2000

EMG Analysis of Trunk Musculature following a Nine Hole Round of Golf: The Fatigue Factor

Nicole Garrett

University of North Dakota

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EMG ANALYSIS OF TRUNK MUSCULATURE FOLLOWING A NINE HOLE ROUND OF GOLF: THE FATIGUE FACTOR

by

Nicole Garrett
Bachelor of Science in Physical Therapy
University of North Dakota, 1999

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
2000
This Independent Study, submitted by Nicole A. Garrett in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

<table>
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[iii]
TABLE OF CONTENTS

List of Figures ................................................. v
List of Tables .................................................. vi
Abstract ....................................................... vii
Chapter I Introduction ...................................... 1
Chapter II Literature Review .............................. 3
Chapter III Methodology .................................. 7
Chapter IV Results .......................................... 15
Chapter V Discussion ...................................... 17
Appendices ................................................... 20
References .................................................... 35
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Figure 3.1 Electrode placement for golf swing analysis</td>
<td>9</td>
</tr>
<tr>
<td>2.</td>
<td>Figure 3.2 Ensemble average pre-round golf swing</td>
<td>13</td>
</tr>
<tr>
<td>3.</td>
<td>Figure 3.3 Ensemble average post-round golf swing</td>
<td>14</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Table 3.1: Sequence of Simulated 9 Hole Round of Golf</td>
<td>11</td>
</tr>
<tr>
<td>2. Table 4.1: Two Way ANOVA Tests of Between-Subject Effects</td>
<td>16</td>
</tr>
<tr>
<td>3. Table 4.2: Scheffe's Post Hoc Analysis of Swing Time Among Subjects</td>
<td>16</td>
</tr>
</tbody>
</table>
ABSTRACT

Four male subjects were tested using EMG spectral analysis to determine if muscle fatigue occurs in the trunk musculature after a simulated nine hole round of golf. The mean frequency of the gluteus maximus, abdominal oblique, and the erector spinae were studied. A significant difference in mean frequency change was noted, therefore supporting the idea that the muscles tested may indeed fatigue during a round of golf. The author supports the use of golf exercise programs for the prevention of injury. Strengthening and endurance exercises should include these trunk muscles since they appear to fatigue after a simulated nine hole round of golf.
CHAPTER I

INTRODUCTION

Problem Statement

There are an increasing number of amateur golfers today with the most commonly reported injury being low back pain. Injuries are most likely to occur during the golf swing. Relatively little research has been done to identify if fatigue occurs in trunk musculature that can lead to improper body mechanics and result in possible injury.

Purpose

The purpose of this study is to determine if fatigue occurs in the trunk musculature following a simulated nine hole round of golf through the EMG analysis of the golf swing. Analyzing the muscle fatigue component of trunk musculature is essential in identifying fatigue as an injury risk factor. It is the significant shift in the median frequency that provides the determinant of muscle fatigue in EMG studies.

Significance

This study is important for the profession of physical therapy by providing information concerning the role muscle fatigue has in the game of golf. By determining whether fatigue is experienced by trunk musculature and identifying which muscles do fatigue, training and conditioning programs can be developed to increase muscle endurance. Increasing endurance may lead to a decrease in the likelihood of muscle compensation patterns during the golf swing, which often results in faulty swing mechanics and an increased risk of injury.
Research Questions

1. Is there a significant difference (SD) in median frequency (MF) change after a simulated nine hole round of golf?

2. Is there a SD in MF change in each muscle in subject group after a simulated nine hole round of golf?

3. Is there a SD in MF change in each muscle in each subject after a simulated nine hole round of golf?

4. Is there a SD in MF change in all muscles grouped together in each subject after a simulated nine hole round of golf?

Null Hypotheses

1. There is no significant difference (NSD) in median frequency (MF) change of all muscles grouped together in subject group after a simulated nine hole round of golf.

2. There is NSD in MF change in each individual muscle in subject group after a simulated nine hole round of golf.

3. There is NSD in MF change in each individual muscle in each subject after a simulated nine hole round of golf.

4. There is NSD in MF change in all muscles grouped together in each individual subject after a simulated nine hole round of golf.
CHAPTER II

LITERATURE REVIEW

Golf has become a growing sport in the world today. People of all ages and socioeconomic backgrounds are playing the sport. Ten to twenty percent of the adult population in many countries practice golf. In the United States alone there are over 25 million golfers.

