To the Graduate Council:

I am submitting herewith a thesis written by Timmy W. Lorance entitled "An Experimental Study on the Neuromuscular Effects of an Intraoral Mandibular Repositioning Device." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

Tyler A. Kress, Major Professor

We have read this thesis
and recommend its acceptance:

John C. Hungerford

Accepted for the Council:

Associate Vice Chancellor and
Dean of the Graduate School

AN EXPERIMENTAL STUDY ON THE NEUROMUSCULAR EFFECTS OF AN INTRAORAL MANDIBULAR REPOSITIONING DEVICE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Timmy W. Lorance

December, 1999

DEDICATION

This thesis is dedicated to my mother

Judy Campbell

whose love and encouragement has inspired

me to be more than I thought possible.

ACKNOWLEDGMENTS

I wish to express special gratitude to Dr. Tyler Kress for persuading me to continue my education and being my friend as well major professor and committee chairman. His valued advice and guidance was instrumental to completing this project.

I also wish to thank the other committee members. Dr. John Hungerford and Dr. Evans Lyne gave valued direction and advice and especially for their infinite patience.

Appreciation is also in order for Dave Halstead, the project principal investigator at The University of Tennessee, for his confidence and support throughout the project.

The final acknowledgement is reserved for my parents, brothers, sisters, nephews and the rest of my family for their constant love and support throughout graduate school and life.

ABSTRACT

This thesis is part of a research project titled "Intraoral Device Evaluation" (IDE). The purpose of the project is to determine if creating a 3-mm vertical and anterior occlusion of the mandible can increase strength capabilities. The standardized device used in this study is The EDGE. Big Picture, Inc produced the EDGE and the placebo used in this project.

To accomplish this purpose a double-blind placebo study was conducted using a series of tests to measure the strength capabilities of muscles during isometric grip strength and clenching and the surface electromyography (EMG) activity of the muscles during the isometric testing. The approach was to have subjects perform a series of isometric tests where both the muscle groups being tested and the antagonistic muscle groups were monitored via surface EMGs. The tests were designed to measure the anterior temporalis, massater, digastricus, sternocleidomastoidues, biceps and triceps muscles of various subjects. There were two types of tests used in the study, bio-assessment and grip strength. The bio-assessment tests consisted of an analysis of the subjects tempromandibular joint (TMJ) to determine if a preexisting TMJ dysfunction existed and isometric jaw clenching to monitor the face and neck muscles using surface EMGs. The isometric grip strength test measured muscle capabilities and monitored the upper arm muscles using surface EMGs. There were 123, 88 male and 35 female, participants in the grip strength test. There were six trials for each test, three with a device and three without a device. The percent

change in grip strength and EMG activity was calculated for each set and analyzed as a unit-less measure.

The analysis of the grip strength and EMG data concluded there was not a statistically significant difference between The EDGE and the placebo at an α = 0.05 level for the given test parameters. The average percent change in grip strength for the male population using The EDGE and the placebo was 2.780 and 2.816 respectively. The standard deviation in the average percent change in grip strength for the male population using The EDGE and the placebo was 5.436 and 6.563 respectively. The average percent change in grip strength for the female population using The EDGE and the placebo was 6.606 and 2.235 respectively. The standard deviation in the average percent change in grip strength for the male population using The EDGE and the placebo was 3.982 and 8.229 respectively. The trend of the data shows a larger increase in percent change in muscle capability for women using The EDGE and a smaller standard deviation than for any other category.

TABLE OF CONTENTS

CHAPTER PAGE

I. INTRODUCTION 1

A. BACKGROUND INFORMATION 1
B. RESEARCH INFORMATION 1
C. OBJECTIVE OF RESEARCH 2

II. BACKGROUND INFORMATION 3

III. EXPERIMENTAL SET-UP 10

A. COMPONENTS OF THE EXPERIMENT 10
B. TEST PARAMETERS 12
C. BIOPAK TESTS 12
D. HAND DYNAMOMETER TEST 17
E. STATISICAL ANALYSIS 20
F. DENTAL APPLIANCE AND PLACEBO 25

IV. RESULTS AND CONCLUSIONS 29

A. GRIP STRENGTH DATA RESULTS 29
B. GRIP STRENGTH EMG DATA RESULTS 31
C. BIO-EMG DATA RESULTS 34
D. CONCLUSIONS 36

V. BIBLIOGRAPHY 38

VI. APPENDICES 43

A. QUESTIONNAIRE AND CONSENT FORMS 44
B. SCORES FOR THE GRIP STRENGTH TESTS 48
C. SCORES FOR THE GRIP STRENGTH EMG TESTS 54
D. SCORES FOR THE BIO-EMG TESTS 57
E. JAW ANATOMY 61
F. MUSCLE ANATOMY 64

VITA 72

LIST OF TABLES

TABLE **PAGE**

1. Breakdown and number of the subjects by groups of The EDGE and placebo and by subgroups of male and female 29

2. Number of subjects and p values for the grip strength data 30

3. Mean and standard deviation of the percent change in grip strength data for each group, as shown in Table 1 30

4. Breakdown of the number of subjects into groups, of the grip strength EMG data, of The EDGE and placebo and into subgroups of male and female 32

5. Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for females using The EDGE 32

6. Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for males using The EDGE 32

7. Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for all subjects using The EDGE 32

8. Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for females using the placebo 33

9. Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for males using the placebo 33

10. Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for all subjects using the placebo 33

11. P values for the percent change in grip strength EMG data in the biceps and triceps muscles comparing devices for the total, male and female populations 33

TABLE **PAGE**

12. Mean and standard deviation in the percent change in EMG data for the different muscle groups and devices and the corresponding p values for the total population 34

13. Mean and standard deviation in the percent change in EMG data for the different muscle groups and devices and the corresponding p values for the male population 35

14. Mean and standard deviation in the percent change in EMG data for the different muscle groups and devices and the corresponding p values for the female population 36

LIST OF FIGURES

FIGURE **PAGE**

1. SONOPACK amplifier box attached to surface EMGs on the face and neck 13
2. SONOPACK amplifier box attached to JVA Headset placed on subjects' TM joint 15
3. Magnet placement on subject 16
4. Front and oblique view of JT-3 Headset on subject 18
5. Hand dynamometer with adjustable grip handle 19
6. A typical subject's biceps EMG data for three seconds obtained with and without a device 21
7. Breakdown of the grip strength data into groups and subgroups 23
8. Flow chart for the analysis of the grip strength data 23
9. Flow chart for the grip strength EMG data analysis 25
10. Flow chart for the analysis of the bio-EMG data for the left side of the face and neck 25
11. Top, front and bottom view of The EDGE in wire frame and solid form 28

NOMENCLATURE

kgs.	kilograms
lbs.	pounds
s	seconds
mm	millimeter
α	alpha level
μ_E	mean percent change is data for The EDGE
μ_P	mean percent change is data for the placebo
μv	micro-volts

ABBREVIATIONS

CM	Conventional Mouthpiece
DA	Digastricus Muscle
EMG	Electromyography
ENG	Electrogrnathography
JT	Jaw Tracker
JVA	Joint Vibration Analysis
L	Left Side
MM	Masseter Muscle
MORA	Mandibular Orthopedic Repositioning Device
MPDS	Myofascial Pain Dysfunction Syndrome
R	Right Side
SCM	Sternocleidomastoidues Muscle
TA	Anterior Temporalis Muscle
TMD	Temporomandibular Disorder
TMJ	Temporomandibular Joint

CHAPTER I

INTRODUCTION

A. BACKGROUND INFORMATION

Today's athletes, both professional and amateur, want to achieve a higher level of performance and many people today are trying to become and look fit. To achieve their goals people are sometimes using performance enhancement devices. Learning how the muscles react to a device could improve the effectiveness of the device and could lead to an improved treatment for an ailment. A mandibular orthopedic repositioning appliance (MORA) is a mechanical device fabricated for the individual and is used as a means to enhance performance by repositioning the mandible. The EDGE is a performance enhancement device similar to the MORA, but differs by causing a standard 3-mm vertical and anterior occlusion of the mandible.

B. RESEARCH INFORMATION

This thesis is part of a research project titled "Intraoral Device Evaluation". The intent of the research project is to determine if repositioning the mandible will increase a person's strength capabilities and if so, to quantify to what degree. The research project tested both the aerobic and anaerobic capabilities of a subject by testing the 1) isometric grip strength, 2) isometric biceps curl, 3) isometric leg extension, 4) bench press, 5) leg press, and 6) the heart rate during

running. A manufacturer claims its' device increases the person's strength capabilities by causing a 3-mm vertical and anterior occlusion of the mandible.

C. OBJECTIVE OF RESEARCH

The objective of the specific project for this thesis is to determine if causing an occlusion of the mandible by a standard amount will increase the strength capability and electromyography (EMG) activity of a muscle during exertion. This thesis is concerned with the isometric grip strength of the study. If the EMG activity changes then this is evidence the repositioning of the mandible affects the neuromuscular system. The research project will utilize an intraoral mandibular repositioning device, known as "The Edge", to create a 3-mm vertical and anterior occlusion of the mandible. The project will determine if the level of muscle activity in the upper arm (biceps and triceps) and in the facial and neck muscles (anterior temproalis, massetar, digastricus, and sternocleidomastoidues) change during griping and in jaw clenching, respectively. The hypothesis to be tested in this study is that The EDGE will cause a significant increase in the percent change in the grip strength and EMG data versus a placebo.

CHAPTER II

BACKGROUND INFORMATION

Mechanical devices may assist the athlete to achieve more efficiency than can be obtained naturally. There are several studies that report increased isometric strength of an athlete wearing a MORA. Other devices to enhance an individual's natural abality are also briefly discussed.

The Breathe Right was developed as a means to reduce snoring and improve sleep quality by dilating the nasal airway, decreasing the airway resistance, and increasing the flow of air. This is achieved by placing an external strip on the bridge of the nose thus opening the nasal airways. The device is now being used as a means to increase the effectiveness of an athlete and reduce fatigue.

Lifting-belts were introduced to help reduce the biomechanical effects of lifting on the lumbosacral spine. A lifting belt is a device that fits tightly around a person's lower trunk and keeps the spine in alignment when lifting from the squatting position. This is accomplished by limiting the movement of the spine when the back muscles are not strong enough to do so naturally. Claims have been made that lifting belts reduced lower back injuries by about 1/3 by limiting lateral bending and twisting motion. Some, however, have concluded that lifting-belts offer no strength advantage to the user because proper foot motion and placement can also reduce lower back pain from lateral bending and twisting.

Running shoes are intended to reduce stress and impact normally transmitted to a runners' back and knees by providing extra shock absorbers in the form of soft soles. By reducing the body's stress the runner may feel less fatigue and be capable of running further or faster. As a way to further reduce the impact of running composite insoles have also be used. Running shoes are now made to compensate for the body's natural turning of the foot during the running motion. The shoes have a thick, soft padded heel to help absorb the shock and a harder midsole to force the foot into the correct follow-through motion.

Another simple device said to increase athletic performance is compression shorts. Researchers believe compression shorts conserve energy by inhibiting excess muscle movement. Limiting muscle movement conserves energy and may decrease fatigue in athletes.

Over the past two decades, articles have been written about temporomandibular disorders (TMD) and their treatment. TMD is the "collective label for several related but probably diagnostically distinct states of chronic orofuacial pain" (Dworkn et al., 574,1990) [also suggested by the American Dental Association (American Dental Association, 76,1983)].

One such distinct state of TMD is temporomandibular joint (TMJ) dysfunction. It has been stated that TMJ will cause "headache, neckache, backache, dizziness, partial hearing loss, sinusitis, jaw-clicking, ear ringing, tension, fatigue, and lack of concentration" (Burfoot, 51, 1981). To help alleviate the symptoms of TMJ, dentists have created MORA's.

In 1958 the first account of TMJ therapy for sports enhancement was recorded with the fabrication of an acrylic TMJ splint and football mouth-guard to alleviate a severe loss of equilibrium for a starting collage varsity lineman. A dentist, Dr. Kaufman, created the MORA to help elevate the pain of bruxism and later reported the use of the MORA as a form of TMJ sports therapy. Some of the MORAs were produced for runners and were worn during their runs. The runners later reported a decrease in fatigue and an increase in stamina while wearing the MORAs. Those athletes using a MORA reported an increase in performance during training and in competition.

