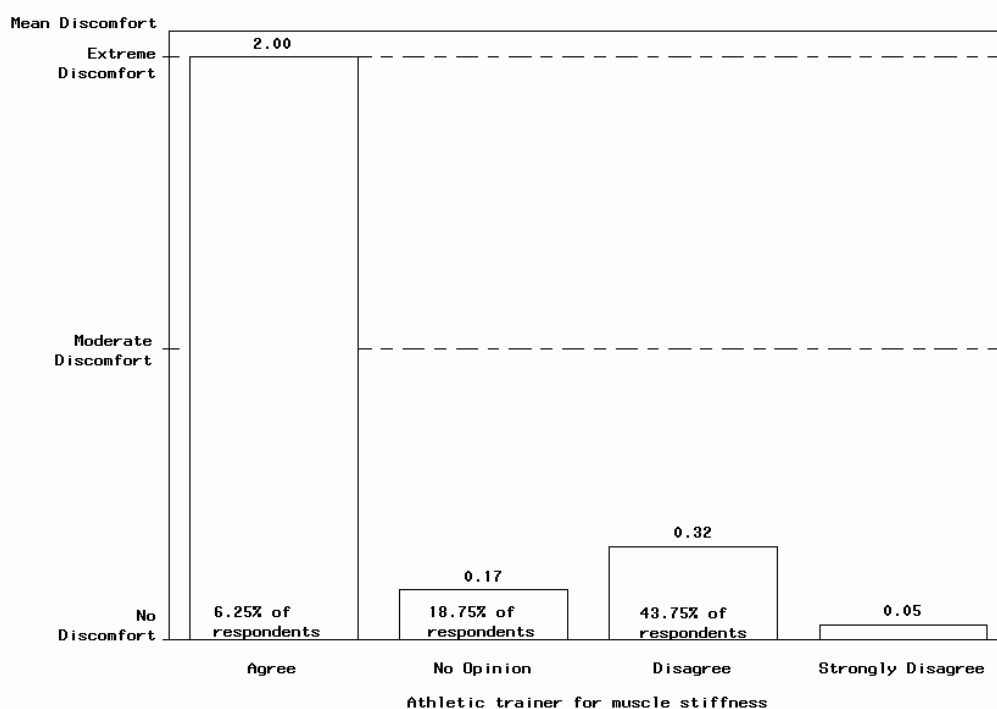
Respondents who were 41-50 years of age reported significantly more pain in their shoulders after four hours of work than did the other age groups. Those who worked an average of 3-4 days per week reported more shoulder discomfort after four hours of work than those who averaged 5-6 days per week, as well as more upper back discomfort after 8 hours of work. This seems to imply that working days are being lost to pain, although further surveying would be

necessary to state this definitively. The same applies to those who report working out to avoid back pain, with those responding that they do work out reporting more lower back discomfort after 8 hours of work than those who do not.

Those dentists who reported the highest mean discomfort level in their upper backs after eight hours of work (6.25%) agreed most strongly with the statement that they had received medical treatment for upper back pain (Figure 4.5). Mean discomfort level is reported at the top of each bar, and percentage of respondents is reported inside each bar. Those who had sought the assistance of an athletic trainer for muscle stiffness also reported much more severe shoulder pain and upper back pain than those who had not (Figs. 4.6, 4.7). In Figure 4.7, the amount would not fit on the graph, but 31.25% of respondents strongly disagreed with having seen an athletic trainer to help with muscle stiffness.

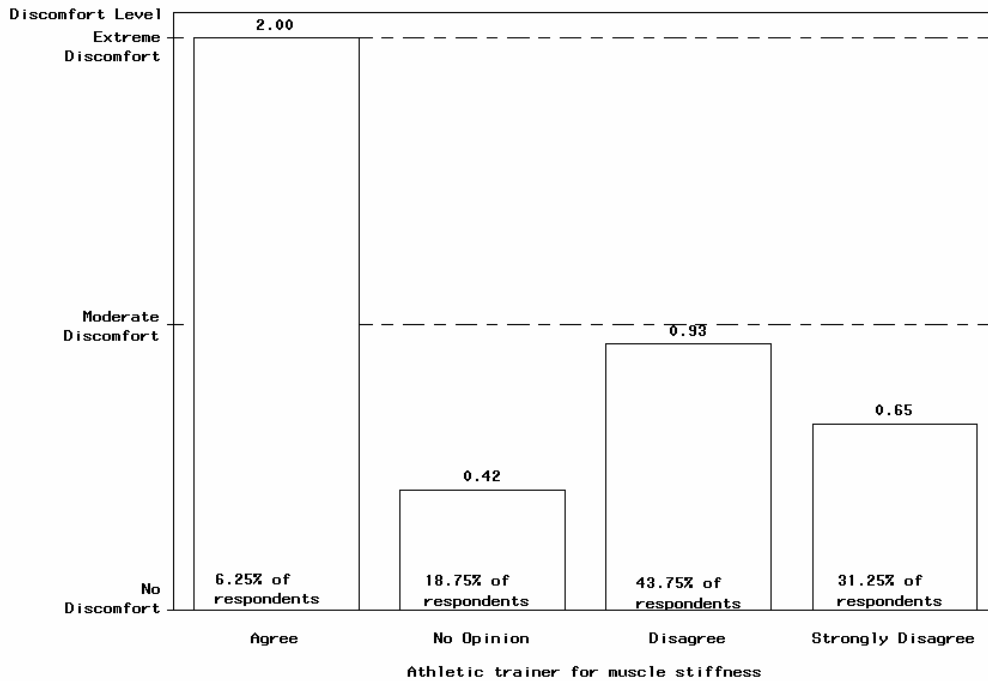


**Figure 4.5. Discomfort Level in the Upper Back as a Function of having received Medical Treatment for Upper Back Pain.**