Golf has been categorized as having a moderate risk activity for sports injury. Injury is most likely to occur during the golf swing, because of the great demand on the muscular and skeletal biomechanics of the body. Back pathologies are the most frequent injury to golfers today. Lower back pain is the most common golf-related injury in amateur golfers and the number one complaint of male PGA golfers. Women PGA golfers' main complaint was left wrist injuries followed by lower back pain. A Golf Digest survey also found the low back to be the most commonly injured area in male amateur golfers, and the second most commonly injured area in female amateur golfers.

Overuse and improper body mechanics are the most common cause of injury. Overuse of muscles leads to fatigue, muscle substitution and poor body mechanics. It has been stated that reduced endurance and force of the lumbar paraspinal musculature have been related to chronic low back pain. It has also been noted that one cause of back injuries is that during fatiguing trunk flexion and extension movements, increases in range of motion in other planes occur due to the loss of muscle control.
The golfer uses different muscles throughout the different phases of the golf swing. The golf swing can be divided into four different phases: set up, backswing, forward swing, and follow through. EMG studies have been conducted to analyze what muscles are active during these different phases. During set up, muscle activity is at a minimal and not much force is used. During the backswing, one study found the left rectus abdominals, left external obliques, and left paraspinals are predominately active. Another study found there to be peak activity of the left external obliques, left erector spinae, and the left and right gluteus maximus to occur during the backswing (also known as takeaway). During forward swing, the right sided muscles lead the swing, in which the right external obliques fire maximally. During forward swing, strong activity of the left abdominal muscles and trunk rotators (left external obliques and a lesser degree the left rectus abdominis) were also noted. The left and right paraspinals, including the erector spinae aided in this phase. Another study found there to be moderate muscle activity of the right and left external obliques, right and left erector spinae, and the right and left gluteus maximus during the forward swing. A recent study found that 92.4% of the paraspinals' maximal voluntary isometric effect was from the top of the swing to ball impact (forward swing). During the follow-through phase, the anterior muscles (obliques and rectus abdominis) are active as the paraspinals become inactive.

The forward swing may cause excessive stress on the spine due to overrotation and overtension. During the forward swing is where most injuries occur. This is where most of the muscle activity occurs and where peak muscle forces occur.

Muscle fatigue is defined as "a decrease in peak tension and power output resulting in a reduced work capacity." Muscle fatigue is also described as when the muscle fails to
maintain the target force. The main features of muscle fatigue are a drop in the muscle twitch tension, slowing contraction time, slowing relaxation time, drop in force, and a drop in velocity. One way to measure muscle fatigue is through the use of EMG analysis. During muscle fatigue, the EMG amplitude increases. This is thought to be due to the recruitment of additional motor units and an increase of firing frequency of the motor units to maintain the force output. There is a decrease in frequency response and lower frequencies predominate. This increase in lower frequencies is due to a decrease in muscle fiber conduction velocity. The shift to a lower frequency is an indicator used for identifying muscle fatigue. The parameters used for measuring EMG spectral shifts are median frequency (MF) and mean power frequency (MPF). The rate of decline in the MF is known as the fatigue rate of the muscle.

An advantage to using EMG (power spectral) analysis is its capability to measure muscle fatigue of individual muscles. It also measures fatigue on a continuous process instead of measuring it as a precise point. Studies have used EMG spectrum to measure muscle fatigability in various muscles, and have shown that EMG power spectral analysis is a reliable method to measure muscle fatigue. One study quantified muscle fatigue of the back trunk extensors during an unsupported trunk hold position. Another study found reliability during isometric contractions at the elbow. During a trunk holding test, another study reported an increase in EMG amplitude was evidence of iliocostalis lumborum and multifidus fatigue. Trunk muscle fatigue was found during a prolonged lateral bend contraction study in which a decrease in the mean power frequency was noted.
There is a lack of data in the literature on EMG analysis of dynamic muscle fatigue. Only one study was found that used the EMG spectrum analysis to measure fatigability in isoinertial (dynamic) lumbar paraspinal muscles. A relationship was found between submaximal objective EMG and subjective estimates using the Borg scale of fatigue when performing isoinertial repetitive upper trunk extension. The authors concluded that EMG analysis serves as a valid indicator of low back muscle fatigue.