Researchers have sinse reported that the "proper relationship of the head upon the spine is essential to proper total body posture and balance" (Gelb, 34, 1977). The role of the jaw and it's alignment has been studied and it has been determined that a "highly dynamic mandible plays a most important role in establishing the posture of the head upon the spine" (Gelb, 35, 1977). If the parts of the mandible "are held out of alignment and away from the axis of gravity, peculiar strains are put upon the spinal structure" (Gelb, 35, 1977). The strains put upon the spinal structure "may give way with results of a quite unforeseen and disastrous nature" (Gelb, 35, 1977). The pain and discomfort reported by patients are sometimes "remote from the site of strain; and, moreover, symptoms may be misleading because of the nature of the referred and reflected pain" (Gelb, 35, 1977). In discussing "symptoms of TMJ dysfunction, or the myofascial pain dysfunction syndrome, then, we allude

primarily to pain and tenderness in joints and masticatory muscles, limited movement, clicking, and crepitation" (Gelb, 73, 1977).

Stenger's (Stenger, 1977) work with a college football team started in 1958, however, he did not report his findings until years later. He suggested that "the relationship of bite support to muscles outside the face and neck seems to be a concept not yet generally recognized by the dental profession" (Stenger, 1977). Stenger's work with the college football team reported "dramatic recovery of numerous players who had previously been sidelined with neck and back injuries" after vertical correction bite support was made (Stenger, 1977).

A study conducted by Smith utilized both a subjective and an objective portion to evaluate arm strength in professional football players. The objective testing was conducted using a Cybex II Dynamometer with a full 90° range of motion. The tests that were performed compared the performance with an isokentic deltoid press for conditions of bite position versus teeth together, stock tray mouth guard versus teeth together. The study showed that 88% of the participants exhibited increased strength while 12% of participants showed no increase comparing wax bite position versus teeth together. Of the participants that showed an increase, 55% showed only a slight increase in strength while 45% showed a significant increase in strength. The results may have been confounded by not using a double blind experimental design as well as not limiting the subjects' knowledge of prior results.

Kaufman and Kaufman studied the effect of a MORA on decreasing headaches following runs for the U.S. Olympic Luge team. The study included

18 members of the team of which 12 had reported headaches after runs. 11 headaches were reported as moderate to most severe with the median strength of the headaches being about 4 on a scale of 1 to 5. The headaches occurred with lugers in all classes of malocclusion. After the members were fitted with and used the MORA during runs, only 5 reported headaches, the highest rating being mild. The median strength of the headaches with a MORA was about 2 on the 1-5 scale. A "McNemar and Wilcoxin" test for significance of changes was performed and determined that the difference was significant at a $p < 0.05$ for both tests.

A study by Greenberg et al, published in 1981, used 14 members of the University of Pennsylvania mens varsity basketball team. Each subject tested was free of clinical or historical evidence of TMJ dysfunction, myofascial pain dysfunction syndrome (MPDS) or posterior bite collapse. The study consisted of a control, placebo and a device test. The subjects were told they were comparing two different devices and that the control, no device, was to be a standard. The device was fabricated using the method described by Gelb (Gelb, 1977). The tests consisted of shoulder abduction and adduction on the dominant arm of each subject. The tests were randomly ordered among the control, placebo and device. The ratio of each subject's performance with and without an appliance normalized the data. The statistical design for a priori comparison of means and groups of means was a single classification Model I analysis of variance (ANOVA) and a two-way ANOVA with replication on the normalized

data. A statistical analysis of the data showed no significant difference for both abduction and adduction at the $p = 0.05$ level.

In 1985, R. Kaufman and A. Kaufman studied the effect of a MORA on players of a college varsity football team to evaluate any affects on performance; number, severity and type of injuries; physical fitness, and satisfaction. The study was double blind and used a MORA and a conventional mouthpiece (CM). The analysis of the data showed a significant statistical difference for the MORA in severity of injury, number of knee injuries, bench-press strength, and satisfaction. The data also indicated a possible improvement for the MORA in performance, number of injuries, vertical jump, and shoulder bursa injuries. The jump rope and ankle injuries were better for the CM but not at a significant level.

Burkett and Bersntein (Burkett et al., 1982) conducted a double study consisting of 45 subjects performing grip strength, and quadriceps and hamstring static and dynamic strength tests. The myocentric position for the experimental group was found by using a myomonitor, the placebo group did not undergo any type of mandibular repositioning while being fitted for their device. The tests consisted of left and right maximum grip strength and grip endurance, left and right maximum quadriceps dynamic and static strength, and left and right maximum hamstring dynamic and static strength. A baseline score was taken before the subjects underwent the tests with the devices. A one-way analysis of variance was conducted on the percent change among the scores, baseline and post baseline, and the critical level for statistical significance was selected to be at 0.05. The analysis of the data for this series of tests indicated that the MORA

had not significantly increased the strength of the muscle groups or the endurance of the hand.

CHAPTER III

EXPERIMENTAL SET-UP

A. COMPONENTS OF THE EXPERIMENT

To help determine the neuromuscular effects of creating a standard occlusion of the mandibular, a series of tests were designed to measure both the muscle activity of the face and arm and the grip strength of an individual with and without a device. The approach of the research project was to design and conduct a double-blind placebo study to determine if creating a standard occlusion of the mandibular would increase athletic performance. The test population consisted of 123 subjects taken from a local Knoxville Tennessee area health club without regard to gender, fitness level, or amount of time they had been working out. Age was taken into consideration only to ensure that a subject was of legal age, otherwise, the consent of a parent or guardian was required. Before the subjects were tested, they were asked to answer a questionnaire (Appendix A). The questionnaire was used to screen out subjects that may have had pre-existing conditions, such as TMJ dysfunction. If a subject answered yes to one or more of questions 1, 3, 4, 5b on the questionnaire (Appendix A), he was disqualified from the study. The study excluded subjects diagnosed with TMJ dysfunction or those that were believed to show signs of TMJ dysfunction during the bio-assessment portion of the test. A description of the jaw and TMJ is given in Appendix E.

Biopak test equipment was utilized to measure and display the activity of several muscles at a time, the movement of the mouth, and the sound and vibration of the TMJ during opening and closing. The muscles monitored by the Biopak system included the (1) anterior temporalis, (2) digastric, (3) masseter, (4) steromcleidomastoid on both sides of the face and neck. The trapezius on one side of the neck was used as a ground. A description of the muscles monitored is given in Appendix F. The Pathway MR-20 was utilized to measure and display the response from two muscles at a time. The muscles monitored by the MR-20 were the biceps and triceps of the subject's arm during the grip strength tests.

The MR-20 EMG system can monitor, display, and store the EMG data of two different muscles simultaneously. This system was set to record the muscle activity every 0.01 seconds. The surface electrodes (Serial no. 6750, Pathway Pre-Gelled Electrode Pads, The Prometheus Group, Portsmouth, NH) were disposable pre-gelled electrode pads with standard silver/silver chloride ECG/EMG electrodes.

An EMG signal is the electrical response to the neuromuscular activation associated with a contracting muscle. Taking the average of the randomly varying EMG values removes the larger of the fluctuations. This achieves "the same results as the analog smoothing operation" (Kendall et al., 1949). The resting EMG values for each participant are the same if they are testing with or without a device; therefore only the values during activation are taken into consideration.

B. TEST PARAMETERS

The following parameters were measured and recorded during the study: jaw movement, TMJ noise and vibration, grip strength, and EMG muscle activity in the biceps, triceps and facial muscles. The jaw movement was recorded by using Jaw Tracker Sensor Array (JT-3) equipment. The TMJ noise and vibration was recorded by using Joint Vibration Analysis (JVA) equipment. The EMG activities in the facial muscles during clinching were recorded by using surface EMGs in conjunction with a SONOPACK amplifier box and BioPAK testing software. The JT and JVA testing equipment were also used in conjunction with a SONOPACK amplifier box and BioPAK testing software. The SONOPACK amplifier box received the muscle EMG data and sent a signal that the computer could read. The facial electrodes were standard three prong electrodes. Figure 1 shows the placement of the surface EMGs on the face and neck attached to the SONOPACK amplifier box.

The grip strength and muscle activity in the biceps and triceps during the gripping exercise were measured and recorded by using a hand dynamometer and the Pathway MR-20 software and equipment respectively.

C. BIOPAK TESTS

The BioPAK tests were conducted in two parts, bio-assessment and isometric clenching. The bio-assessment tests were conducted to determine if a subject experienced preexisting TMJ dysfunction. The isometric clenching was conducted to determine if the use of an intraoral mandibular repositioning deivce

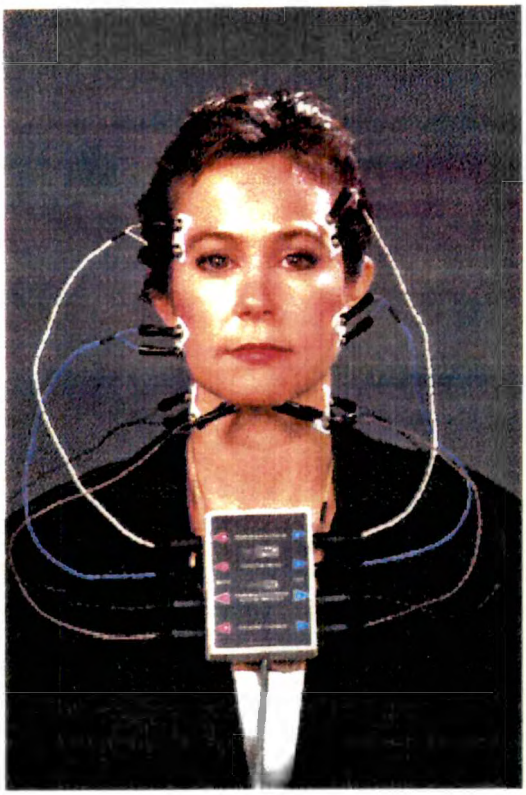


Figure 1: SONOPACK amplifier box attached to surface EMGs on the face and neck. From BioPAK Version 1.33, BioResearch Associates, Inc., Milwaukee, WI., 1996.

would increase the EMG activity of different muscle groups during clenching. The test technician used a disposable plastic, ruled range-of-motion scale (Great Lakes Orthodontics Ltd. CPT 95851) to take a physical measurement of the subject's bite. The bite measurement was taken in two parts. The first part was the widest interincisal opening (distance of the mouth taken from the top of the lower central incisors to the bottom of the maxillary anterior teeth). "Limited" opening exists if the subject cannot open beyond 35 to 40 mm. The second part was the measurement of the overbite, from the "edge of the maxillary central incisors to the mandibular central incisors" (BioPAK, Operation Manual p. 52,

1996). The two parts were added to obtain a single bite measurement to be used with the Biopak software. The technician handed out the device and prepared it by placing it in hot water for one minute to soften the material. When the device was ready, it was fitted to the subject to form directly over their top molars. The soft material conformed to the subject's teeth and mouth and then re-hardened when it was allowed to cool in the subject's mouth.

The skin of the subject was swabbed with alcohol (or water if the subject was allergic to alcohol or if they had any abrasions). The surface of the subject's skin was prepared for the attachment of the electrodes on the intended muscle sites. The subjects then performed the isometric clenching test, which was performed with seven electrodes placed on the subject's face and neck that measured the muscle activity during clinching with and without device. Six tests were conducted, three with the device and three without. The subjects were allowed to rest for one minute between each test.

The TMJ joint vibration test was recorded by using the JVA headset. The JVA headset was placed on the subject's TMJ's and plugged into the SONOPACK amplifier box. The JVA Headset was used as a computer-enhanced electronic device of joint vibration. The JVA was connected to the SONOPACK amplifier box, which received the vibration data, and sent a signal the computer could read. Figure 2 shows the SONOPAK amplifier box attached to the JVA Headset positioned on the subject's TMJ.

The TMJ's were found by placing an index finger on both sides of the subject's face and feeling close to the ear for the joint location as the subject

opened and closed his mouth. A mark was placed at the location of the subject's TMJ to be used later in the testing procedure. The joint vibration was measured by having the subject open his mouth as wide as possible without causing pain and then having him close his mouth until tooth contact at a frequency of 1.5 seconds per open/close cycle.