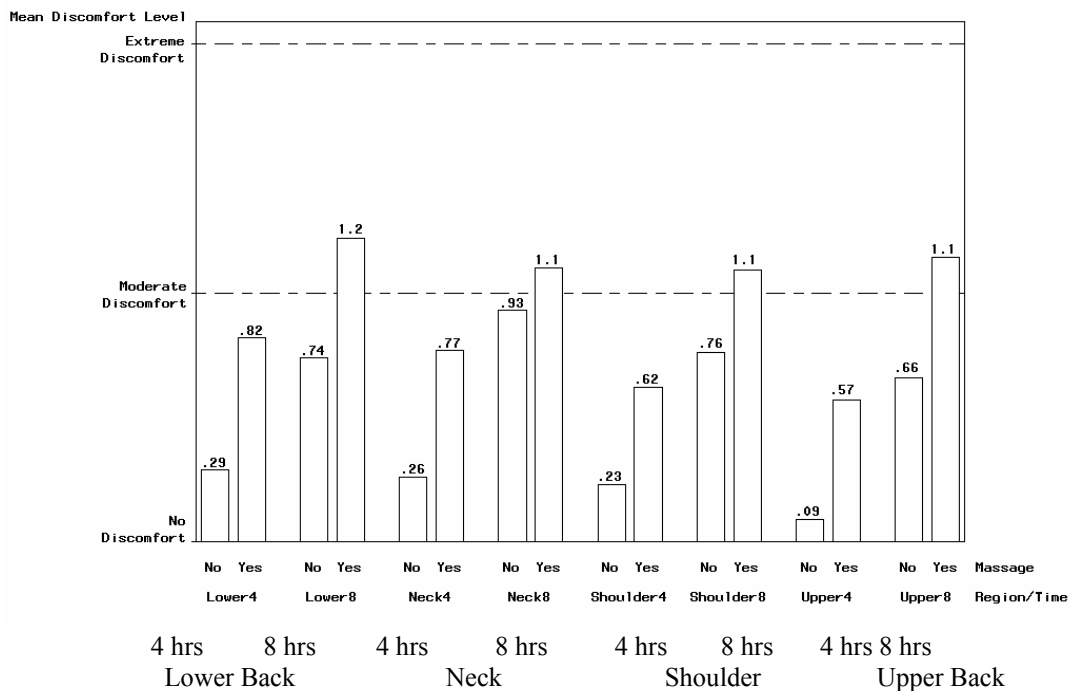


**Figure 4.6. Shoulder Pain after 4 Hours and Agreement with having sought Treatment from an Athletic Trainer for Muscle Stiffness.**

Respondents who reported higher levels of discomfort than those who had not in all four regions after four hours of work, and in the lower back and upper back after eight hours of work said that they had received massage therapy for pain. After eight hours, discomfort in the neck and shoulders was not significantly different for those who had and had not sought massage therapy (Figure 4.8). The number and percentage of respondents represented in each bar of Figure 4.8 is detailed in Table 4.4 which details differing levels of discomfort, cross-tabulated by hours worked and whether or not massage was used as a means of relief. This is unlikely to indicate that massage therapy is a causative factor in pain, but rather that respondents who were experiencing less discomfort were less likely to seek professional help.



**Figure 4.7. Upper Back Pain after 8 Hours and Agreement with having sought Treatment from an Athletic Trainer for Muscle Stiffness.**



**Figure 4.8. Mean Discomfort Levels for Those who did/did not get Massage Therapy.**

**Table 4.4. Detail of Percent of Respondents Reporting Differing Levels of Discomfort, Cross-Tabulated by Hours worked and whether or not Massage was used as a Means of Relief.**

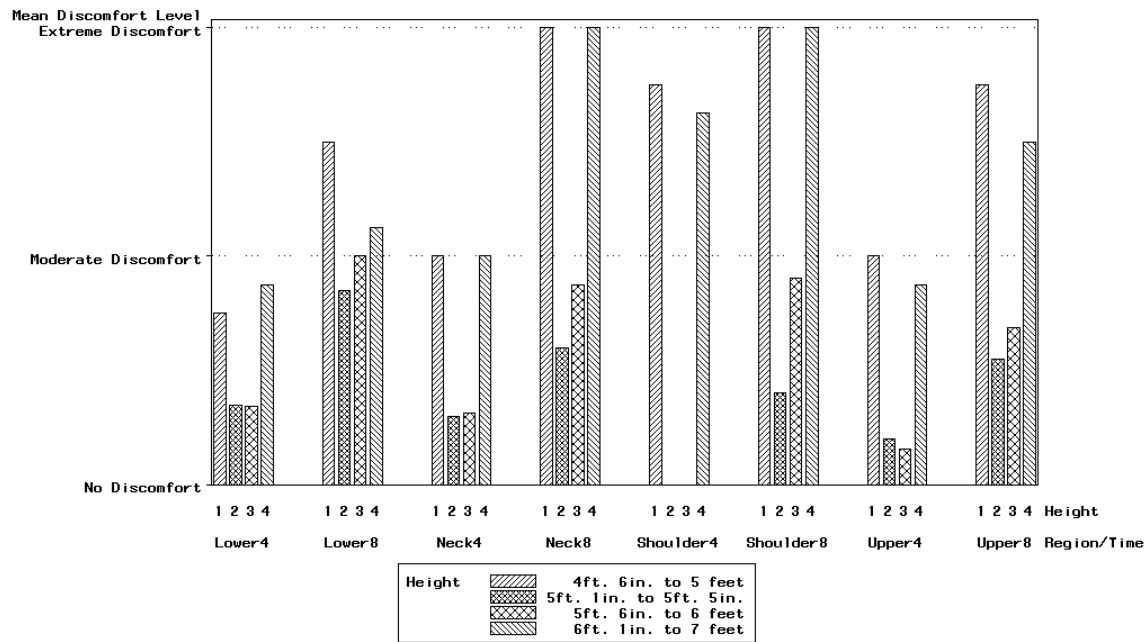
Region	Received Massage	After 4 Hours of Work			After 8 Hours of Work		
		No Discomfort	Moderate Discomfort	Extreme Discomfort	No Discomfort	Moderate Discomfort	Extreme Discomfort
Lower Back	Yes	12.50%	40.63%	0.00%	1.56%	39.06%	12.50%
	No	43.75%	3.13%	0.00%	10.94%	35.94%	0.00%
Upper Back	Yes	23.44%	29.69%	0.00%	7.81%	32.81%	12.50%
	No	45.31%	1.56%	0.00%	23.44%	23.44%	0.00%
Shoulder	Yes	35.94%	4.69%	12.50%	20.31%	7.81%	25.00%
	No	45.31%	1.56%	0.00%	23.44%	9.38%	14.06%
Neck	Yes	14.06%	39.06%	0.00%	14.06%	20.31%	18.75%
	No	42.19%	4.69%	0.00%	10.94%	29.69%	6.25%