This study will use EMG analysis to determine if muscle fatigue does occur in the dynamic trunk musculature during a golf swing, after the subjects have played an assimilated nine hole round of golf.
CHAPTER III
METHODOLOGY

This project was reviewed and approved by the University of North Dakota Institutional Review Board prior to the initiation of the study (See Appendix A).

Subjects

The voluntary participants in this study were four adult males who met all participation guidelines: negative history of low back injury, male, age 18-30, and an average score of 45 strokes during a nine hole round of golf. All subjects were UND students. The purpose and procedures of the study were explained to each participant. Each subject read and signed a statement of informed consent prior to participation. (See Appendix A)

Instrumentation

Self-adhesive pre-gelled silver/silver chloride EMG surface electrodes (Multi Bio Sensors, El Paso, TX, 79913) were placed on the subjects to record EMG activity. The analog EMG data was collected with the Noraxon Norswitch and Noraxon Telemyo8 telemetry transmitter (Noraxon USA, 13430 N. Scottsdale Rd., Scottsdale, AZ, 85254). This data was transmitted via telemetry to the Noraxon receiver. The analog data was converted to a digital signal with a 16 bit A/D PC card. A data sampling rate of 1,000 Hz (PCM-DAS 16S/16, Computer Boards, Inc. Mansfield, MA, 02048) was used for this conversion. The data was then stored on an IBM compatible PC utilizing a Pentium processor. An Infrared Retro-Reflective A.C./D.C. Photo-Electric Sensor, Number
NX5RM7B, (Sunx, 1207 Maple St., West Des Moines, IA, 50265) was placed between the subject’s legs on the floor with the reflector perpendicular to the subject 5 feet away. A reusable footswitch (Noraxon USA, 13430 N. Scottsdale Rd., Scottsdale, AZ, 85254) was placed over the plantar surface of the right mid-heel, and secured by athletic tape.

Procedure

Subjects were tested independently at the University of North Dakota Physical Therapy Department in Grand Forks, ND. Prior to initiation of the study, EMG equipment was pre-tested by the researchers to ensure proper signal transmission and reception. The procedure and purpose of the study were explained to the subjects prior to individual testing. Each participant signed a statement of informed consent.

The subjects were dressed in a t-shirt and athletic shorts. Electrode sites were prepared by shaving excess hair from the area followed by scrubbing the sites with rubbing alcohol to aid in signal conduction. Surface electrodes were placed bilaterally over predetermined motor points. The motor points were marked as follows (See Figure 3.1): 1) gluteus maximus muscles at the midpoint of a line running from the inferior lateral angle of the sacrum to the greater trochanter, 2) the abdominal oblique muscles 5 cm superior to the ASIS, 3) the erector spinae muscles horizontally aligned with the L3-L4 interspace, 4 cm lateral to the midline. A ground electrode was placed over the ASIS. Leads from the electrodes and footswitch were connected to respective transmitters. The transmitters were secured to the subject’s right thigh using an adjustable belt in order to avoid interference of the golf swing. Subjects performed maximum manual muscle tests (MMT) bilaterally for each muscle to establish a maximum voluntary contraction for further analysis. The MMT was used to normalize EMG data allowing comparison and
FIGURE 3.1. Electrode placement for golf swing analysis.
statistical analysis across subjects for particular trials.

Subjects were instructed to address the ball with the right heel elevated, but as relaxed as possible in a vertical posture. The club head was positioned forward of the infrared light beam set up between the subjects' feet. Data collection began when minimal EMG muscle activity appeared, the subject then lowered the right heel to the floor, triggering the foot switch, and assumed a natural swing posture to begin the pre-contact phase of the swing. The light beam was broken on take-away and used as the first event marker signaling the start of the swing. The subject proceeded to complete a normal golf swing. After follow-through, the swing was concluded with the subject returning to the beginning position with both heels on the ground. During the swing, the lifting of the right heel was the second event marker signaling contact of the club with the ball. The return of the right heel to the floor signaled the end of the swing. The subjects were allowed 2-3 warm-up swings to become comfortable with the equipment and swing procedure.

