2000

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

Christine Wellner
University of North Dakota

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

by

Christine Wellner
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 Christine Wellner 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.

[Signatures]

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

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

Department Physical Therapy

Degree Master of Physical Therapy

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Signature

Date 1/13/99
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ACKNOWLEDGEMENTS

I would first like to thank Mr. Dave Reiling for all the time and effort he put in to helping the four of us with this study. His patience was invaluable and this study never would have been completed without his hard work. I would also like to thank Michelle, Katie and Nicole. I can’t think of 3 better partners to work with, or laugh with about our frustrations. My fellow classmates must also be thanked because without them PT school would not have been so memorable. Finally, my parents for giving me love and support for the past 22 years.
ABSTRACT

The purpose of this study was to determine the fatigue component in trunk musculature following a simulated 9 hole round of golf by analyzing the EMG output of the erector spinae, gluteus maximus and abdominal oblique muscles during the golf swing.

Four males, ages 22-26 performed 5 EMG monitored golf swings with a driver prior to and following a simulated 9 hole round of golf. The data was subjected to analysis by the Fast Fourier Transformation to determine median frequency.

The results show that a significant shift in median frequency occurred, signifying muscle fatigue, in 2 of the 4 subjects when all muscles were analyzed collectively. When individual muscles were analyzed, each muscle experienced a significant shift in median frequency except the left abdominal oblique. The swing times for each subject were also analyzed and compared. The 2 subjects who fatigued demonstrated faster swing times suggesting a possible relationship between speed of the golf swing with resulting increased muscle force output, and increased muscle fatigue. This study provides initial support to the theory of muscle fatigue as a possible contributor to faulty swing mechanics associated with golfing and low back pain. These initial results provide credibility for establishing training and conditioning programs targeting the muscles shown to fatigue. These programs can be developed to increase muscle endurance and decrease the likelihood of faulty swing mechanics and injury.
CHAPTER I
INTRODUCTION

The sport of golf has become very popular in the United States and all over the world. There are nearly 25 million golfers in the U.S. alone and it is played by up to 10-20% of the adult population in many countries.\(^1\) With the increased popularity of the sport, golf-related injuries are more common. The most common complaint of male PGA golfers is low back pain and it is also the most common golf-related injury among amateur golfers.\(^2\) Little research has been performed to find the factors relating to the cause of low back injuries in golfers.

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. It is thought that trunk muscle fatigue can lead to improper body mechanics and result in possible injury. However, relatively little research has been done to identify if fatigue actually occurs in trunk musculature during a round of golf.

Purpose

The purpose of this study is to determine if fatigue occurs in trunk musculature following a simulated nine hole round of golf through the EMG analysis of the golf swing. Analyzing muscle fatigue within the 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 Question

Is there a significant median frequency shift in trunk musculature after a simulated nine hole round of golf?

Null Hypothesis

There is no significant median frequency shift in trunk musculature after a simulated nine hole round of golf.
CHAPTER II

LITERATURE REVIEW

The game of golf is considered a lifetime sport and is one that many people enjoy throughout their younger and elder years. Even though the sport is not an aerobically demanding one, it does require significant skill and practice in order for one to be proficient. The combination of overuse, poor technique and increasing age of the participant are all factors in golf-related injuries.\(^2\)

In a study by Jobe and Yocum, the back was the most common site of injury in 412 amateur golfers, with overpractice cited as the most common etiological factor.\(^2\) Another survey by McCarroll reported back injuries were experienced by 1144 respondents as their most common injuries.\(^1,2\) Amateur golfers were prevented from playing an average of 5.2 weeks per year because of chronic golf-related injuries. These injuries were due to excessive play/practice or poor swing mechanics in the majority of cases. Players with a low handicap (1 to 9) or greater than 50 years of age showed a higher prevalence of injury. Recreational and professional golfers both sustain golf related back injuries, but technical deficiencies are more often the cause in amateur golfers while injuries in professionals result from overuse.\(^1\)

Amateur golfers, especially less skilled players, often do not have sufficient trunk rotation to hit a long ball secondary to decreased joint flexibility or existing dorsolumbar
disease. When these golfers play a longer and narrower course their swings need to be stronger and more precise. Increased swing performance in these players will only be achieved through dorsolumbar and abdominal musculature overload, which can lead to muscular fatigue, muscular compensation and ultimately injuries.