Respondents' height also had a highly significant effect on level of discomfort for all four regions and both four and eight hours after beginning work. The dentists in the shortest (4'6" to 5') and the tallest (6'1" to 7') height groups consistently reported more discomfort than did those of more "average" height (5'1" to 6'). In Figure 4.9, the bars with slanting lines are the shortest and tallest height groups and those with crosshatches are the two central height groups.

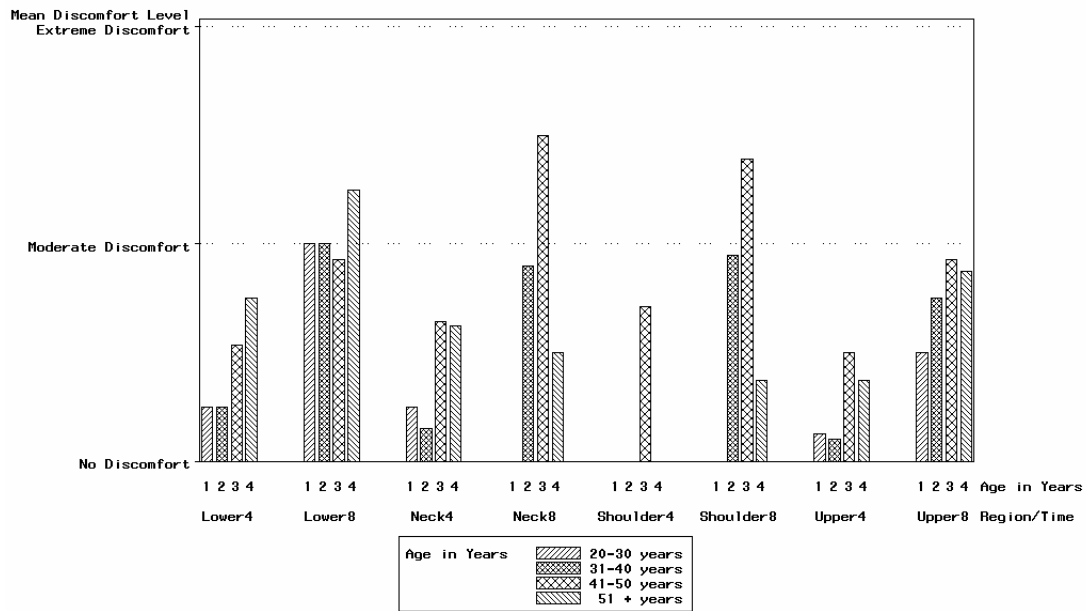
## 4.2 Field Study Results

### 4.2.1 Performed Dental Procedures

Data from 8 out of the 10 dentists that agreed to participate in the study was deemed acceptable. Job tasks performed by each of the 8 participating dentists during the day of the EMG field study were catalogued in an effort to quantify the procedure in terms of time and degree of difficulty. Verification that each dentists' work day was on par with the other was critical. Table 4.5 shows the dental procedures performed. Definitions of these procedures are as follows:



**Figure 4.9. Discomfort as a Function of Respondent's Height.**



**Figure 4.10. Discomfort as a Function of Respondent's Age. Missing Bars are a Result of not having any Respondents in the Corresponding Category.**

A *Filling* procedure is performed when tooth decay has developed. The decay is cleaned out and the cavity is replaced with an amalgam or composite resin. (20-30 minutes)

A *Crown* procedure is performed when the tooth cannot be restored by a filling due to extensive tooth decay. (90-120 minutes)

A *Root Canal* procedure is performed when the nerve of the tooth is removed from the canal inside the root and replaced with a gutta percha.. (45-60 minutes)

A *Partial Denture* procedure is performed when some of the teeth in either the upper or lower arch are replaced by a removable prosthesis. (30-60 minutes)

*Prophylaxis* is the procedure of cleaning the teeth. (30 minutes)

#### **4.2.2 Testing the Hypotheses for EMG Field Observations**

Data from the field experiment showed that noise had a significant effect on data collection of the latissimus dorsi muscle. Lower back readings for only two of the participants were deemed acceptable and thus the power value associated with this part of the study is too low for any statistical comparison. Data gathered for the upper trapezius muscle was accepted and analyzed.

The EMG measurements for the upper trapezius muscle were considered as the dependent variable in a repeated measures mixed model with time as a fixed effect. Time was found to be significant, with a p-value of 0.0092, so the least-squares means for each time were compared to determine which times were significantly different (Table 4.7). It was determined that the measurements during the last minute of the first patient visit of the day were significantly higher than both the first and last minutes of the last patient visit of the day. This signifies a decreasing shift in median frequency, which is a sign of fatigue. These differences are shown in Figure 4.11.