Each subject then performed five swings with a driver hitting a foam practice ball from a rubber tee into a practice net to obtain pre-round EMG data. The subject was then disconnected from the EMG receiver and accompanied by two researchers to a practice field about 500 yards from the testing area. The subject performed a repeated sequence of golf swings with a maximum of 45 total strokes to simulate a nine hole round of golf. (Table 3.1).
Table 3.1 Sequence of Simulated 9 Hole Round of Golf

<table>
<thead>
<tr>
<th>Club</th>
<th>Number of Swings/Hole</th>
</tr>
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<tbody>
<tr>
<td>Driver</td>
<td>1</td>
</tr>
<tr>
<td>5 Iron</td>
<td>2</td>
</tr>
<tr>
<td>Putter</td>
<td>2</td>
</tr>
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</table>

The Subject and researchers returned to the testing area and began EMG data collection as previously described within five minutes of finishing the simulated round. Each subject performed five swings in the same manner as before the simulated round to obtain the final post-round data.

Data Analysis

The raw EMG data was analyzed with the MyoResearch 97 software package (Noraxon USA, 13430 N. Scottsdale Rd., Scottsdale, AZ, 85254). Each individual trial was displayed and event markers were placed where the light beam was disrupted (marker A), when the heel switch was de-activated (marker B), and when the heel switch was reactivated (marker C).

Swing Time

The time of swing was determined by reading the chronological time between markers A and C. No attempt was made to control or normalize time of swing across subjects.

EMG

All subjects performed maximal voluntary contractions (MVC) with a five-second hold prior to initiating the pre-round swings. The raw EMG output for the MVC was rectified for each individual muscle group (Gluteus Maximus, Abdominal Obliques, and
Erector Spinae). The maximal 1000 points (1 second of data) of the MVC was used for normalizing the rectified EMG in subsequent phases of the experiment. Each subject then performed 5 pre-round and 5 post-round swings. The raw EMG for each of the trials was rectified and then normalized to the MVC of the appropriate muscle group. All trials were combined to form an ensemble average for the pre-round and post-round golf swings. (See Figure 3.2 and Figure 3.3).

Median Frequency

The digitized raw EMG data from marker A to marker C was used to determine median frequency. The EMG output was processed through Fast Fourier Transformation (FFT) using the MyoResearch 97 software. The median frequency was determined for the period of time from marker A to marker C. A shift toward a lower median frequency was operationally defined as representing muscle fatigue.

Statistical Analysis

The main effects of a two-way analysis of variance (ANOVA) (Subject X Swing Time) on change in median frequency was performed at the $p=.05$ significance level. This was followed by a Scheffe post-hoc analysis of the results.

The paired t-test was used to analyze the median frequency shift occurring between pre-round and post-round trials. Paired t-tests were performed for all subjects and all muscles, as a group and individually (all subjects, all muscles Pre vs Post; individual subject #1,2,3,4 all muscles Pre vs Post; individual muscle #1,2,3,4,5,6, individual subject #1,2,3,4). A significance level of $p=.05$ was used to determine significance during these tests. The normalized muscle activity was not tested for statistical significance.
FIGURE 3.2. Ensemble average pre-round golf swing.
FIGURE 3.3. Ensemble average post-round golf swing.
CHAPTER IV

RESULTS

Subjects

The subject group consisted of four adult males with an age range of 22-26 years old (mean age=24), average weight 173.75 lbs., and average height 72 in. There was a zero drop out rate for the study. Average golfing ability was 45 (SD=± 5) strokes per nine holes of golf.

EMG

The results of the EMG data were used to determine if there is a significant MF shift in the following: 1) all subjects, all muscles Pre vs. Post round, 2) individual muscles, all subjects Pre vs. Post round, 3) all muscles, individual subjects Pre vs. Post round.