Figure 2: SONOPACK amplifier box attached to JVA Headset placed on subjects' TM joint. From BioPAK Version 1.33, BioResearch Associates, Inc., Milwaukee, WI., 1996.

The technician aligned a magnet within the subject's mouth at the center of the mandibular frenum below the central incisors. The magnet was positioned at the gingival third of the teeth, or lower until the maxillary anterior teeth no longer interfered with the magnet, using a stomahesive. The magnet has a small groove on one side and was placed with the groove on the left side of the subject

facing outward and parallel to the inter-pupillary line. Figure 3 shows the placement of the magnet in the subject's mouth.

The electrognathography (ENG) portion of the test was recorded using the JT-3 Sensor Array along with the JVA headset. The sensor array of the JVA was aligned so that the upper cross bar was parallel to the inter-pupillary line of the



Figure 3: Magnet placement on subject. From BioPAK Version 1.33, BioResearch Associates, Inc., Milwaukee, WI. 1996.

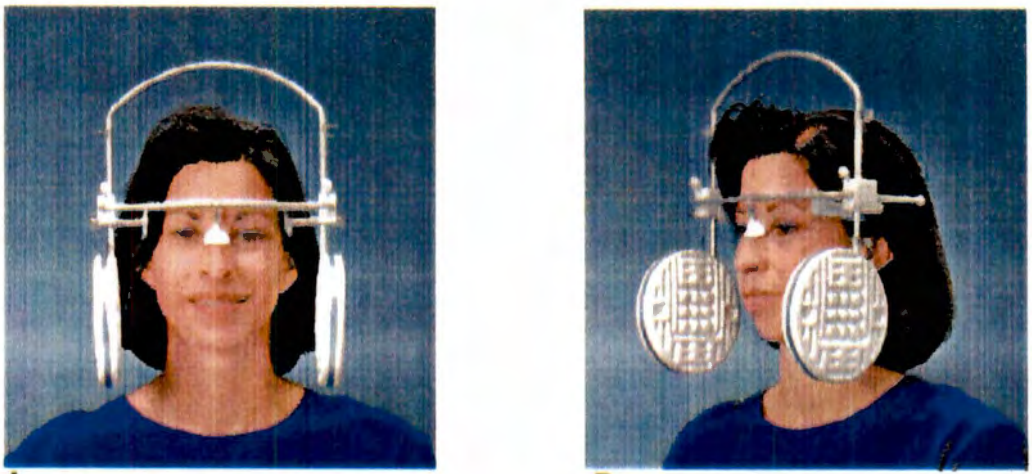
subject's eyes. The sidebars were placed "snug against the subject's head and parallel to the Frankfurt plane" (BioPAK, Operation Manual p. 41, 1996). The JT-3 was aligned with the magnet in the subject's mouth by placing the positioner inside the array ahead of the anterior 3 circles in the panel pattern. The array was adjusted until the clear plastic pointer on the magnet positioner was directly

in front of the magnet. The ENG test was performed by having the subject open his mouth as wide as possible without causing pain and then having him close his mouth until tooth contact at a frequency of 1.5 seconds per open/close cycle.

The JT-3 Sensor Array is used along with a magnet to measure the mandibular movement of the jaw in three coordinates (vertical, anterior/posterior and lateral). The measurements were used to determine misalignment of the jaw and/or possible jaw joint damage. These data were used to screen out subjects that may have had pre-existing conditions, such as TMJ dysfunction. Figure 4 shows the JT-3 Jaw Tracker Sensor Array positioned on the subject's head.

D. HAND DYNAMOMETER TEST

A hand dynamometer was used to measure the maximum grip strength of a subject for three seconds. The hand dynamometer used was a Vital Signs™ model 68840 produced by Country Technology, Inc. The Vital Signs™ is a Baseline Hydraulic Hand Dynamometer with a range of 0 – 200 lbs. The hand dynamometer has an adjustable handle to allow for different grip sizes. Figure 5 shows the hand dynamometer with an adjustable grip handle. The tests were performed in such a manner that the subject was not aware of the results. Half of the subjects began the test with the device in their mouths while the other half started with nothing in their mouths.



A B

Figure 4A-B: Front and oblique view of JT-3 Headset on subject. From BioPAK Version 1.33, BioResearch Associates, Inc., Milwaukee, WI. 1996.



Figure 5: Hand dynamometer with adjustable grip handle.

Electrodes were placed on the biceps and triceps of the arm the subject choose to be tested. A two-channel EMG, intended to be a stand-alone recording system (Model MR-20, Pathway Dual Channel Surface EMG, The Prometheus Group, Portsmouth, NH), was used to record the muscle EMG activity for the arm. The hand dynamometer was adjusted to fit the subject's hand. The feet of the subject hung straight down not touching anything. The testing arm and free arm hung straight down with his free arm not allowed to grip or hold anything. A strap was fit snugly around the subject's trunk to prompt stability during testing. The hand dynamometer test was preformed by having a subject grip the hand dynamometer as hard as he could while simultaneously clenching his jaws for three seconds. The test was repeated six times, three with the device and three without. The subjects were allowed to rest for one minute between each test. All maximum grip strengths and the EMG data were recorded. Figure 6 shows a typical subject's EMG data obtained with and without a device for three seconds.

E. STATISTICAL ANALYSIS

The data for this study were divided into three groups for statistical analysis. The three groups were "grip strength data", "grip strength EMG data", and "bio-EMG data". In the three analysis groups, each subject had performed six trials alternating between performing with and without a device. The null hypothesis for each of the three groups were the mean percent change in scores

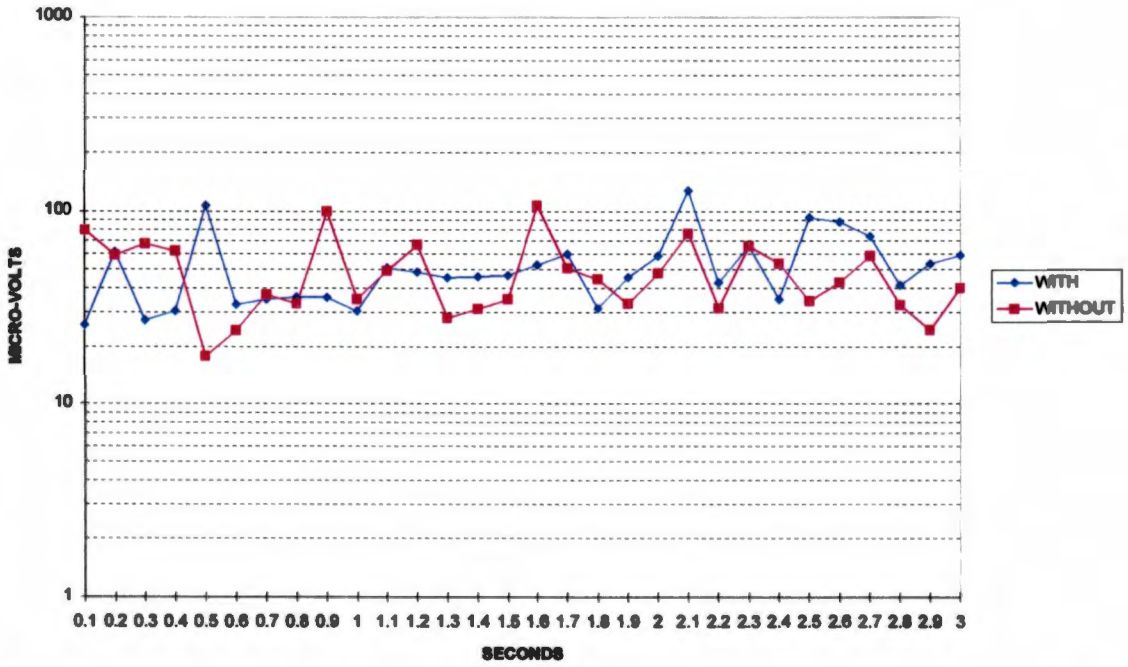


Figure 6: A typical subject's biceps EMG data for three seconds obtained with and without a device.

between with and without a device for The EDGE and the placebo were equal ($\mu_E = \mu_P$).

The grip strength data were measured in units of pounds (lbs.) and the EMG data were measured in units of micro-volts (μv). The EMG data were measured with respect to time (s) and the area under the μv-s curve for each trial was used to calculate the average percent change between trials with and without a device for each participant. The unit less percent change was calculated using the formula shown in Equation 1.

$$\text{Percent change} = 100 * [\frac{with - without}{without}] \qquad \text{Equation 1}$$

An analysis of the percent changes for the three analysis groups determined the mean value and standard deviation for each test and computed the p value for each analysis. The p value is the probability of rejecting a true null hypothesis for the given sample if the null hypothesis is true. To ensure a wrong conclusion did not occur when deciding to reject the null hypothesis, a 95% confidence interval was chosen so that there was only a 5% chance of rejecting a true null hypothesis. The 5%, or 0.05, is the alpha value (α) for the statistical analysis and the p value, for the results to be considered significant, must be equal to or less than α. The F-test used in the grip strength analysis is a one tailed analysis while the t-test used in the EMG analysis is a two tailed analysis. The two-tailed test was employed so that no bias occurred in the analysis. The results of the t-test were considered significant if $p \leq \alpha/2$ because it was a two-tailed test. The "Levene's" test for equality of variances was run on the EMG data before the p values were selected.

The grip strength data were divided into two main groups, The EDGE and placebo. The data were broken down further into subgroups of male and female and were then separated by sequence (with or without first) as shown in Figure 7. The flow chart for the analysis of the individual subjects' grip strength data is shown in Figure 8.

The three sets used to analyze the grip strength data, set A, set B and set C, were grouped as trials 1 versus 2, 3 versus 4 and 5 versus 6 respectively. The six trials for the grip strength tests were a series of related measures and the

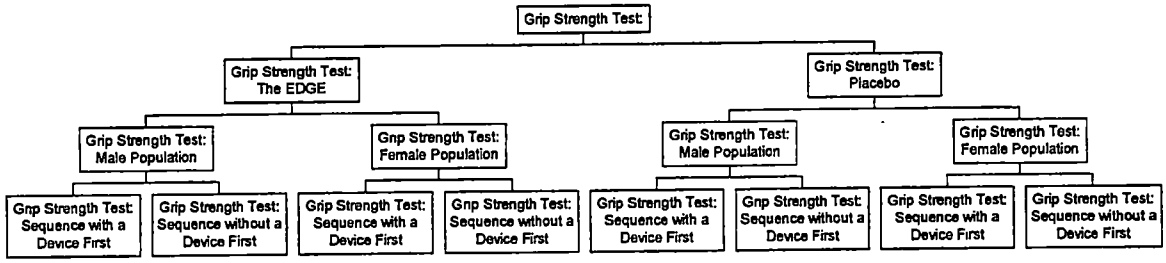


Figure 7: Breakdown of the grip strength data into groups and subgroups.

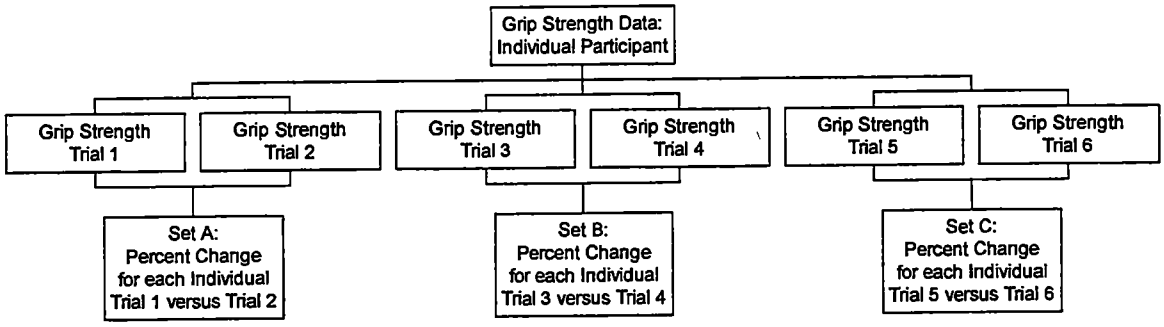


Figure 8: Flow chart for the analysis of the grip strength data.

three sets were the related responses to the percent changes for the grouped trials. The analysis of related responses for two or more cases is called a repeated-measures and responce analysis. The analysis of the grip strength data compared the mean percent changes between The EDGE and the placebo for the total, male, and female population.