**Table 4.5.**  
**Quantification of Dental Procedures Performed (D=Dentist)**

D1	6 filling procedures 4 cleanings 1 extraction	D5	6 fillings 2 crowns 3 extractions
D2	7 filling procedures 6 cleanings 1 root canal 1 partial	D6	2 fillings 6 cleanings 1 denture 1 crown
D3	1 filling procedure 2 cleanings 2 dentures 1 extraction 1 crown 10 exams	D7	1 filling procedure 4 cleanings 1 extraction 9 exams
D4	3 fillings 1 cleaning 2 extractions 1 crown 12 exams	D8	1 filling procedure 2 cleanings 2 dentures 1 extraction 1 crown

**Table 4.6. Upper and Lower Back EMG Median Frequency Data.**

Dentist	1 <sup>st</sup> Min AM	Last Min AM	1 <sup>st</sup> Min PM	Last Min PM	1 <sup>st</sup> Min AM	Last Min AM	1 <sup>st</sup> Min PM	Last Min PM
	<i>Upper</i>	<i>Upper</i>	<i>Upper</i>	<i>Upper</i>	<i>Lower</i>	<i>Lower</i>	<i>Lower</i>	<i>Lower</i>
1	59.1	57.8	57.8	56.7	86.9	60.0	72.0	71.6
2	64.0	68.7	62.6	55.1	48.6	45.4	129.0	63.0
3	60.4	65.1	59.4	57.4	60.0	60.0	76.9	76.0
4	69.5	68.8	66.7	67.4	47.1	53.1	28.7	60.0
5	57.9	68.3	54.1	57.6	56.5	51.9	67.6	65.3
6	53.4	53.9	53.6	51.2	60.0	70.0	73.9	70.7
7	63.3	62.0	58.8	62.4	60.0	60.0	60.0	60.0
8	63.0	63.0	57.8	63.0	78.5	60.0	72.7	33.3
<i>Units= Hz</i>								

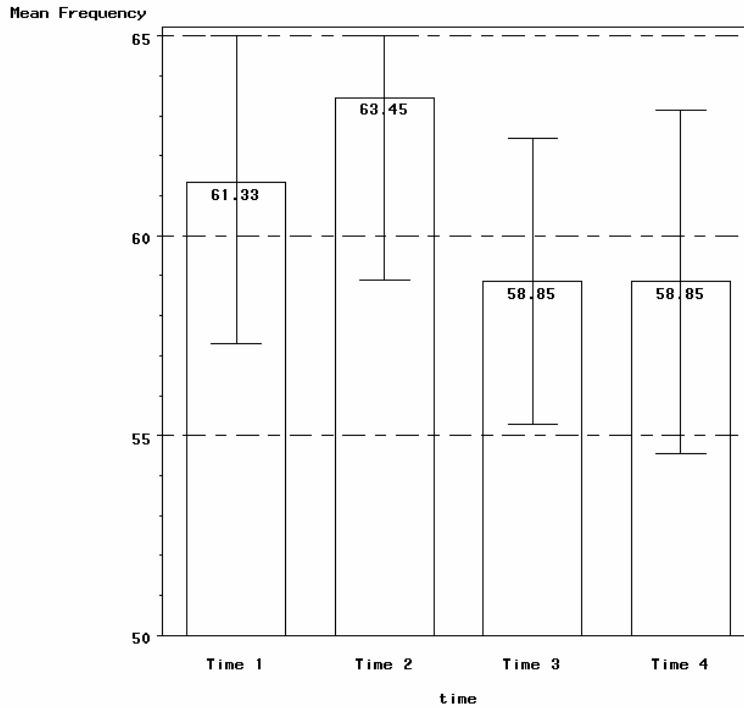
### 4.3 Field Survey Results versus EMG Data

In an effort to measure the perception of pain experienced by dentists before they participated in the EMG field study, the survey in Appendix C was re-administered. The results of their survey are accompanied by their median frequency data. Because the number of



**Table 4.7. Least Squares Means for Time Effect.**

Hypothesis	Estimated Difference	Standard Error	DF	t Value	Adjusted P	Lower 95% C.I.	Upper 95% C.I.
$\mu_{1Upper} = \mu_{2Upper}$	-2.1250	1.4064	21	-1.51	0.4490	-5.0497	0.7997
$\mu_{1Upper} = \mu_{3Upper}$	2.4750	1.4064	21	1.76	0.3197	-0.4497	5.3997
$\mu_{1Upper} = \mu_{4Upper}$	2.4750	1.4064	21	1.76	0.3197	-0.4497	5.3997
$\mu_{2Upper} = \mu_{3Upper}$	4.6000	1.4064	21	3.27	0.0177	1.6753	7.5247
$\mu_{2Upper} = \mu_{4Upper}$	4.6000	1.4064	21	3.27	0.0177	1.6753	7.5247
$\mu_{3Upper} = \mu_{4Upper}$	2.29E-13	1.4064	21	0.00	1.0000	-2.9247	2.9247



**Figure 4.11. Mean EMG Values at Each Measurement Time for the Upper Trapezius. (Error Bars Represent Variation, and Extend 3 Standard Deviation from the Mean in Either Direction.)**

participants in the field study was so low (which yields a low power value), only limited statistical analyses were performed on these survey results. A summary of the perceived pain of

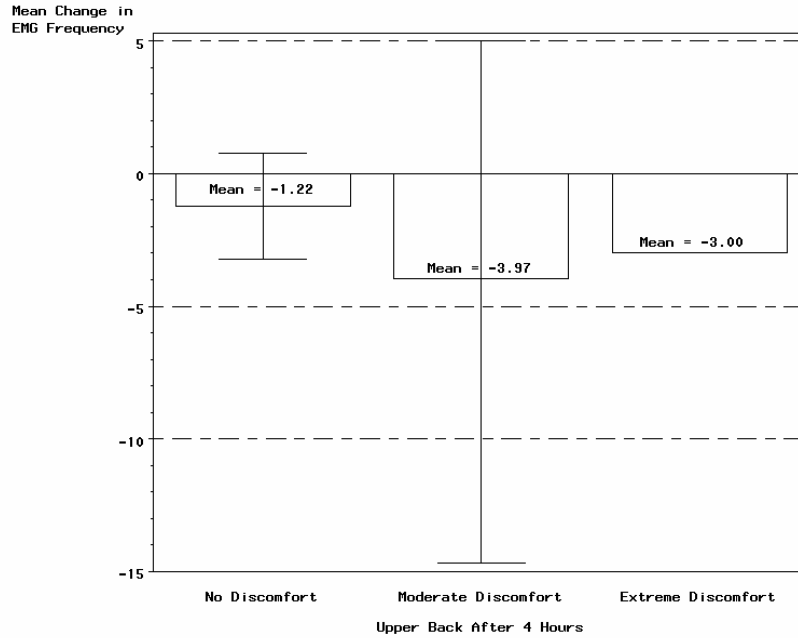
each dentist, along with the respective data showing the EMG median frequency values are shown in Appendix D. These comparisons were additionally evaluated as individual case studies.