All four subjects were looked at collectively to determine if there was a significant shift in MF of all six muscles grouped together between pre-round and post-round data. A paired t-test found a significant shift in MF (p<.001). All subjects collectively and each muscle were also looked at for significance. A paired t-test found a significant shift in MF for the right abdominal oblique (p=.025), left gluteus maximus (p=.08), right gluteus maximus (p=.007), left erector spinae (p=.017), and right erector spinae (p=.016). The left abdominal oblique showed no significant shift in MF (p=.773) in a paired t-test. When looking at each subject individually with relation to all muscles together, a paired t-test showed subjects 2 and 3 displayed a significant shift in MF.
(p2=.002, p3<.001). Subjects 1 and 4 showed no significant shift in MF with a paired t-test (p1=.051, p4=.073)(See Appendix B)

Swing Time

A two way ANOVA main effects only, demonstrated a significant difference between subject’s swing times. There was, however, no significant difference within a subject’s swing times when comparing before and after the simulated nine hole round of golf (See Table 4.1). Mean swing times for subjects 1, 2, 3 and 4 were 3.98s, 2.300s, 3.109s, and 4.212s respectively. Post hoc analysis between subjects revealed a significant difference in swing times between subjects 1-2, 2-4, and 3-4 (See Table 4.2)

Table 4.1: Two Way ANOVA Tests of Between-Subject Effects

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<th>F</th>
<th>Significance</th>
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Table 4.2 Scheffe’s Post Hoc Analysis of Swing Time Among Subjects

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*The mean difference is significant at the .05 level
CHAPTER V

DISCUSSION

This study has found that muscle fatigue appears to occur after a simulated nine hole round of golf. When looking at the subjects collectively, all six muscles grouped together had a significant mean frequency decrease. This decrease in frequency is indicative of muscle fatigue. This suggests that the subjects as a group did show a grouped muscle fatigue after a simulated nine hole round of golf. When the muscles were looked at individually, all muscles had a significant mean frequency shift except the left abdominal oblique. A recent study of EMG analysis of the muscles during the golf swing found the left abdominal oblique to actually be just as active, if not more active, than the right abdominal oblique. It is possible that the left abdominal oblique does fatigue in only one phase of the swing, but overall no fatigue is noted.

When grouping the muscles and looking at each subject individually, only subject 2 and 3 showed a decrease in their mean frequency. It was noted that subjects 2 and 3 had faster swing times than did subjects 1 and 4. The increased speed of the golf club may cause increased activity of the trunk muscles in follow through in order to decelerate and control the club. Another possible explanation for only subjects 2 and 3 showing fatigue is that subjects 1 and 4 may have better conditioned trunk muscles than subject 2 and 3. No testing was done prior to compare the endurance of the subjects’ specific muscles looked at in this study.
Limitations

This study could have been improved in several ways. Only four subjects were used in this study. An increase in the sample size may be beneficial for future research. A limiting factor may also be electrode placement. Although the electrodes were placed over the proper motor points, it is uncertain that only the activity of a specific muscle such as the external obliques is being picked up. Surface EMG will recognize all electrical activity and is unable to specifically differentiate muscles like needle EMG.

Another area of concern is the idea of time of recovery for muscle fatigue, which occurs in 4-5 minutes. The study was conducted in such a way to try to prevent this by getting each subject’s data as soon as possible after the simulated nine hole round of golf. Exact timing between the last stroke of the simulated round of golf and the beginning of the post-round data collection was not measured and collected. We therefore cannot rule out the possibility that some recovery of the muscles may have occurred. This study was conducted using a simulated round of golf, in which the subjects hit a series of swings in a practice field. It would have been more accurate to collect pre and post data before and after an actual game of golf. This would take into consideration the aerobic component of the game of golf as well as the time between each swing when a person may have time to rest waiting for a golfing partner to swing or walking between swings.

Further Research

Further research is needed in the area of golf and the fatigue of muscles. It may be beneficial in future research to include an averaged time of rest between swings and include the walking component to simulate a more accurate golf game. Future research may want to closely monitor the time between the last swing and start of the data.
collection to try and prevent the muscles from recovering. The golf swing may be broken up into phases such as pre-contact and post-contact and see if there is muscle fatigue during certain stages in the swing.