The grip strength EMG data and bio-EMG data were divided into two main groups, The EDGE and placebo, and were broken down further into subgroups of male and female. The EMG data, both with and without a device, were used for analysis only if the time of the trial was at least three seconds. The trials lasting less than three seconds were not used and the remaining trials were combined and averaged over three seconds. The two sets of data, with and without, for

each participant were calculated as a single percent change using the formula from Equation 1. The EMG data were calculated and analyzed as a single percent change between devices for each muscle group. The analysis of data between groups called for an independent t-test for equality of means. The t-test for this type of data was two tailed and therefore the p value to reject the null hypothesis was $p \leq \alpha/2$ (0.025).

The grip strength EMG data were measured during the grip strength testing and were collected from the biceps and triceps of the participants' arm used during the grip strength test. Appendix D shows the average EMG data set for a participant's biceps muscle with and without a device. Figure 9 shows the flow chart for the analysis of the grip strength EMG data.

The bio-EMG data were measured during the isometric-clenching portion of the bio-assessment testing and were measured from the anterior temporalis, masseter, digastricus, and the sternocleidomastoidues muscles on both sides of the participants' face and neck. The flow chart for the individual subjects' bio-EMG data for the muscles on the left side is shown in Figure 10.

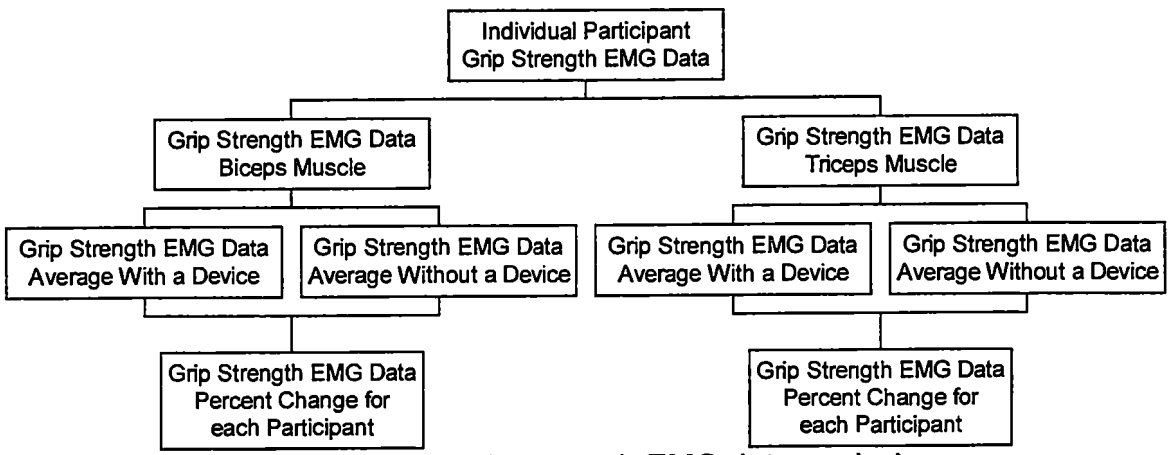


Figure 9: Flow chart for the grip strength EMG data analysis.

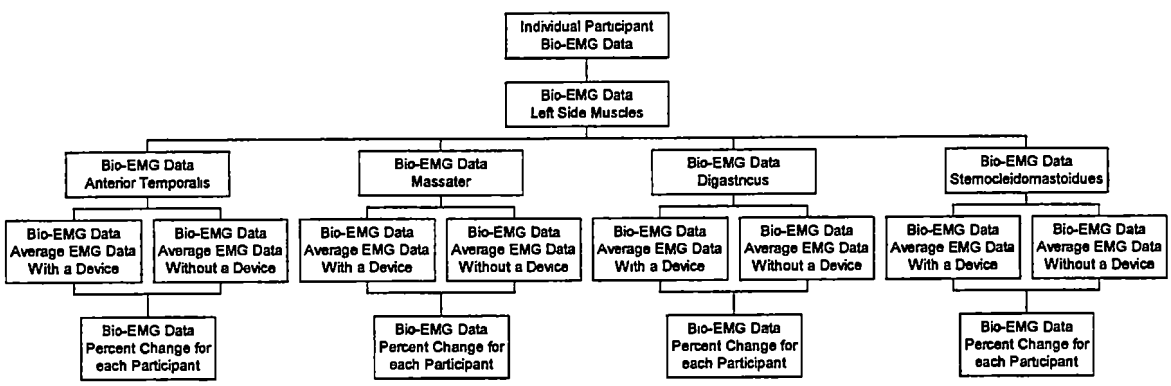


Figure 10: Flow chart for the analysis of the bio-EMG data for the left side of the face and neck.

F. DENTAL APPLIANCE AND PLACEBO

The Edge is made in three components, the arch, the occlusal posterior pads and the stiffener inside the arch. The occlusal posterior pads and the arch of the appliance form a tunnel around the arch and upper teeth of the mouth, thus allowing movement of the tongue and unhindered breathing.

The occlusal posterior pads engage the upper posterior teeth (molars) and are divided into three components, bottom, intermediate, and top layer. The

bottom layer of the base is made in a wedge shape being thicker posteriorly and thinner anteriorly. It is made of a hard thermoplastic elastomer composite material, made of about 50% Kraton by weight and 50% ethylene vinyl acetate by weight. The composite material forces the condyle of the lower jaw to follow the wedge shape form of the appliance and form the required occlusion. The intermediate layer of the base made with a thermoplastic rubber. The intermediate layer is made of a somewhat hard material which can be shaped and formed by hot water but will keep its stiffness once it is allowed to cool. The top layer is made with about 50% polycaprolactone polymer by weight and 50% ethylene vinyl acetate by weight.

The arch of The EDGE is made of the same material as the intermediate layer of the occlusal pads and is molded with the intermediate layer of the occlusal pads. The arch of the appliance connects the two occlusal pads and helps to keep the pads in their proper place and from being swallowed.

The stiffener embedded within the arch of the dental appliance is made of the same hard material as the bottom layer of the occlusal pads. The stiffener is made in a series of loops winding back and forth in a serpentine fashion through the arch. The stiffener will flex in length when placed in warm water to allow for a proper fit in the arch.

The placebo is made in three components, the arch, the occlusal posterior pads and the stiffener inside the arch. The occlusal posterior pads and the arch of the appliance are the same material as the arch in the dental appliance and

form a tunnel around the arch and upper teeth of the mouth, thus allowing movement of the tongue and unhindered breathing.

The occlusal posterior pads of the placebo engage the upper posterior teeth (molars) and, unlike those of The EDGE, are single units. The occlusal posterior pads of the placebo have the same shape as The EDGE. The bottom of the occlusal pads is made in a wedge shape, being thicker posteriorly and thinner anteriorly. The material used for the occlusal pads allows the teeth to bite through the pads without causing an occlusion during the setting of the placebo.

The arch of the placebo is connected to the occlusal pads by being molded to what is considered the intermediate layer of the dental appliance. The arch of the placebo connects the two occlusal posterior pads and helps to keep the pads in their proper place and from being swallowed. The stiffener within the arch of the placebo is comprised of the same hard material and is embedded in the same serpentine fashion as used in The EDGE. The top, front and bottom view of the EDGE in wire frame and solid form is shown in Figure 11.

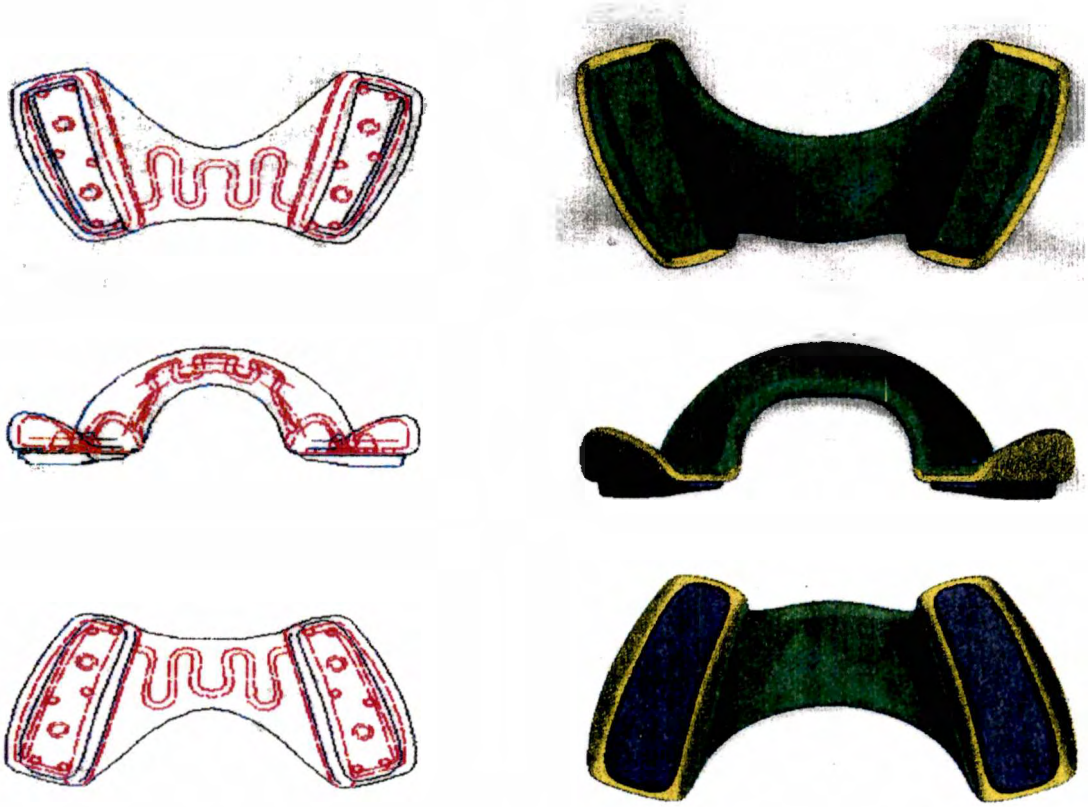


Figure 11: Top, front and bottom view of The EDGE in wire frame and solid form.

CHAPTER IV

RESULTS AND CONCLUSIONS

A. GRIP STRENGTH DATA RESULTS

A series of tests were developed to determine if a 3-mm vertical and anterior occlusion of the mandibular could enhance the grip strength of individuals. Data from the tests were separated into two main groups, The EDGE group and the placebo group. Two main subgroups were formed, male and female. These were broken down further into subgroups of 1) starting the tests with a device and 2) starting the tests without a device, with and without respectively. A breakdown of the groups and subgroups is shown in Table 1 along with the number of participants in the grip strength tests in each subgroup. The total, male, and female number of subjects to partake in the study were 123, 88, and 35, respectively.

Appendix B shows the scores for the grip strength tests as broken-down into subgroups by Table 1. The series of trials for the grip strength tests were labeled as 1-6 and compared as sets of 1 versus 2, 3 versus 4, and 5 versus 6.

Table 1: Breakdown and number of the subjects by groups of The EDGE and placebo and by subgroups of male and female.

The EDGE				Placebo			
Male		Female		Male		Female	
With	Without	With	Without	With	Without	With	Without
25	21	9	6	21	21	7	13

The groups and sets of data are defined in the statistical analysis portion, Chapter III, Section E. The number of subjects and p values for the grip strength data are listed in Table 2. The mean percent changes and standard deviations for the grip strength data for subjects starting with and without a device are listed in Table 3.

The mean percent change in grip strength data for the female population group using The EDGE is almost three times the group using the placebo and the standard deviation for the group using The EDGE is less than half that of the

Table 2: Number of subjects and p values for the grip strength data.

Population	Number of			p value
	Total participants	EDGE participants	Placebo participants	EDGE vs. placebo
Total	123	61	62	0.4683
Male	88	46	42	0.7006
Female	35	15	20	0.0345

Table 3: Mean and standard deviation of the percent change in grip strength data for each group, as shown in Table 1.

Gender and Device	Mean	Standard Deviation
Men with EDGE	2.780	5.436
Men with Placebo	2.816	6.563
Women with EDGE	6.606	3.928
Women with Placebo	2.235	8.229

group using the placebo. The mean and standard deviation for the EDGE and placebo groups for the total population are about the same and the analysis of the data shows no statistical significance difference between devices. The analysis of the grip strength data by gender shows a statistical significance for the female population between The EDGE group versus the placebo group. The male population shows no statistically significant difference between The EDGE group versus the placebo group.