The period of the game in which most injuries occur is during the golf swing. The swing requires the greatest demand from all involved musculoskeletal components from a biomechanical perspective. The modern golf swing is exemplified by a tightly coiled body which is required to store a maximum amount of power for club head acceleration. It also consists of a large shoulder turn to increase torque in the back and shoulders. The follow-through ends with the golfer in a “reversed C” position with a hyperextended back. This swing technique is suspected of being a major cause of injuries, which most likely develop secondary to the rotation of the lumbar spine at the top of the back swing and the uncoiling and hyperextension of the body through the downswing and follow-through. The golf swing will be repeated approximately 25-30 times for the average amateur golfer during a 9-hole round. Musculoskeletal injuries can be caused by excess tension, twisting of the tissues or the stress of the actual physical impact when the ball is hit.

The golf swing is an asymmetrical muscular activity which can be divided into four components: set-up, back swing, forward swing through to impact and follow-through. In the first phase, a golfer’s ideal stance would include an equal weight distribution on feet which are shoulder width apart, slight anterior trunk flexion at the
hips while maintaining a straight back. A spine that is straight will allow easier trunk rotation. Arms and shoulders should also be extended and relaxed, not overextended and tense.¹

During the back swing of a right handed golfer, rotation to the right occurs around the spinal vertical axis of the upper limbs, hips and knees to raise the golf club to its highest point.¹ The trunk musculature activity is relatively low as measured by EMG during this take away phase.⁴ The most activity seen is in the trailing erector spinae muscle (left) and both oblique muscles. This phase is the least strenuous on the dorsolumbar region. Back injuries that may occur during this phase are typically a result of abnormal muscular tension during the back swing because of trunk flexion at the lumbar spine instead of at the hips.

The next phase of the golf swing is the forward swing. This phase begins with a weight shift from the left foot to the right as the knees, hips and trunk begin to rotate to the left side.¹ Watkins et al, broke down the forward swing into two phases for the purpose of their EMG study: forward swing which represents the interval from the completion of the take-away phase until the golf club is parallel to the ground and the accelerating phase which is the interval from the previous phase until impact.⁴ During early forward swing the gluteus maximus, especially the trailing right side, was shown to have high activity. This indicates the importance of the hip stabilizers while the center of mass begins to shift towards the left during the beginning of club acceleration. During the acceleration phase all trunk muscles (bilateral obliques, gluteus maximus and erector
spineae) are relatively active as they are all important in generating maximal power to drive the ball. The left gluteus maximus has higher activity than the right in this late forward swing phase suggesting the importance of stabilization over power generated by the right side. During the forward swing the body begins to go through a "controlled fall" in which gravity and rotational forces are resisted to maintain body position. The counteraction of gravity is maintained by the erector spineae, more by the right because the golfer falls forward while rotating from the right to left. The obliques are responsible for trunk rotation during the acceleration phase. Injuries in this phase occur in the muscles of the greatest activity. Thoracic and abdominal muscular strains are closely associated with the vigorous trunk rotation that occurs on the downswing.

Table 2.1 SWING PHASE

<table>
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<tr>
<th>Take away</th>
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<th>Follow-through</th>
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<tr>
<td>Active Muscles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left erector spine</td>
<td>Obliques</td>
<td>Obliques</td>
</tr>
<tr>
<td>Bilateral obliques</td>
<td>Gluteus maximus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Erector spineae</td>
<td></td>
</tr>
<tr>
<td>Potential Injuries</td>
<td>Result from trunk</td>
<td>Thoracic and</td>
</tr>
<tr>
<td></td>
<td>flexion at spine</td>
<td>abdominal muscle</td>
</tr>
<tr>
<td></td>
<td>instead of hips</td>
<td>strains assoc. with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>trunk rotation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Posterior lumbar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>joints secondary to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>overextension on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>follow-through</td>
</tr>
</tbody>
</table>

During the follow-through portion of the golf swing the activity in the trunk muscles begins to decrease except for the obliques which remain relatively active. The
difference in activity in the right and left obliques decreases as the activity in the right oblique decreases. The activity of the oblique muscles during the follow-through suggests their role in decelerating the trunk after contact. If the deceleration of the club and body stops harshly there is an increased risk of injuries to the lumbar area, for both muscles and joints. This can also occur if the spine overly extends at follow-through. Abnormal high stresses can be placed on the lumbar vertebral bodies during the follow through, especially the posterior joints.¹

The most important aspect in achieving maximal speed during the golf swing and therefore the greatest distance covered by the ball is the rotation of the trunk during the swing. Less skilled or older players have 50% less trunk rotational capacity than younger and more skilled players. The less skilled player must compensate with greater muscular activity to hit the ball as far.¹ The high activity in the abdominal and erector spinae muscles throughout the golf swing demonstrate their importance in generating force. It also demonstrates their potential to fatigue.⁵ Unconditioned trunk muscles will fatigue easily which predisposes players to use compensatory muscle patterns as they try to “muscle” the club to achieve distance. Parnianpar et al⁵ reported in their study on the effect of fatigue on motion that fatigued muscles were slower and had longer accommodation time to changes in load. This leads to compensation from other muscle groups and abnormal loading of joints, which can lead to injury. It is known that the body’s muscles will fatigue after vigorous activities, but the role of trunk muscle fatigue in the game of golf has not been studied. If the trunk musculature fatigues significantly
after 9 holes of golf, muscle compensation may occur leading to faulty swing mechanics and increased potential of injury.