**Conclusion**

EMG analysis of the trunk muscle after a simulated nine hole round of golf does show muscle fatigue. Because fatigue is known to cause substitution and poor body mechanics, this is clinically an important issue to address in the prevention of golf injuries. To prevent muscle fatigue, proper strengthening and endurance exercises should be implemented along with proper stretching techniques and warm up and cool down techniques. It is felt that exercises should include the muscles that are most active during the golf swing, with emphasis on the muscles that are noted to fatigue. Strengthening exercises for the abdominal obliques, gluteus maximus, and the erector spinae muscles should be incorporated into the golf exercise program. One may not only prevent back injury, but may also better his or her golf game by strengthening and conditioning these muscles.
APPENDIX A
UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Dave Reling, Michelle Ballan, Katie Gleissling, Nicole Garrett, Christine Wellner
TELEPHONE: (701) 777-4091 DATE: March 20, 1999
ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 501 N. Columbia Road, P.O. Box 9037, Grand Forks, ND 58202-9037

SCHOOL/COLLEGE: Medicine DEPARTMENT: Physical Therapy PROJECT DATES: April
1999- April 2000
PROJECT TITLE: EMG Analysis of Trunk Musculature Following a 9 Hole Round of Golf: The Fatigue Factor

FUNDING AGENCIES (IF APPLICABLE):

TYPE OF PROJECT (Check ALL that apply): 
- X NEW PROJECT
- ___ CONTINUATION
- ___ RENEWAL
- ___ THESIS RESEARCH
- ___ STUDENT RESEARCH PROJECT
- ___ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: David Reling, MS, PT

INVOLES A PROPOSED PROJECT: 
- ___ INVOLVES NEW DRUGS (IND)
- ___ USE OF DRUG

COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

- ___ MINORS (<18 YEARS)
- ___ PREGNANT WOMEN
- ___ MENTALLY DISABLED
- ___ FETUSES
- ___ MENTALLY RETARDED
- ___ PRISONERS
- ___ ABORTUSES
- ___ UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE

IF YOUR PROJECT HAS BEEN WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S):

Status: ___ Submitted; Date ____________________ ___ Approved; Date_________________ ___ Pending

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.

There are nearly 25 million golfers in the US. The most common golf related injury reported by amateurs is low back pain. Injuries are most likely to occur during the golf swing. Golf injuries tend to result from overuse of the trunk musculature. Studies have shown fatigue may lead to improper body mechanics resulting in abnormal stresses and possible overuse injuries. For this reason, analyzing the muscle fatigue component of trunk musculature is essential for identifying fatigue as an injury risk factor. In reviewing the literature relatively few studies of this subject were found. The purpose of this study is to determine the fatigue component in trunk musculature following a round of golf through analysis of the swing.

We hypothesize that trunk musculature will show a significant amount of fatigue following a 9 hole round of golf. The results will attempt to provide information on establishing training and conditioning programs targeting trunk musculature. This information will be beneficial to physical therapists working with all levels of golfers, both in
training and rehabilitation of low back injuries. Healthy human subjects are necessary to determine which muscles are active, when they are active, and muscle fatigability while performing the golf swing.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

Subjects
The subject sample will consist of 10 male subjects, right hand dominant, from the University of North Dakota voluntarily recruited for this study. The subjects will be between the ages of 18-30 and will have no previous or existing trunk injuries. All subjects will appear to be in good general health. The subject’s average score for a nine hole round of golf will fall into the range of 40-50 strokes. All participants will sign appropriate human subject consent forms.

Procedure
The study will be conducted in the University of North Dakota physical therapy department and north intramural fields. Upon entering the facility the subjects will be given verbal instructions on the purpose and procedure of the study and then will be asked to sign a consent form. Self-adhesive EMG electrodes will be placed over the erector spinae, obliques, and gluteus maximus muscles bilaterally. Surface electrodes will be placed over pre-determined motor points of the above muscles. If necessary the skin will be shaved and cleansed with alcohol before attachment of the EMG electrodes to ensure adequate conduction. The EMG signals will be transmitted to a receiver unit, then fed into a computer for display and recording of data. Maximal voluntary contractions of the previously mentioned muscles will be measured using manual muscle testing techniques administered by the testers. Muscle activity recorded during the maximal voluntary contraction will be considered as 100% activity level. This procedure is done to normalize the EMG data for later analysis.

The subject will be allowed 5 warm-up swings with electrodes attached and transmitter unit on thigh to ensure comfort and unobstructed swing. Each subject will take 5 normal golf swings with a driver, hitting a practice ball into a net, to obtain initial baseline EMG and motion analysis data. The subject will proceed to walk with testers _ yards to the north Intramural fields to perform repeated swings. Swings will consist of 1 swing with a driver, 2 with a 5 iron and 2 with a putter. This pattern will be repeated 9 times to simulate a nine hole round of golf. All swings will make contact with a real golf ball. Immediately following this simulated round the subjects will walk with the testers back to the physical therapy department to complete the collection of EMG muscle activity data. The subject will again take 5 swings with a driver, making contact with a plastic ball, to collect final data.