B. GRIP STRENGTH EMG DATA RESULTS

The subjects monitored with surface EMGs on their biceps and triceps during the grip strength tests were divided into groups and subgroups as shown in Table 4. Tables 5-7 show the mean and standard deviation of the EMG data for the biceps and triceps taken during the grip strength trials for the female, male and total population using The EDGE, respectively. Tables 8-10 show the mean and standard deviation of the EMG data for the biceps and triceps taken during the grip strength trials for the female, male and total population using the placebo, respectively. Table 11 shows the p values in the percent change for the EMG data, separated by muscle and gender.

The EMG data for each series of trials, 1-6, of the grip strength tests for each participant was combined to form a total area under the curve for the EMG scores. Appendix C shows the scores for the grip strength EMG tests as broken-down into subgroups by Table 4. The EMG scores are listed as with and without a device for the individual subjects' biceps and triceps.

Table 4: Breakdown of the number of subjects into groups, for the grip strength EMG data, of The EDGE and placebo and into subgroups of male and female.

The EDGE		Placebo	
Male	Female	Male	Female
11	7	5	8

Table 5: Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for females using The EDGE.

EDGE Female	Biceps	Triceps
Mean	13.1542	-8.8450
Standard Deviation	15.8576	28.7943

Table 6: Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for males using The EDGE.

EDGE Male	Biceps	Triceps
Mean	3.3005	-5.5360
Standard Deviation	23.2539	26.4995

Table 7: Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for all subjects using The EDGE.

EDGE	Biceps	Triceps
Mean	7.1325	-6.8228
Standard deviation	20.7589	26.6168

Table 8: Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for females using the placebo.

Placebo Female	Biceps	Triceps
Mean	-10.4687	-13.1709
Standard Deviation	31.1716	13.7067

Table 9: Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for males using the placebo.

Placebo Male	Biceps	Triceps
Mean	-5.8931	2.9494
Standard deviation	41.5648	43.2194

Table 10: Mean and standard deviation of the percent change of the area under the curve for the usable trials for the EMG biceps and triceps data for all subjects using the placebo.

Placebo	Biceps	Triceps
Mean	-8.7088	-6.9708
Standard deviation	33.8829	28.2641

Table 11: P values for the percent change in grip strength EMG data in the biceps and triceps muscles comparing devices for the total, male and female populations. (Based on 2-tailed t-tests)

p values	Total	Male	Female
Biceps	0.117	0.575	0.094
Triceps	0.988	0.632	0.710

C. BIO-EMG DATA RESULTS

Tables 12-14 show the mean, standard deviation and p values for the bio-EMG data of the different muscle groups and devices for the total, male, and female populations respectively. Appendix D shows the scores for the bio-EMG tests as broken into groups in Table 4.

Table 12: Mean and standard deviation in the percent change in EMG data for the different muscle groups and devices and the corresponding p values for the total population.

Muscle	Device	Mean	Standard Deviation	p value
TA-R	EDGE	10.6879	45.6119	0.347
	placebo	23.6515	26.4719	
TA-L	EDGE	8.9832	29.1435	0.258
	placebo	20.6923	29.2483	
MM-R	EDGE	24.4257	27.8728	0.687
	placebo	28.6289	32.0731	
MM-L	EDGE	16.09	35.8488	0.319
	placebo	28.8193	36.3846	
SCM-R	EDGE	30.5079	57.5721	0.677
	placebo	23.5531	26.2091	
SCM-L	EDGE	29.9779	48.841	0.802
	placebo	26.0764	36.6942	
DA-R	EDGE	15.3037	52.3427	0.595
	placebo	23.9887	36.1617	
DA-L	EDGE	3.7999	35.9588	0.057
	placebo	28.9337	37.3856	

Table 13: Mean and standard deviation in the percent change in EMG data for the different muscle groups and devices and the corresponding p values for the male population.

Muscle	Device	Mean	Standard Deviation	p value
TA-R	EDGE	9.8425	51.5933	0.710
	placebo	18.3711	28.3658	
TA-L	EDGE	5.9808	27.3515	0.170
	placebo	26.2296	33.1033	
MM-R	EDGE	18.1057	25.2495	0.330
	placebo	32.0465	35.6237	
MM-L	EDGE	12.343	39.3542	0.366
	placebo	28.7208	26.3667	
SCM-R	EDGE	32.4241	68.956	0.549
	placebo	14.858	11.9769	
SCM-L	EDGE	34.3406	52.6544	0.594
	placebo	22.2925	16.0338	
DA-R	EDGE	13.5453	61.9177	0.893
	placebo	9.9816	19.3278	
DA-L	EDGE	-2.5505	40.4995	0.395
	placebo	12.8095	21.039	

Table 14: Mean and standard deviation in the percent change in EMG data for the different muscle groups and devices and the corresponding p values for the female population.

Muscle	Device	Mean	Standard Deviation	p value
TA-R	EDGE	12.6607	31.2756	0.349
	placebo	27.6119	26.1699	
TA-L	EDGE	15.989	34.6167	0.974
	placebo	16.5393	27.5678	
MM-R	EDGE	39.1722	30.3611	0.449
	placebo	26.0658	31.4075	
MM-L	EDGE	24.8332	26.9392	0.847
	placebo	28.8931	44.2941	
SCM-R	EDGE	26.0366	14.0778	0.760
	placebo	30.0744	32.5551	
SCM-L	EDGE	19.7983	40.9704	0.715
	placebo	28.9142	47.911	
DA-R	EDGE	19.4066	20.3547	0.447
	placebo	34.494	43.2134	
DA-L	EDGE	18.6174	16.5101	0.213
	placebo	41.0268	43.4689	

D. CONCLUSIONS

The EDGE did not increase the grip strength for the total or male population at a statistically significant level. The EDGE did increase the grip strength for the female population at a statistically significant level. Though there is a difference in the grip strength data for the female population, the variation in the data would suggest the mean differences are within the same range for the EDGE and placebo groups.

The trend of the grip strength EMG data suggests The EDGE did cause the biceps to increase in EMG activity and the triceps to decrease in EMG activity. The placebo group shows a decrease in both the biceps and triceps

EMG scores and the triceps monitored in the placebo group decrease about the same amount as the EDGE group. Though the data in the EDGE and placebo groups differ, there is not an improvement in EMG scores in the EDGE group at a statistically significant level for the total, male or female population. The variance in the data for the EDGE and placebo groups suggests the mean differences are within the same range.

There is no evidence in the data or trends in the analysis of the bio-EMG data to conclude that The EDGE increases the jaw clenching ability for the total, male or female population in this study.

The difference between the male and female populations scores could be attributed to "80 percent of reported TM joint cases are women" (Stenger, p. 13, 1977). If the females tested have a TMJ dysfunction that could not be detected The EDGE could have properly aligned the mandible and increased their potential.

A closer and more detailed study should be conducted to examine the difference in means and standard deviations between the women and men. A larger population should be used to try and decrease the amount of variance in the scores. The larger muscle groups (biceps, triceps, quadriceps, and hamstring) should be studied under isometric conditions to learn if they react differently with a mandibluar repositioning device.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. American Dental Association: President's conference on the examination, diagnosis, and treatment of temporomandibular disorders, The Journal of American Dental Association, Vol. 66, January 1983, p. 75-77.

2. Frogione, Albert G., Mehta, Noshir R., Westcott, Wayne L.: Strength and bite, Part I: An analytical review. The Journal of Craniomandibular Practice, October 1991, Vol. 9, no. 4.

3. Smith, Stephen D., Muscular strength correlated to jaw posture and the temprormandibular joint, NY State Dental Journal. Vol. 44, no. 7, 1978, p. 278-285.

4. Kaufman, Richard S., Kaufman, Adrienne: An experimental study on the effects of the MORA on football players. Basal Facts. Vol. 6, no. 4, 1984, p. 119-126.

5. Asmussen, Erling, Hansen, Ole, Lammert, Ole: The relation between isometric and dynamic muscle strength in man, Communications: Testing and Observation Institute of the Danish National Association for Infantile Paralysis: 3-11.

6. Dworkin, Samuel F., Leresche, Linda, DeRouen, Timothy: Reliability of clinical measurement in temporomandibular disorders. The Clinical Journal of Pain, Vol. 4, no. 2, 1988, p. 89-99.

7. Tsolka, Pepie, Fenlon, Michael R., McCullock, Andrew J., Preiskel, Harold W.: A controlled clinical, electromyographic and kinesiographic assessment of craniomandibular disorders in women. Journal of Orofacial Pain, Volume 8, Number 1, 1994, p. 80-89.

8. Snell, Richard S.: Clinical anatomy for medical students. Little, Brown and Company, Boston. 1973.

9. Kaufman, Richard S., Kaufman, Adrienne: Usefulness of the MORA to reduce headaches on the U.S. Olympic Luge Team. Basal Facts. Volume 5, Number 4.

10. Williams, Michael O., Chaconas, Spiro J., Bader, Philip: The effect on mandibular position on appendage muscle strength. The Journal of Prosthetic Dentistry. Volume 49, Number 4. April 1983.

11. Greenberg, Martin S., Cohen, S. Gary, Springer, Philip, Kotwick, John E., Vegso, Joseph J.: Mandibular position and upper body strength: a controlled clinical trial. JADA, Vol. 103, October 1981.

12. Burkett, Lee N., Bernstein, Allan K.: Strength testing after jaw repositioning with a mandibular orthopedic appliance. The Physician and Sportsmedicine. Vol. 10, no. 2, February 82, p. 101-107.

13. Bates, Robert E., Atkinson, Walter B.: The effects of maxillary MORA's on strength and muscle efficiency tests. The Journal of Craniomandibular Practice. Vol. 1, no. 4, Sept.-Nov. 1983. p. 37-42.

14. Verban, Emil M., Groppel, Jack L., Pfautsch, Eric W., Ramseyer, Gary C.: The effects of a mandibular orthopedic repositioning appliance on shoulder strength. The Journal of Craniomandibular Practice. Vol. 2, no. 3, June-Aug. 1984, p. 323-237.

15. Stenger, J., Lawson, E., Wright, J., Ricketts, J.: Mouthgaurds: Protection against shock to head, neck and teeth. JADA vol. 69 no. 273, 1964.

16. Stenger, J.M.: Physiologic dentistry with Notre Dame athletes. Basal Facts. Vol. 2, 1977. P. 8-18.

17. Gelb, Harold: Clinical management of head, neck, and TMJ pain and dysfunction; A multi-disciplinary approach to diagnosis and treatment. W. B. Saunders Company, 1977.

18. Todd, M.: The thinking body. New York, Dance Horizons, 1968.

19. Stanten, Michele: Dress for exercise success. Prevention. Vol. 49 July 1997, p. 50-51.

20. Ulfberg, J., Fenton, G.: Effect of Breathe Right nasal strip on snoring. Rhinology. Vol. 35 n. 2, June 1997. p. 50-52.

21. Viles, Gail: Hidden hazards in your running shoes. New Scientist, vol. 114 no. 1558, p. 40.

22. Pact, Virginia, Sirotkin-Roses, Marcia, Beatus, Joseph: Muscle testing handbook. Little, Brown & Company, 1984.

23. Kendall, Henry O., Kendall, Florence P.: Muscles: testing and function. The Williams & Wilkins Company, 1949.

24. Basmajian, John V., Deluca, Carlo J.: Muscles alive: their functions revealed by electromyography, 5th edition. Williams & Wilkins, 1985.

25. Ohtsuki, T: Decrease in grip strength induced by simultaneous bilateral exertion with reference to finger strength. Ergonomics. Vol. 24, 1981, p. 37-48.

26. Knoll, Bernie: NIOSH previews back belt study. Material Handling Engineering. Vol. 52, no. 8, August 1997, p. 32.

27. Brown, Kathyrn A, McArthur, David L., Peek-Asa, Corinne: Back support belts work, says study. Material Handling Engineering. Vol. 51, no. 12, November 1996, p. 11.

28. Lavender, Steven A., Thomas, James S., Chang, Dennis: Effect of lifting belts, foot movement, and lift asymmetry on trunk motions. Human Factors. Vol. 37, no. 4, December 1995, p. 844-853.