For the eight dentists who provided EMG data and answered the survey questions again, the dependent variable was calculated as the change in EMG readings for the upper trapezius muscle from the first measurement of the day to the last. Analysis of variance was used to test the relationship between the level of discomfort in the upper back reported after four and eight hours of work and the change in EMG readings. Perception of pain was found to have a significant relationship to change in EMG frequency at both times, with a p-value of 0.023 at four hours and 0.0065 at 8 hours. Pairwise comparisons could not be made due to the small sample size, so box plots were used to illustrate the differences (Figs. 4.12 and 4.13). Error bars represent variance, and extend three standard deviations from the mean in either direction. Note that only one respondent reported extreme discomfort after four hours, so no variance estimate is available for that level.

#### **4.4 Forces Acting on the Dentists' Body Posture while Performing Dental Work**

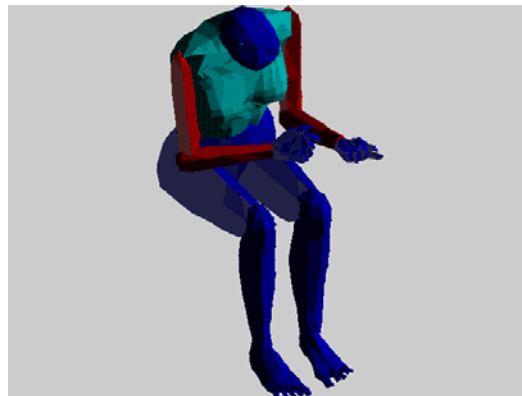
The digital pictures of dentists at work led to a computer model through which gravitational forces on various parts of the body were calculated. The model was based on an approximation of the positions assumed by the participants while not using a device such as the magnifying loupe used by Dentist 5 and Dentist 8. The unaided postures of the participating dentists did not vary significantly, and, therefore, one model was deemed sufficient to estimate the forces at work on each. The forces and moments acting on the model generated are shown below in Table 4.8. The relatively low magnitudes found acting on the neck and shoulder (12.3

lbs and 8.6 lbs respectively) suggest that pain associated with this posture is not from the dynamic force acting on the body, but, is from the result of static forces acting upon the body in

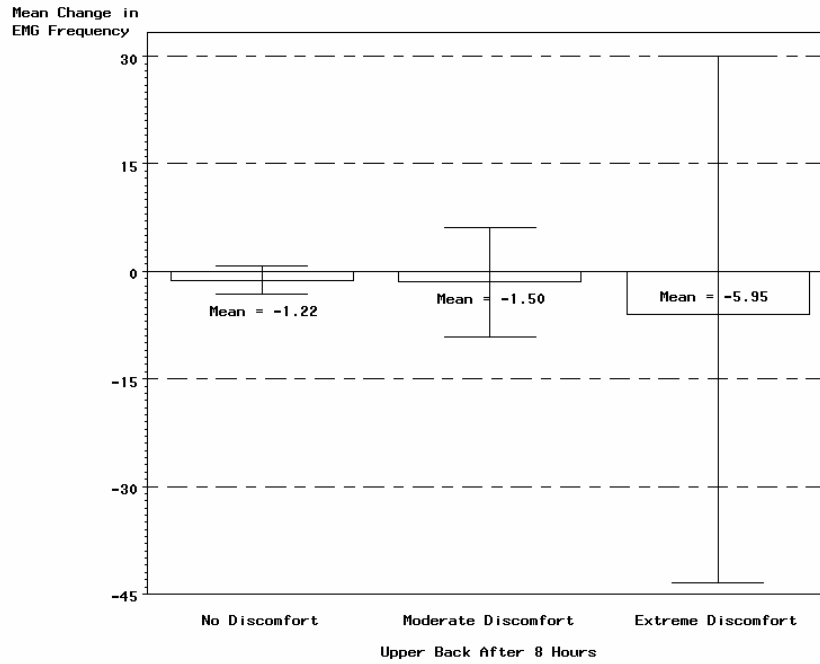


**Figure 4.12. Change in EMG Frequency by Level of Discomfort after Four Hours of Work.**

The force acting on the back (77 lbs) is considered to be relatively low given the effect of gravity on the body. Note that gender and weight are also determinants of force measurement in biomechanics.



**Figure 4.13. Mannequin Model, Actual.**



**Figure 4.14. Change in EMG Frequency by Level of Discomfort after Eight Hours of Work.**

Based on the discomfort levels noted by the participants routinely hunching over their patients, it was assumed that the forces resulting from such a position often lead to an uncomfortable level

**Table 4.8. Force and Moments Acting on the Dentists' Body Posture while Performing Dental Work**

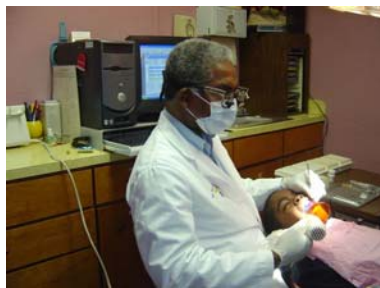
Joint	Rotation x	Rotation y	Rotation z	Force(lbs)	Moment(lb-in)	Moment(lb-in)
Head	10	2	-1	9.8	38.4	38.4
Neck	48	18	24	12.3	71.4	71.4
L.Shoulder	-38	43	-19	8.6	54.1	54.1
L.Elbow	-65	-40	-38	4.3	31.9	31.9
L.Wrist	0	0	0	1.2	4.6	4.6
R.Shoulder	-31	4	-1	8.8	42.7	42.7
R.Elbow	-79	134	48	4.4	31.4	31.4
R.Wrist	20	0	0	1.2	4	4
Back	0	7	0	77.2	363	363
L.Hip	-105	0	0	31.9	334.1	334.1
L.Knee	90	0	0	10.8	2.3	2.3
L.Ankle	0	0	0	2.1	3.7	3.7

R.Hip		-105	0	0	32.5	339.1	339.1
R.Knee		90	0	0	10.9	2.9	2.9
R.Ankle		0	0	0	2.2	3.8	3.8



**Figure 4.15. Mannequin Model, Side View.**

of pain. On the other hand, the forces acting on the body when in an upright position are noticeably lower. Therefore, the use of a magnifying loupe is very helpful in allowing dentists to maintain a straight posture that will ultimately reduce the force and moment levels acting on the back to a point where chronic trauma such as pain and fatigue are far less likely to be the result from a dentist's ordinary working day. This was evidenced in the observation of Dentist 8 (Figure 4.16) as he did not report, nor show through EMG measurements, any lower back pain.