Data collection will consist of measurements of muscle activity and fatigue around the trunk and pelvis. Statistical analysis of the mean activity of each monitored muscle will be performed prior to and following the simulated round of golf. The EMG data collected during the experimental trials will be expressed as a percentage of the EMG activity recorded during the maximal voluntary contraction prior to the experimental trials. Data collected before and after the simulated nine hole round of golf will be compared to determine if muscle fatigue has occurred.

3. BENEFITS: (Describe the benefits to the individual or society.)

Possible benefits of this study will include obtaining information on the amount of fatigue experienced by trunk musculature during a 9 hole round of golf. By identifying which muscles and to what extent they fatigue, training and conditioning programs can be developed to help increase endurance. By increasing muscular endurance it is possible to decrease the likelihood of muscle compensation patterns that may lead to faulty swing mechanics which in turn increase the risk of injury.

By establishing data on trunk muscle fatigability and trunk and pelvis motion before and after a 9 hole round of golf we will provide information that can be used clinically in the treatment of patients and for further research endeavors.
4. **RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

Physical risks to the subjects of this study are minimal to moderate. EMG poses no risk to subjects. Muscle strains are a possible risk to the subjects, but should be minimal due to the ability and health of the golfers. Each subject will be given a warm-up period which will also decrease the risk of muscle strains.

All data will be collected and remain confidential throughout and following the study. Subjects will be assigned code numbers to ensure confidentiality and eliminate the use of their names for data collection purposes. Participation in this study is voluntary and subjects are free to withdraw at anytime for any reason without fear of retribution. Data will be kept for three years in the UND Physical Therapy Department.

5. **CONSENT FORM:** A copy of the CONSENT FORM to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no CONSENT FORM is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

A copy of the consent form is attached. Signed consent forms will be kept by David Reiling for three years in the UND Physical Therapy Department.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For **EXEMPT or EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University’s policies and procedures governing the use of human subjects.

**SIGNATURES:**

Principal Investigator ____________________________ Date

Project Director or Student Adviser ____________________________ Date

Training or Center Grant Director ____________________________ Date

(Revised 3/1996)
STUDENT RESEARCHERS: As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board’s access to those portions of my educational record which involve research that I wish to conduct under the Board’s auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The study to which this release pertains is EMG Analysis of Trunk Musculature Following a 9 Hole Round of Golf: The Fatigue Factor.

I understand that such information concerning my educational record will not be released except on the condition that the Institutional Review Board will not permit any other party to have access to such information without my written consent. I also understand that this policy will be explained to those persons requesting any educational information and that this release will be kept with the study documentation.

Date ______________________  Signature of Student Researcher

1Consent required by 20 U.S.C. 1232g.
INFORMATION AND CONSENT FORM

TITLE: EMG Analysis of Trunk Musculature Following a 9 Hole Round of Golf: The Fatigue Factor.

You are being invited to participate in a study conducted by Dave Relling, a physical therapy instructor at the University of North Dakota, Michelle Ballan, Nicole Garrett, Katie Glessing and Christine Wellner, physical therapy students at the University of North Dakota. The purpose of this study is to determine the amount of fatigue trunk musculature experiences following a nine hole round of golf through analysis of the golf swing. The results will attempt to provide information on establishing training and conditioning programs targeting trunk musculature, especially on increasing endurance to prevent muscle compensation patterns that result from muscle fatigue. They will also provide information that will help reduce and prevent golf-related injuries. Only healthy subjects will be used to participate in this study.

You will be asked to take 10 total swings with a driver while connected to the EMG equipment. Five swings will be taken before and after you play a simulated 9 hole round of golf. During the round you will take 1 swing with a driver, 2 with a 5 iron and 2 putts and all swings will be with real golf balls. This sequence will be repeated 9 times to simulate an actual round of golf. You will be given a few minutes to warm up before performing the actual trials.

This study will take approximately two hours of your time. You will be asked to report to the University of North Dakota physical therapy department at the designated time. We will record your age and gender for data analysis purposes. During the experiment we will be recording the amount of muscle activity during the golf swing.