29. Woodhouse, Michael L., McCoy, Raymond W., Redondo, Diego R.: Effects of back support on intra-abdominal pressure and lumbar kinetics during heavy lifting. Human Factors. Vol. 37, no. 3, September 1995, p. 582-590.

30. Hilgen, Thomas: The use of abdominal belts in the prevention of low back injuries. Professional Safety. Vol. 37, no. 6, June 1992, p. 40-42.

31. First in-depth study proves back support belt benefits. Material Handling Engineering, vol. 52, no. 1, January 1997, p. 47-48.

32. Laverder, Steven A., Kenyeri, Ron: Lifting belts: a psychophysical analysis. Ergonomics. Vol. 38, no. 9, September 1995, p. 1723-1727.

33. Viles, Gail: Hidden hazards in your running shoes. New Scientist. Vol. 44, no. 9, May 2, 1988, p. 100-101.

34. Murray, Irwin MasKay: Human anatomy made simple. Doubleday & Company, Inc., 1988.

35. McMinn, R., M., H., Hutchings, R., T.: Color atlas of human anatomy, second edition. Doubleday & Company, Inc., 1988.

36. Reith, Edward J., Breidenback, Bertha, Lorenc, Mary: Textbook of anatomy and physiology, second edition. McGraw-Hill Bookcompany, 1978.

37. Truex, Raymond C., Kellner, Carl E.: Detailed atlas of the head and neck. Oxford University Press, 1948.

38. Crouch, James E.: Functional human anatomy, third edition. Lea & Febiger, 1978.

39. Snell, Richard S.: Atlas of clinical anatomy. Little, Brown and Company, 1978.

40. Grey, Henry, Goss, Charles Mayo: Anatomy of the human body, twenty-ninth American edition. Lea & Febiger, 1973.

41. Wilson, Doris Burda, Wilson, Wilford J.: Human anatomy. Oxford University Press, 1983.

42. Woodburne, Russell T., edited by Burkel, William E.: Essentials of human anatomy. Oxford University Press, 1994.

43. Langman, Jan, Woerdeman, M. W.: Atlas of medical anatomy, Saunders, Philadelphia, 1978.

44. Easton, Dexter M.: Mechanisms of body functions; an introduction to human functional anatomy and physiology. Prentice-Hall, Inc., 1963.

45. BioPAK Version 1.33, BioReaserch Associates, Inc., Milwaukee, WI. 1996.

46. A.D.A.M. Comprehensive, A.D.A.M. Software, Inc., Atlanta, GA. 1995.

APPENDICES

APPENDIX A

QUESTIONNAIRE AND CONSENT FORMS

Participant ID#: _____

Participant Questionnaire

Name: _____

Date: _____ **Sex:** _____ **Age:** _____ **Phone:** _____

1. **Is your physical activity limited by your physician?** _____
2. **Do you have any current dental pain, loose fillings, loose crowns, or loose teeth?** _____
3. **Have you ever been treated for Temporal Mandibular Joint Dysfunction?**

_____

4a. Please mark any of the following dental work you have had.

☐ **fillings**	☐ **caps**	☐ **crowns**
☐ **braces**	☐ **root canal**	☐ **simple extraction**
☐ **bridges**	☐ **partial dentures**	☐ **full dentures**

4b. Have you had any other major dental work beyond the list above? _____

5. **Are you missing any molars?** _____
6. **Do you feel able to perform at your normal level today?** _____
7. **Do you routinely participate in Aerobics?** _____
8. **Do you routinely lift free weights in an effort to determine your personal best?** _____
9. **Currently how many times per week do you work out?** _____

FOR OFFICE USE ONLY
ALL NATURAL
ALL ARTIFICIAL
NATURAL AND ARTIFICIAL

INFORMED CONSENT STATEMENT

INTRAORAL DEVICE EVALUATION

You are invited to participate in a research study. Your participation in this study is strictly voluntary and you may refuse to participate, or withdraw at any time. The purpose of this study is to determine if the use of an intraoral device affects the wearer's performance while undertaking one or more physical activities or athletic experiences.

INFORMATION

You will first be requested to supply the researchers with some personal information about your physical activity and condition.

Subsequently, you will be asked to intermittently wear a particular intraoral device while participating in your normal sport, exercising on a piece of equipment that you might normally use, perform on a "CYBEX" or similar machine, and/or use a hand dynamometer. You will be hooked up to a device called a 3D Digital Electric Myoghaphy (DEM).

The "CYBEX" type machine measures forces applied by specific large muscle groups. The hand dynamometer measures the muscle group of the hand. The DEM is used for tracking mandibular (jaw) motion and electrical activity in specific muscle groups. None of these machines are invasive.

You will be requested to perform your best each time you are using the "CYBEX" or hand dynamometer. However, you are not to attempt to strain a muscle group beyond what you believe to be the safe limit for you personally.

The total maximum amount of time we estimate will be requested of you is four (4) hours. The length of time for any one session is expected to an hour or less. The study will be spread out over 3-4 months starting this April.

There are no anticipated immediate benefits to you as a participant in this study.

RISKS

You may experience a muscle pull, or a sprain, etc., while participating in you chosen athletic activity or while working strenuously on the machines described above. You will not be requested to perform above any level that you feel is too strenuous. The device itself has no greater risk to you than using a mouthguard.

EMERGENCY MEDICAL TREATMENT

There is only a minor chance that serious injury will occur. In the event that physical injury occurs, as a result of the study, The University of Tennessee does not automatically provide reimbursement for medical care or other compensation. If physical injury is suffered in the course of research, or for more information, please notify the investigators in charge, P. David Halstead (974-2070) and Dr. Tyler Kress (974-3982).

CONFIDENTIALY

The information in the study records will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study unless you specifically give permission

_____ Participant's Initials

in writing to do otherwise. No reference will be make in oral or written reports which could link you to the study.

All information gathered about you personally, both prior to and during the research activities will be recorded solely by a participant identification number, which will be assigned to you. Your participant number will be kept confidential and available only to the few researchers identified below.

However, your efforts ***will be*** available to others by participant identification number, but by participant identification number only.

The data about you will be destroyed after three (3) years.

COMPENSATION

You will receive Court South gift certificate(s) for participating in this study.

CONTACT

If you have any questions at any time about the study or the procedures, or you experience adverse effects as a result of participating in this study, you may contact one of you researchers, P. David Halstead – 974-2070, Cherie F. Alexander – 974-2070 or Tyler Kress – 974-3982.

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed.

CONSENT

I have read and understand the above information. I have received a copy of this form. I agree to participate in the study.

Participant's Signature _____ Date _____

Phone Number _____ Participant Identification Number _____

Test Technician's Signature _____ Date _____

_____ Participant's Initials

APPENDIX B

Scores for the grip strength tests as broken into groups in Table 1.

B1. Grip strength scores for men using The EDGE in trials 1, 3, and 5. (Male with)

1ST	2ND	3RD	4TH	5TH	6TH
90	85	80	93	95	90
120	120	120	105	118	110
110	81	85	100	90	90
116	116	125	119	130	125
71	79	80	80	80	74
130	130	135	125	125	120
105	115	125	120	115	118
112	110	111	114	110	113
130	125	125	125	126	129
40	30	40	28	40	35
105	104	109	110	105	107
140	125	135	130	135	135
90	78	80	80	82	80
127	120	120	110	120	109
115	119	115	120	120	120
85	95	100	85	80	80
115	135	130	160	133	132
125	120	124	115	120	120
109	111	106	106	99	109
100	90	90	92	96	78
115	120	116	105	116	103
95	100	94	88	90	90
97	82	98	104	95	106
85	75	80	80	85	82
149	143	142	141	140	129

B2. Grip strength scores for men using The EDGE in trials 2, 4, and 6. (Male without)

1ST	2ND	3RD	4TH	5TH	6TH
155	155	155	160	163	165
119	124	119	130	160	133
85	87	86	90	90	95
120	115	112	117	130	120
110	105	102	97	98	95
113	120	110	110	106	112
105	110	106	116	110	112
105	110	130	109	145	114
140	135	144	154	134	140
119	131	120	124	119	121
85	91	91	87	72	95
81	81	80	79	73	90
124	130	138	120	130	124
106	110	104	105	104	105
125	127	119	122	102	106
107	115	125	120	115	124
65	80	65	70	68	71
146	160	155	154	155	157
99	97	104	98	91	95
120	170	143	115	116	129
95	100	99	102	87	104

B3. Grip strength scores for women using The EDGE in trials 1, 3, and 5. (Female with)

1ST	2ND	3RD	4TH	5TH	6TH
85	90	92	84	80	79
51	48	51	53	51	44
81	79	79	74	75	67
80	65	66	62	70	69
76	78	80	69	72	54
68	70	69	66	68	69
61	57	56	56	57	53
81	80	86	82	91	81
47	41	40	36	35	36

B4. Grip strength scores for women using The EDGE in trials 2, 4, and 6. (Female without)

1ST	2ND	3RD	4TH	5TH	6TH
40	50	40	44	48	46
55	65	67	70	65	73
80	82	85	87	80	80
40	47	45	47	42	42
40	41	38	41	40	45
49	53	48	52	55	48

B5. Grip strength scores for men using the placebo in trials 1, 3, and 5. (Male with)

1ST	2ND	3RD	4TH	5TH	6TH
120	115	120	110	120	105
85	80	85	82	86	80
85	85	80	85	83	87
115	105	108	106	105	100
140	120	140	145	135	121
110	92	90	80	110	80
145	136	136	138	121	110
135	135	133	134	127	139
60	70	75	65	70	68
103	107	104	105	101	101
154	155	158	150	145	138
85	80	70	55	70	65
87	102	91	106	103	114
70	90	100	65	90	59
105	92	95	102	112	100
115	115	120	120	114	125
90	85	92	75	90	82
95	90	100	105	100	95
106	102	101	100	97	96
108	111	102	90	98	99
76	66	81	80	90	91

B6. Grip strength scores for men using the placebo in trials 2, 4, and 6. (Male without)

1ST	2ND	3RD	4TH	5TH	6TH
140	130	105	110	120	120
96	104	105	95	110	102
135	145	130	130	130	121
110	115	105	105	107	110
91	91	99	91	90	93
100	100	85	90	95	85
110	105	100	105	100	95
119	115	115	119	124	120
109	108	105	114	109	101
86	105	105	106	103	106
142	145	145	140	134	145
115	111	113	114	125	115
80	100	85	91	85	94
120	124	120	117	114	116
110	120	102	115	114	115
60	65	55	54	50	58
100	100	90	94	90	85
106	110	102	108	110	112
155	158	170	167	160	155
100	112	111	111	103	100
106	115	114	115	114	130

B7. Grip strength scores for women using the placebo in trials 1, 3, and 5. (Female with)

1ST	2ND	3RD	4TH	5TH	6TH
85	65	83	75	84	75
70	72	75	70	68	68
36	34	33	35	40	40
61	61	58	60	51	59
61	65	65	65	65	70
52	50	45	50	55	55
76	74	74	75	74	75

B8. Grip strength scores for women using the placebo in trials 2, 4, and 6. (Female without)

1ST	2ND	3RD	4TH	5TH	6TH
85	115	101	86	95	132
58	65	67	72	66	68
90	88	90	84	80	85
80	80	82	80	80	80
60	60	61	60	60	50
45	40	40	40	56	58
59	55	52	54	55	55
56	50	64	67	63	61
41	40	34	30	40	38
55	55	55	55	55	50
55	61	62	56	53	45
50	59	46	54	46	50
65	67	63	70	70	75

APPENDIX C

Scores for the grip strength EMG data as broken into groups in Table 4.

C1: EMG data for the male participants using The EDGE.

POSITION	WITH DEVICE	WITHOUT DEVICE
BICEP	188.04	160.58
TRICEP	227.01	325.90
BICEP	38.31	34.61
TRICEP	106.56	81.89
BICEP	28.87	37.56
TRICEP	68.56	73.38
BICEP	359.60	331.65
TRICEP	40.83	45.71
BICEP	179.01	120.13
TRICEP	121.20	127.63
BICEP	31.87	32.34
TRICEP	122.26	146.11
BICEP	265.41	361.62
TRICEP	75.41	48.86
BICEP	465.48	495.15
TRICEP	44.61	66.37
BICEP	364.03	405.92
TRICEP	25.53	29.25
BICEP	377.11	250.29
TRICEP	178.76	151.56
BICEP	727.42	556.56
TRICEP	490.01	410.62

C2: EMG data for the female participants using The EDGE.