**Figure 4.16. Photograph of Dentist 8 in Upright Posture using Magnifying Loupes.**

Even though the use of magnifying loupes (Figure 4.17) is a relatively new concept in dentistry,



**Figure 4.17. Magnifying Loupe Dental Equipment.**

the benefits appear to be an improved working posture, reduced eye strain and a clearer working view. An improved working posture will translate into reduced incidences of lower back, shoulder and neck pain. Reduced eye strain will lesson the occurrence of eye fatigue and lead to an increase in productivity. And lastly, a clearer working view allows for a better assessment of a problem and a quicker and more accurate solution and treatment.

## CHAPTER 5

### CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDIES

In conformity with the research objectives, the following conclusions are derived:

Fifty-eight percent of all of the respondents reported that they experience or have experienced some form of pain in their lower back, shoulder or neck during their tenure as a practicing dentist. Sixty-nine percent stated that the pain is such a real issue that they work out regularly to avoid it. Forty-seven percent report that they find comfort and muscle relaxation through massages and massage therapy. Very few (nineteen percent) reported the use of muscle relaxers. These statistics indicate an awareness of the perceived pain and identify a seemingly common preventative measure in working out through physical activity. In summary, every respondent reported at least moderate discomfort in the lower back, shoulders and/or neck after eight hours of work. There was considerably less discomfort reported after four hours of work.

The results of the ANOVA indicate that the level of discomfort felt in each of the areas in question (upper and lower back, neck, and shoulders) was significantly affected by whether or not respondents sought various types of treatment for their pain. This is unlikely to indicate that treatment has been ineffective, but rather that those with more pain have sought more treatment. Additionally, height was a significant factor in level of discomfort in all areas after both four and eight hours of work. The respondents who were of more “average” height consistently reported less discomfort.

Fatigue characterization was determined by using the fatigue characterization analysis outlined by Seidel *et al.*, (1987) where muscular fatigue in isometric contractions was studied using spectral analysis, and the identification of fatigue was determined by a significant drop in median frequency. This was tested using repeated measures analysis of the EMG data. It was

found that the median frequency decreased significantly in the upper trapezius from the last minute of the first patient to both the first and last minutes of the last patients. This shows that in all eight dentists tested, characteristics of fatigue begin to develop after 4 and 8 hours of work.

Despite the perception of pain at the end of the day, the present protocol failed to uncover the onset of fatigue developing in the lower back. We suspect muscle substitution and electrical noise to be negative contributing factors to inaccurate or skewed readings.

In an effort to relate perception of pain to the evidence of muscle fatigue found in the EMG data, the change in median frequency between the last and first measurements was calculated for each dentist and analyzed as the dependent variable. This change was found to be significantly different for respondents reporting higher amounts of pain in the upper back after both four and eight hours of work.

Recommendations for future studies would include a gender based distinction in dentists reporting pain, a controlled environment for EMG measurements, an increase in field participants and an expansion of analyzed areas of pain to include the wrist and elbow.

A future experiment should account for the difference in gender for those experiencing pain after four and eight hours of work as a function of height and weight.

The second suggestion of further research is to set up a controlled dental environment in an effort to eliminate the probability of noise interrupting EMG signal collection. For complete accuracy, the dentist must assume the exact isotonic posture for each test and better controls must be developed. Also, measurements taken at more intermediate times in the day than the first and last patient may help to determine when this fatigue begins to occur.



The third suggestion is to increase the number of field participants. This will provide a level of statistical significance that is needed to make an informed observation regarding EMG and fatigue.

The fourth suggestion is to expand the areas of examination to the elbow and wrist when targeting pain and discomfort. It was discovered in the field study that dentists were experiencing pain on the outside (lateral) of the upper forearm just below the bend of the elbow. This tenderness hinders such activities as gripping and lifting. The wrist was also an area of discomfort because certain procedures require dentists to keep their wrist flexed or extended for an extensive amount of time. This median nerve compression pinches the nerve between the underlying ligaments and bones of the wrist and the transverse carpal ligament. This results in a constant aching and numbness of the hand and a serious hinderance in productivity.

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APPENDIX – A  
CONSENT FORM

## APPENDIX – A

### CONSENT FORM

Study Title: Musculoskeletal Disorders in Dentistry

Performance Site: Louisiana State University, IE dept., Ergonomics Laboratory.

Investigators: The following investigators are available for questions about this study, M-F, 8:00 a.m. - 4:30p.m.

Dr. Fred Aghazadeh 225-578-5367 Maurice Pitts 225-445-2453

Purpose of the Study: The purpose of this research is to assess the behavior of the upper trapezius muscle and lower erector spinea muscle of dentists during isotonic postures while performing various dental procedures. The specific objective is to attain Electromyographic (EMG) measurements in the lower and upper back of the Dentists in an effort to determine fatigue.

Subject Inclusion: 10 participants will be recruited from referrals from friends and family.

Number of subjects: 10

Study Procedures: the experiment will be explained to the participants and they will be asked to read and sign the consent form and then discuss the experiment with the investigator. Any questions concerning the research will be answered. Each experiment will take place on different days at each individual dentist office. EMG Electrodes will be attached to the dentists' lower and upper back areas and EMG measurements will be taken during the 1<sup>st</sup> and last minute of the first patient's visit. After those measurements are taken, the investigator will leave the premises. The investigator will return at the end of the day and repeat the procedure for the last patient's procedure.