The process of physical performance testing always involves some degree of risk, but the investigators in this study feel that the risk of injury or discomfort is minimal. In order for us to record the muscle activity, we will be placing thirteen adhesive electrodes on the skin of your trunk and pelvis. Shaving of the hair from the area where the electrode is placed may be necessary. These electrodes only record information from your muscles and joints, they do not stimulate the skin. The amount of exercise that you will be asked to perform will be minimal to moderate.

Your name will not be used in any reports of this study’s results. Any information that is obtained in connection with this study that can be identified with you will remain confidential and will only be disclosed with your permission. A number known only to the investigator will identify the data. You or the investigator may stop the experiment at
any time if the participant is experiencing discomfort, pain, fatigue or any other symptoms that may be detrimental to your health. Your decision on whether or not to participate will not prejudice your current or future relationship to the physical therapy department or the University of North Dakota. You are also free to discontinue participation at any time without consequences.

The investigators involved are available to answer any current or future questions you have concerning this study. Questions may be addressed to Dave Relling or any one of the other investigators at (701) 777-2831. A copy of this consent form is available to all participants in the study. Signed consent forms will be kept by Dave Relling in the University of North Dakota Physical Therapy Department for 3 years.

In the event that this research activity results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to any member of the general public. You and your third party payer must provide payment for any such treatment, if applicable.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above information and willingly agree to participate in this study as explained to me by Dave Relling, Michelle Ballan, Nicole Garrett, Katie Glesing or Christine Wellner.

Participant’s Signature ___________________________ Date __________

Witness (not the investigator) ___________________________ Date __________
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

DATE: April 7, 1999  PROJECT NUMBER: IRB-9904-205
Dave Relling, Michelle Ballan, Katie Glessing,
NAME: Nicole Garrett, Christine Wellner
DEPARTMENT/COLLEGE: Physical Therapy

PROJECT TITLE: EMG Analysis of Trunk Musculature Following a 9 Hole Round of Golf: The
Fatigue Factor

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on April 7, 1999, and the following action was taken:

☑ Project approved. EXPEDITED REVIEW NO. 4
Next scheduled review is on April 2000

☐ Project approved. EXEMPT CATEGORY NO. ____________ No periodic review scheduled unless so stated in the Remarks Section.

☐ Project approved PENDING receipt of corrections/additions. These corrections/additions should be submitted to ORPD for review and approval. This study may not be started until final IRB approval has been received. (See Remarks Section for further information.)

☐ Project approval deferred. This study may not be started until final IRB approval has been received. (See Remarks Section for further information.)

☐ Project denied. (See Remarks Section for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature.

cc: David Relling, Adviser
Dean, Medical School  
Signature of Designated IRB Member  
UND's Institutional Review Board  
Date  

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency; a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

(1/98)
Paired T-Test of Left Oblique for all subjects and swings

Paired Samples Test

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<th>Paired Differences</th>
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<th>Std. Error Mean</th>
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<th>df</th>
<th>Sig. (2-tailed)</th>
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Paired T-Test of Right Oblique for all subjects and swings

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Paired T-Test of Left Gluteal for all subjects and swings

Paired Samples Test

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Paired T-Test of Right Gluteal for all subjects and swings

Paired Samples Test

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Paired T-Test for the Left Erector for all subjects and swings

**Paired Samples Test**

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Paired T-Test for Right Erector for all subjects and swings

**Paired Samples Test**

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Paired T-Test of Subject #1 for Pre-Round and Post-Round Median Frequency

Paired Samples Test

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<th>Paired Differences</th>
<th>Mean</th>
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<th>Std. Error Mean</th>
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Paired T-Test of Subject #2 for Pre-Round and Post-Round Median Frequency

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<th>Sig. (2-tailed)</th>
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Paired T-Test of Subject #3 for Pre-Round and Post-Round Median Frequency

**Paired Samples Test**

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<th>Sig. (2-tailed)</th>
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Paired T-Test of Subject #4 for Pre-Round and Post-Round Median Frequency

**Paired Samples Test**

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Paired T-Test of Pre-Round and Post-Round Median Frequency of all subjects combined

Paired Samples Test

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REFERENCES