POSITION	WITH DEVICE	WITHOUT DEVICE
BICEP	121.77	88.08
TRICEP	117.51	122.46
BICEP	26.50	27.14
TRICEP	46.83	43.52
BICEP	39.47	40.23
TRICEP	17.06	19.26
BICEP	35.02	28.39
TRICEP	38.80	38.47
BICEP	23.93	23.10
TRICEP	48.47	53.54
BICEP	206.06	125.89
TRICEP	21.42	16.03
BICEP	29.31	27.13
TRICEP	14.57	24.39

C3: EMG data for the male participants using the placebo.

POSITION	WITH DEVICE	WITHOUT DEVICE
BICEP	292.93	260.76
TRICEP	228.91	206.41
BICEP	158.45	146.39
TRICEP	175.11	123.85
BICEP	142.66	107.50
TRICEP	135.19	88.46
BICEP	47.98	85.94
TRICEP	36.14	62.18
BICEP	296.95	277.93
TRICEP	980.52	851.64

C4: EMG data for the female participants using the placebo.

POSITION	WITH DEVICE	WITHOUT DEVICE
BICEP	72.66	53.58
TRICEP	230.48	235.62
BICEP	32.99	34.83
TRICEP	19.40	18.72
BICEP	38.77	52.83
TRICEP	27.24	25.77
BICEP	61.98	39.18
TRICEP	20.10	25.09
BICEP	35.60	45.60
TRICEP	23.47	27.60
BICEP	41.79	65.83
TRICEP	104.15	123.27
BICEP	133.78	144.84
TRICEP	27.77	33.17
BICEP	130.66	145.11
TRICEP	91.22	120.31

APPENDIX D

Scores for the bio-EMG data as broken into groups in Table 4.

D1: Bio-EMG data, in μv, for the male subjects using The EDGE.

EDGE Male																
ID	TA-R		TA-L		MM-R		MM-L		SCM-R		SCM-L		DA-R		DA-L	
Number	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o
2	38.1	47.3	52.2	39.2	5.7	5.7	241.8	222.7	6.3	6.3	6.4	5	9.1	5.8	9.4	6.4
4	128.5	47.2	72.8	45.1	5.6	5.7	29.9	301.5	37	14.1	11.4	5.9	17.9	16.9	250.2	408.8
6	45.3	44.8	41.2	47.1	53.8	37	32.3	30.3	8.1	6.3	6.4	4.9	7.6	6.1	7.6	6.5
10	67.3	54.2	84.1	70.5	75.5	63.3	63.3	48.5	17.3	11.7	10.2	8	12.2	9	15.8	12.3
61	52.1	81	36.9	54	12.3	14.8	15.2	17.6	7	11.3	12.6	11	6.1	23.8	6.2	26.5
67	96.2	120	128.3	120.3	73.2	67.7	130.1	104	8.2	7.2	10.1	7.6	7.1	7.5	6.9	6.6
79	103.7	119	105.4	122.1	145.2	129.5	138.3	139.3	8.6	8	6.3	6.1	9.1	7.7	10.4	9.2
81	40.4	37.9	37	47.2	31.4	26.8	26.6	21.6	4.1	2.8	8.5	6.3	7.8	6.1	8.4	6.8
83	5.5	5.3	158.1	129.7	158.6	124.9	112.5	95.1	22.3	17.3	29.5	22.2	35.2	24.3	49.9	36.9
84	87	119.2	97.3	140.2	261.5	218.9	304.2	351.3	22.7	28.1	14.4	17.5	15.5	18.3	20.1	14.7
85	139.2	180.2	154.1	180.8	102.2	122.4	100.8	98	12	13.1	27.7	25.2	15.3	16.8	17.9	18.8
86	109.8	96.5	100	83.2	83.9	74.4	89.7	65	8.7	9.9	13	12.3	10.5	16.7	9.6	18.2
87	74	67.2	113.3	94.9	70.9	43.3	94.2	51.9	21.6	7.1	21.1	7.2	32.6	11.6	5.4	5.5
88	119.6	83.3	104.3	82.4	208.9	127.7	143.1	91.7	17.1	18.6	18.3	19.9	23.3	65.1	14.7	52.1

D2: Bio-EMG data, in μv, for the female subjects using The EDGE.

EDGE Female																
ID	TA-R		TA-L		MM-R		MM-L		SCM-R		SCM-L		DA-R		DA-L	
Number	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o
13	33	22.9	37.9	21.3	70.5	47.6	24.8	14.9	19.6	15.5	14.5	8.6	7.3	7.2	8.5	7.2
52	87.5	67.4	119.6	93.1	167.2	122.6	47.9	42.1	24.8	19	12.9	13	20.5	14.9	14.4	10.4
55	65.7	53.7	54.6	49.5	73	39.2	60.6	42.1	10.6	7.1	13.2	8.4	17.3	11.7	14.1	10.9
58	53.8	64.1	40.3	38.1	40.9	30.4	31.2	24.8	9.3	7.4	6.6	5	6.1	6.1	5.7	5.7
62	54.1	84.1	64.1	82.1	90.8	65.6	50.3	46.8	8.6	8	4.9	8.4	12.2	9.8	13.8	10.8
63	122.1	92.9	78.5	82.3	114.3	125.1	185.3	202.4	18.8	16.1	11.9	11.5	18.5	17.6	15.1	15.4

D3: Bio-EMG data, in μv, for the male subjects using the placebo.

Placebo Male																
ID	TA-R		TA-L		MM-R		MM-L		SCM-R		SCM-L		DA-R		DA-L	
Number	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o
9	39.5	50.4	38.2	43	39.7	45.5	39.1	33.6	22.9	20.2	10.2	8.3	7.9	8.2	7.2	7
16	51.7	41.3	54.8	39.4	46.6	26.8	39.2	26.2	4.1	3.5	4.8	3.2	4.3	3.7	5.9	4.1
51	55.4	44.7	65.1	35.2	73.9	46.8	29.3	17	6.3	6	5.7	4.4	7	5.6	7	6.1
53	153.1	93.7	82.4	69.1	167.1	109	69.9	61.3	19	15.1	7.7	7	17.2	12.9	14.5	11.3
65	38.6	38.4	28.7	24.4	37.8	40.1	36.4	34.9	11.2	11.4	8.8	8.3	16.5	20.5	8.5	8.3
77	116.8	98.3	95.8	89	102.8	81.8	78.3	67.7	14.9	11.5	9.8	8.5	10.2	9.4	9.9	11.7

D4: Bio-EMG data, in μv, for the female subjects using the placebo.

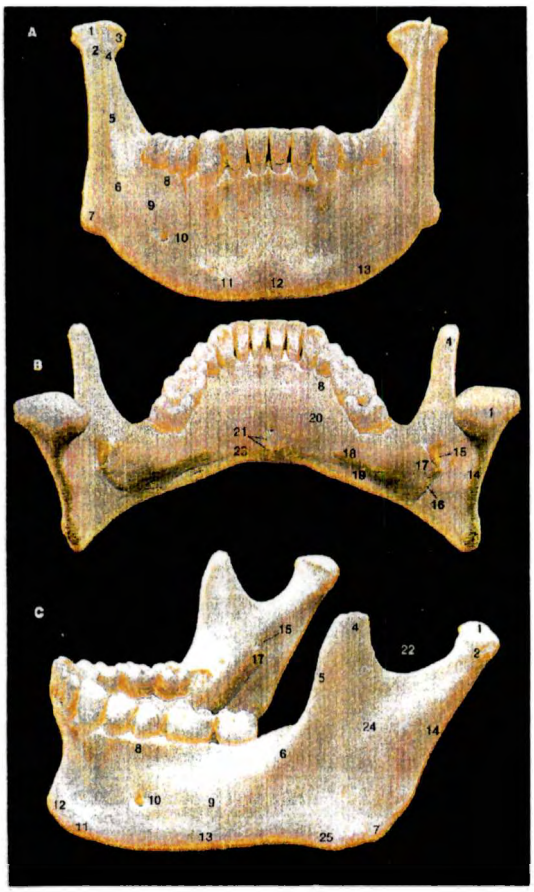
Placebo Female																
ID	TA-R		TA-L		MM-R		MM-L		SCM-R		SCM-L		DA-R		DA-L	
Number	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o	w	w/o
7	174.8	155.8	99.3	95.1	60.5	56.3	78.7	78.8	11.3	8.9	9.7	8.2	15.1	12.2	11.6	11
8	37	23.2	8.9	8.6	39.1	27.6	19.3	17.8	7	6.3	3.9	5.2	5.9	4.8	5.4	4.8
56	91.2	60.4	66.9	41.9	58.6	31	100.8	46.4	14.1	8.6	12.4	6.8	16.3	8.4	19	9.5
57	89.5	67.2	59.8	66.7	244	218.7	48.5	60	10.2	9.6	5.4	5.6	21.7	12.8	24.9	12.7
59	30	34.5	30.7	29.3	48.5	48.8	24.1	19.3	7.2	7.3	8.6	9	11.2	18.6	10.9	10.9
64	75.7	55.7	52.7	33.9	107.6	95.8	129.7	94.3	15.5	10.1	9.9	5.6	12.4	9.8	14.4	9.8
78	108.4	111.7	126.4	140.3	170	172.1	141.9	145.4	8.5	8.7	9.1	9.9	15.6	14.9	12.4	12.9
80	166.9	115	117.4	94.1	88.1	59.4	127.2	77.2	26.1	14.3	46.6	23.9	11.5	6.6	16.6	9.7

APPENDIX E

JAW ANATOMY

The jaw consists of two components, the upper jaw and lower jaw. The upper jaw, the maxilla, is attached to the skull and the TMJ connects the lower jaw, the mandible, to the skull. The mandibule is separated into four components: 1) the body, 2) the ramus, 3) the conronoid process, and 4) the condyle. The TMJ also consists of two components, the upper portion and the lower portion. The upper portion of the TMJ is a gliding joint and is located "between the mandibular fossa of the temporal bone and the articular eminence and the articular disc" (Gelb, 15, 1977). The mandibular fossa, located at the posterior side of the zygomatic process, acts as a saddle or hinge joint to the mandibular condyle. This joint gives the jaw its rotational, lateral and anterior range of motion. The lower portion of the TMJ is a hinge joint and is "located between the inferior surface of the articulator disc and the head of the condyle" (Gelb, 15, 1977). E1 shows the mandible and mandibular joint.

The occlusion of the teeth determines the degree to which the maxillo-mandibular relationship is altered when the teeth are in contact (Gelb, 17, 1977). Occlusion refers to the relationship of the jaws, muscles, joints, and the surrounding structures, not just the teeth. A MORA is intended to reposition an altered maxillo-mandibular relationship to a more optimal position. Pain and other symptoms of TMJ dysfunction can be attributed to changes in the muscles



1. Head
2. Neck
3. Pterygoid fovea
4. Coronoid process
5. Anterior border of ramus
6. Oblique line
7. Angle
8. Alveolar part
9. Body
10. Mental foremen
11. Mental tubercle
12. Mental protuberance
13. Base
14. Posterior border of ramus
15. Mandibular foramen
16. Mylohyoid groove
17. Lingula
18. Mylohyoid line
19. Submandibular fossa
20. Sublingual fossa
21. Superior and inferior mental spines
22. Mandibular notch
23. Digastric fossa
24. Ramus
25. Inferior border of ramus

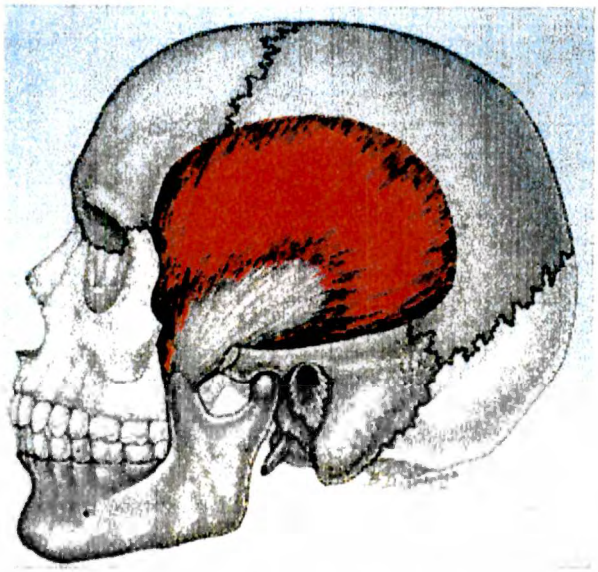
E1: Mandible joint from the anterior, posterior, and left front, A, B and C respectively. From McMimm and Hutchings: Color atlas of human anatomy. Year Book Medical Publishers, Inc. (p. 23)

of the head and neck. The repetitive contracting of the jaw muscles, as seen in clenching and bruxism, can cause the muscles to fatigue. If the teeth are in contact and the jaw muscles are not allowed to shorten themselves for an extended period of time, the muscles would essentially perform isometric contractions. This would also cause the jaw muscles to fatigue. The fatigue experienced with these types of jaw muscle use can produce soreness common to TMJ dysfunction. Three activities similar to those experienced in clenching and bruxism are as follows: 1) strong contractions of the muscle in a shortened state, 2) muscular contraction involving short jerky movements, and 3) muscle contraction involving repetitious movements over extended periods of time.