Benefits: There are no potential benefits to be gained by the participants. The expected benefits of this pilot study are as follow:  
To determine a correlation between time per patient and fatigue  
To determine a correlation between a dentist' work day and fatigue  
To determine precautionary measures relating to fatigue prevention

Risks: There are no associated risks in this project.

If this research project causes any physical injury to participants, treatment is not available at Louisiana State University, nor is there any insurance carried by the University or its personnel applicable to cover any such injury. Treatment and financial compensation for such injury must be provided through the participant's own insurance program. In case of an emergency, the local emergency service (911) will be contacted.

Right to Refuse: Subjects may choose not to participate or to withdraw from the study at any time without penalty or loss of any benefit to which they might otherwise be entitled.

Privacy: Results of the study may be published, but no names or identifying information will be included in the publication. Subject identity will remain confidential unless the law requires disclosure. The screening questionnaires of rejected subjects will be destroyed.

Signatures:

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about subjects' rights or other concerns, I can contact Dr. Robert Mathews, Institutional Review Board, (225) 578-1492. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form.

Signature of Subject \_\_\_\_\_ Date

APPENDIX B

INSTITUTIONAL REVIEW BOARD  
ACTION ON PROTOCOL APPROVAL REQUEST





**Institutional Review Board**  
 203 B-1 David Boyd Hall  
 Louisiana State University and A&M College  
 Baton Rouge LA 70803

(225) 578-8692

FAX: 578-6792  
 irb@lsu.edu

**INSTITUTIONAL REVIEW BOARD**

**ACTION ON PROTOCOL APPROVAL REQUEST**

**TO:** F. Aghazadeh  
 Department of Industrial Engineering

**FROM:** Robert C. Mathews  
 Chair, Institutional Review Board for Research with Human Subjects

**DATE:** February 4, 2005

**RE:** IRB# 2501

**TITLE:** "Musculoskeletal Disorders in Dentistry"

**New Protocol/Modification/Continuation :** N

**Review type:** Full  Expedited  **Review date:** 02/02/2005

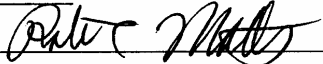
**Risk Factor:** Minimal  Uncertain  Greater Than Minimal

**Approved**  **Disapproved**

**Approval Date:** 02/04/005 **Approval Expiration Date:** 02/04/2006

**Re-review frequency:** (annual unless otherwise stated)

**Number of subjects approved:** 10

**By:** Robert C. Mathews, Chairman 

**PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING -- Continuing approval is CONDITIONAL on:**

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects\*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. SPECIAL NOTE:

*\*All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at <http://www.fas.lsu.edu/osp/irb>*

APPENDIX C  
SURVEY QUESTIONNAIRE

## APPENDIX C

The following questionnaire is designed to measure perception and activities associated with the Dental occupation. The questionnaire should take approximately 10 minutes. It is not necessary to include your name unless you would like to receive a report outlining the study results. If so, please indicate your name, address, and e-mail address on the back of this form. Any additional comments should be included on the back of this form.

Return Fax: 225-201-1556  
Attention: Maurice Pitts

Rate your agreement with each of the following statements With a yes or no answer.	Yes	No
While working, I often experience lower back pain	Yes	No
While working, I often experience severe shoulder pain	Yes	No
While working, I often experience severe neck stiffness	Yes	No
While working, I often have to stand up and stretch due to severe back pain	Yes	No
I take several breaks during my work day to avoid shoulder and neck pain	Yes	No
I take several breaks during my workday to avoid lower back pain	Yes	No
I often workout to avoid back pain	Yes	No
I often get massages to avoid back pain	Yes	No
I often get massages to avoid neck and shoulder stiffness	Yes	No
I often use a heating pad for back pain	Yes	No
I often use muscle relaxers for back pain	Yes	No

Rate your agreement with each of the following statements from extremely agree (EA) to extremely disagree (ED)	EA	Agree	No Opinion	Disagree	ED
Have you ever received medical treatment for upper back pain?	1	2	3	4	5
Have you ever received medical treatment for shoulder pain?	1	2	3	4	5
Have you ever sought treatment for muscle stiffness from a physical therapist?	1	2	3	4	5
Have you ever received medical treatment for neck pain?	1	2	3	4	5
Have you ever sought treatment for muscle stiffness from a massage therapist?	1	2	3	4	5
Have you ever sought treatment for muscle stiffness from an athletic trainer?	1	2	3	4	5
Have you ever received medical treatment for lower back pain?	1	2	3	4	5
Have you ever sought treatment for muscle stiffness from a medical doctor?	1	2	3	4	5

Rate your level of discomfort in each of the following situations

After 4 hours of work, the feeling in my lower back is best described as

After 4 hours of work, the feeling in my upper back is best described as

After 4 hours of work, the feeling in my shoulder is best described as

No	Moderate	Extreme
Discomfort	Discomfort	Discomfort
1	2	3

1	2	3
---	---	---

1	2	3
---	---	---

No	Moderate	Extreme
Discomfort	Discomfort	Discomfort

After 4 hours of work, the feeling in my neck is best described as

1	2	3
---	---	---

After 8 hours of work, the feeling in my lower back is best described as

1	2	3
---	---	---

After 8 hours of work, the feeling in my upper back is best described as

1	2	3
---	---	---

After 8 hours of work, the feeling in my shoulder is best described as

1	2	3
---	---	---

After 8 hours of work, the feeling in my neck is best described as

1	2	3
---	---	---

#### Demographics

Age:

- 20-30       31-40       41-50  
 51 and over

Years in profession:

- 1-9       10-15       16-20  
 21-25       26 and over

Average workday:

- 1-3 hrs       4-6hrs       7-9hrs  
 10 and over

Average workdays per week:

- 1-2     3-4     5-6  
 7

Average age of seating equipment:

- 1-5yrs old     6-10 yrs old  
 11-15 yrs old  
 16-20 yrs old     21 yrs and older

Height:

- 4'6"-5'       5'1"-5'5"       5'6"-6'  
 6'-7'

Weight:

- 120-150lbs     151-180lbs  
 181-220lbs  
 220-250lbs     251-300

## APPENDIX D

### SUMMARY OF INDIVIDUAL DENTISTS EMG DATA

## APPENDIX D Summary of Individual Dentists

### 4.4.1 Dentist 1 (D1)



**Figure 4.13.1. Dentist 1.**

Dentist 1 reported moderate discomfort in the lower back, neck and shoulder after 4 hours of work. After 8 hours of work, she reported moderate discomfort in her lower back and extreme discomfort in her neck and shoulder region. The median frequency shift associated with D1 is consistent with the characteristics of fatigue development over time. However, the numbers do not indicate an extreme shift in frequency associated with the neck and shoulder region.