APPENDIX F

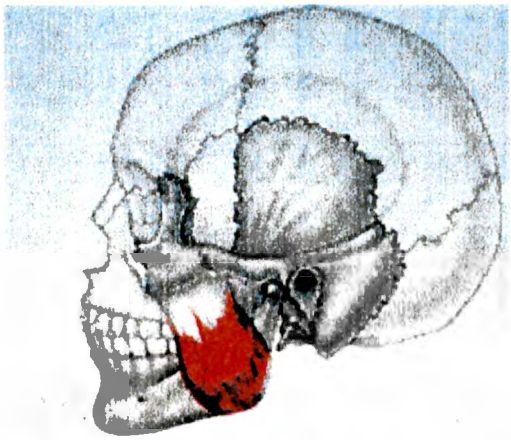
MUSCLE ANATOMY

The temporalis and masseter muscles produce occlusion, or closing, of the jaw and together with the internal pterygoid, and the external pterygoid are the muscles of mastication. The location of the temporalis and masseter muscles in relation to the skull are shown in F1 and F2 respectively.



F1: Location of the left temporalis muscle in relation to the skull. From Travell & Simons: Myofascial pain and dysfunction. Williams & Wilkins. Baltimore, 1983 (p. 238) (B. D. Cummings, Illustrator)

During mandibular depression the digastricus muscle is essential for the maximum depression of force or complete opening of the mouth. The anterior belly of the digastricus muscle is connected to the back of the mandible and the posterior belly of the digastricus muscle is connected to the interior of the

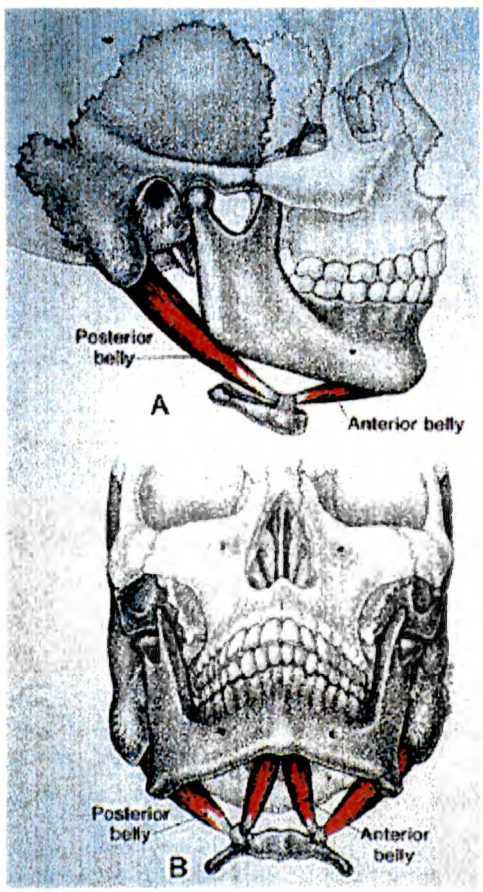


F2: Location of the left massater muscle in relation to the skull. From Travell & Simons: Myofascial pain and dysfunction. Williams & Wilkins. Baltimore, 1983 (p. 222) (B. D. Cummings, Illustrator)

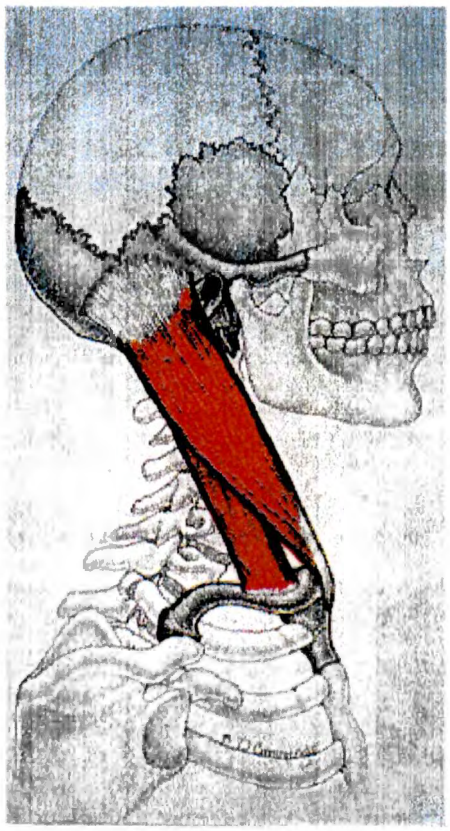
tympanic part. The sternocleidomastoidues muscle runs from the base of the skull, on the clavicle, to the manubrium of the sternum. The locations of the digastricus and sternocleidomastoidues muscles in relation to the neck and skull are shown in F3 and F4. The trapezius muscle was used as the ground for the EMG data. The trapezius muscle and the placement of the ground surface EMG is shown in F5.

The muscles of the hand to be used to collect EMG data during the grip strength portion of the test are the First dorsal interosseous and the Abductor. Digiti minimi were too small for reliable reading. A problem could arise in fitting the surface EMGs to the intended location of the muscles of the hand and thus receiving a good signal. The muscles of the participant's biceps and triceps were chosen instead because they are large enough to pick up a good signal from the surface EMGs.

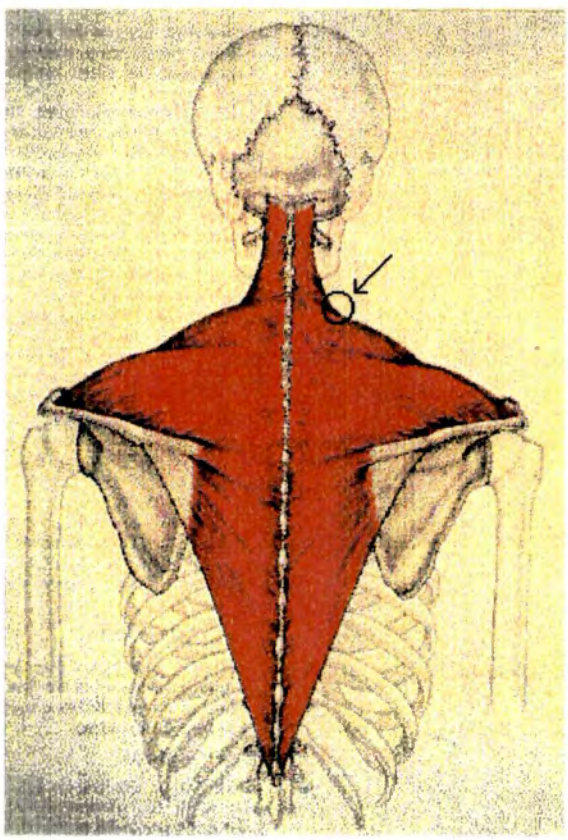
The biceps is a two-headed muscle consisting of the long and short heads. While the triceps is a three headed muscle consisting of the long, lateral and the medial heads. The musculocutaneous nerve, containing fibers from the fifth and sixth cervical nerves, branches into the two heads of the biceps and the radial nerve, containing fibers from the seventh and eighth cervical nerves, branches into the three heads of the triceps. The biceps and triceps muscles are shown in F6 and F7, respectively.



F3: Location of digastricus muscle in relation to the skull from the right and front view, A and B respectively. From Travell & Simons: Myofascial pain and dysfunction. Williams & Wilkins. Baltimore, 1983 (p. 275) (B. D. Cummings, Illustrator)



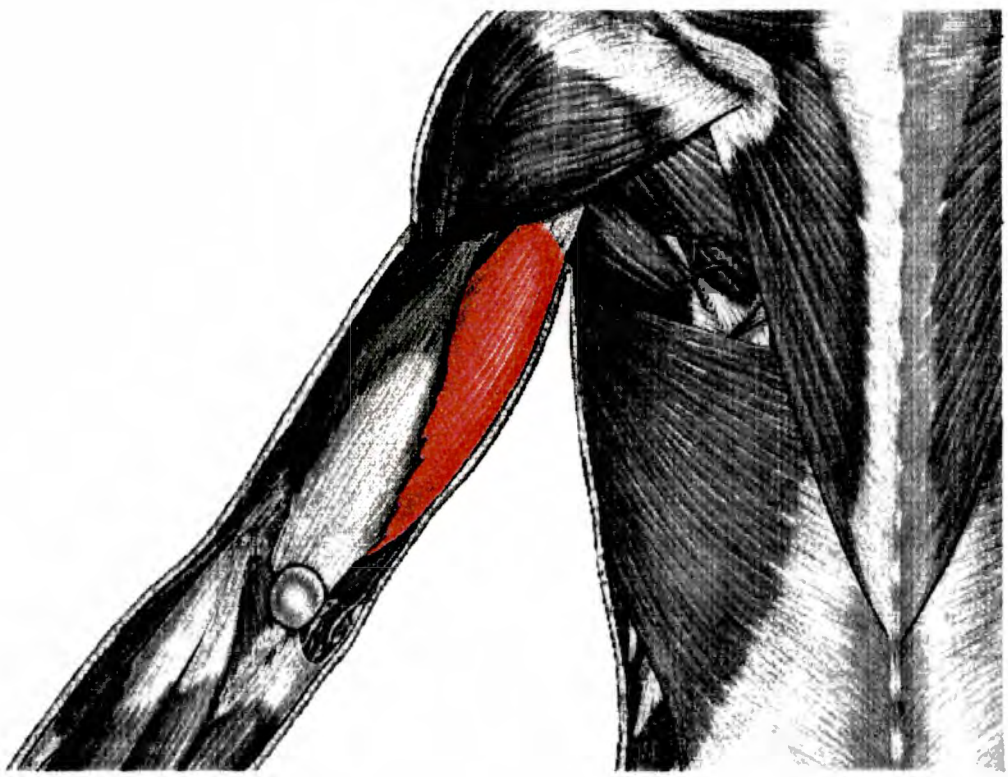
F4: Location of sternocleidomastoidues muscle in relation to the skull from the right side. From Travell & Simons: Myofascial pain and dysfunction. Williams & Wilkins. Baltimore, 1983 (p. 205) (B. D. Cummings, Illustrator)



F5: Location of the trapezius muscle in relation to the skull and neck, posterior view. From Travell & Simons: Myofascial pain and dysfunction. Williams & Wilkins. Baltimore, 1983 (p. 187) (B. D. Cummings, Illustrator)



F6: Location of biceps muscles. From A.D.A.M. Comprehensive, A.D.A.M. Software, Inc., Atlanta, GA. 1995.



F7: Location of triceps muscles. From A.D.A.M. Comprehensive, A.D.A.M. Software, Inc., Atlanta, GA. 1995.

VITA

Timmy W. Lorance was born in Nashville, Tennessee on July 14, 1968. He attended schools in the public system of Nashville, Tennessee where he graduated from DuPont High School in May 1986. He entered The University of Tennessee, Knoxville during August of 1993 where in May, 1996 he received the Bachelor of Science in Mechanical Engineering. He entered the Master's program in Industrial Engineering at The University of Tennessee, Knoxville in August of 1996, officially receiving the Master's degree in December, 1999.