#### MDF

Dentist	First Min AM		Last Min AM		First Min PM		Last Min PM	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
1	59.1	86.9	57.8	60	57.8	72.0	56.7	71.6

#### 4.4.2 Dentist 2 (D2)



**Figure 4.13.2. Dentist 2**

Dentist 2 reported moderate discomfort in the lower back and extreme discomfort in the neck and shoulder after 4 hours of work. After 8 hours of work, she reported moderate discomfort in her lower back and neck and extreme discomfort in her shoulder region. The median frequency shift in D2 is consistent with her perception of pain. There are extreme shifts in her lower back and neck regions.

#### MDF

Dentist	First Min AM		Last Min AM		First Min PM		Last Min PM	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
2	64.0	48.6	68.7	45.4	62.6	129.0	55.1	63.0

### 4.4.3 Dentist 3 (D3)



**Figure 4.13.3. Dentist 3.**

After 4 hours of work, D3 reported no discomfort in her neck and lower back area and moderate discomfort in her upper back and shoulder. After 8 hours of work, D3 reported moderate discomfort in her lower back, upper back and shoulder. Again, she reported no discomfort in her neck. The median frequency data are consistent with D3's perception of pain as there are no significant frequency shifts in her lower back region. However, the data points to a frequency shift in her upper trapezius area that could be significant.

#### MDF

Dentist	First Min AM		Last Min AM		First Min PM		Last Min PM	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
3	60.4	60.0	65.1	60.0	59.4	76.9	57.4	76.0



#### 4.4.4 Dentist 4 (D4)



**Figure 4.13.4. Dentist 4.**

After 4 hours of work, D4 reported no discomfort in her lower and upper back area and neck and moderate discomfort in her shoulder. After 8 hours of work, D4 reported moderate discomfort in her lower back and shoulder and no discomfort in her upper back and neck. D4's median frequency data are consistent with no significant perception of pain in her lower and upper back.

MDF

Dentist	First Min AM		Last Min AM		First Min PM		Last Min PM	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
4	69.5	47.1	68.8	53.1	66.7	28.7	67.4	60.0

#### 4.4.5 Dentist 5 (D5)



**Figure 4.13.5. Dentist 5.**

Dentist 5 reported no discomfort in his lower back, upper back and shoulder area with moderate discomfort in his neck after 4 hours of work. After 8 hours of work, D5 reported moderate discomfort in his neck only. D5 uses optical lenses that allow him to see inside of the patient's mouth without maintaining an awkward posture. D5's median frequency data are consistent with no significant perception of pain in his lower and upper back.

#### MDF

Dentist	First Min AM		Last Min AM		First Min PM		Last Min PM	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
5	57.9	56.5	68.3	51.9	54.1	67.6	57.6	65.3

#### 4.4.6 Dentist 6 (D6)



**Figure 4.13.6. Dentist 6.**

After 4 hours of work, Dentist 6 reported no discomfort in her lower back, moderate discomfort in upper back and extreme discomfort in her shoulder and neck. After 8 hours of work, the perception of pain was identical in the same areas. D6's median frequency data are consistent with moderate discomfort in her upper back. The characteristics of fatigue do not show an extreme discomfort level.

#### MDF

Dentist	First Min AM		Last Min AM		First Min PM		Last Min PM	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
6	53.4	60.0	53.9	70.0	53.6	73.9	51.2	70.7

#### 4.4.7 Dentist 7 (D7)



**Figure 4.13.7. Dentist 7.**

After 4 hours of work, Dentist 7 reported no discomfort in her upper back and moderate discomfort in her lower back, shoulder and neck area. After 8 hours of work, her perception remained the same in all areas. The median frequency data for D7 are consistent with little to no discomfort due to the development of fatigue.

#### MDF

Dentist	First Min AM		Last Min AM		First Min PM		Last Min PM	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
7	63.3	60.0	62.0	60.0	58.8	60.0	62.4	60.0

#### 4.4.8 Dentist 8 (D8)



**Figure 4.13.8. Dentist 8.**

Dentist 8 reported no discomfort in his lower back, upper back and shoulder area with moderate discomfort in his neck after 4 hours of work. After 8 hours of work, D8 reported moderate discomfort in his neck only. D8 uses optical lenses that allow him to see inside of the patient's mouth without assuming an awkward posture. D8's median frequency data are consistent with no significant perception of pain in his lower and upper back.

Dentist	First Min AM		Last Min AM		First Min PM		Last Min PM	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
8	63.0	78.5	63.0	60.0	57.8	72.7	63.0	33.3

## VITA

Frank Maurice Pitts was born in Atlanta, Georgia and attended High School in Baton Rouge, Louisiana. He holds a Bachelor of Science degree in mechanical engineering from Southern University (May 1993) and is currently a candidate for the Master of Science in Industrial Engineering from Louisiana State University. He is expected to graduate in December 2005.

Prior to his studies at Louisiana State University, he worked at General Motors as a Test Engineer and also as a technical consultant for startup companies. He is currently a Commercial Sales Engineer for Carrier Corporation; the largest supplier of air conditioners in the world.

His professional interests lie in the areas of ergonomic design, industrial hygiene and indoor and outdoor air quality.