In a static muscle endurance test protocol, Ng and Richardson demonstrated decreased muscle endurance in low back pain patients, even though their strength was normal. The endurance capacity of the erector spinae musculature is related to the occurrence of low back pain. Ng and Richardson used EMG power spectral analysis to study trunk musculature endurance during the static holding test. The results were studied by examining the median frequency (MF) output. The MF has been shown to be a valid measure of the frequency shift associated with muscle fatigue. Localized muscle fatigue is shown by a shift of the frequency content towards lower values. The slope of the MF is more sensitive to type II muscle fibers than type I, thus reflecting the specificity of muscle endurance. This is true because the initial MF may correlate with the percentage of fast twitch muscle fibers in the muscle. In higher percentage MVC's more type II fibers are recruited thus a more consistent pattern of frequency changes during fatigue will result. Ng and Richardson showed that EMG power spectral analysis is a reliable method of quantifying fatigue in individual back muscles. The decrease in median frequency with fatigue may be due to a decrease in muscle fiber conduction velocity and changes in synchronization of motor units.

Ng and Richardson only studied static isometric contractions. Most of our daily activities involve dynamic movements of the spine while supporting light loads. A study performed by Kankaanpaa et al showed progressive decreases in median frequency and
mean power frequency after subject performance of dynamic repetitive upper trunk
extension tests. The loads applied in their study were less than those applied in studies
which used static isometric contractions, but were just as effective in producing fatigue.
When a muscle fatigues, there is a drop in force, a slowing of relaxation, and a reduction
in the rate that the muscle fibers can shorten. A fatigued fiber takes longer to redevelop
force and the cross-bridges cycle at a slower rate. The decrease in MF and mean power
frequency could also be due to changes in the metabolic profile of the muscle, including
accumulation of lactic acid and hydrogen ion concentration.

Whether or not muscular fatigue is related to golfing injuries, especially the low
back, is unknown. It first needs to be decided if the trunk muscles actually show
significant fatigue following a round of golf. This is what this study attempts to
determine.
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 NX5-RM7B, (Sunx, 1207 Maple St., West Des Moines, IA, 50265) was placed between the subjects 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
FIGURE 3.2. Electrode placement for golf swing analysis.
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 statistical analysis across subjects for particular trials.\textsuperscript{11}

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>
</thead>
<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>
</tbody>
</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 \( p=0.05 \) 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.
FIGURE 3.2. Ensemble average pre-round golf swing.
FIGURE 3.3. Ensemble average post-round golf swing.
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.
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 173.75lbs. and average height 72in. 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=.008), 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 
\( p_2 = .002, p_3 < .001 \). Subjects 1 and 4 showed no significant shift in MF with a paired t-
test \( (p_1 = .051, p_4 = .073) \) (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 3.938s, 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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Table 4.2: Scheffe’s Post Hoc Analysis of Swing Time Among Subjects

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<tr>
<th>Subject</th>
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*The mean difference is significant at the .05 level
EMG analysis of muscle fatigue is defined as a shift in median frequency towards a lesser value. A significant shift in median frequency occurred among the six muscles grouped together when all four subjects were looked at collectively. When each subject was analyzed individually, only subjects 2 and 3 demonstrated a significant shift in median frequency in all six muscles grouped together.

Swing times were also analyzed among the four subjects to determine any significant difference within or between the subjects. There was no significant difference between any individual subject's swing time pre-round and post-round. The subjects with the fastest mean swing time were #2 and #3. A person may swing faster if he is trying to "muscle" the club in order to generate greater club speed and thus greater distance. A golf swing of a more skilled player consists of greater trunk rotation as the golfer "coils" during the back swing. The swing will also be slower secondary to this greater trunk rotation and because the more skilled golfer will use more momentum from the uncoiling action to generate more power and greater distance.

On average, golfers #2 and #3 had greater EMG output from all trunk musculature than golfer #1 during the pre-contact phase of the golf swing. This could elicit a greater force output and could explain the significant shift in median frequency that occurred with these subjects. It could also be explained by the relation of muscle fatigue and
muscle length. In a study conducted by Doud and Walsh, fatigue was produced at all muscle lengths of the biceps brachii while performing non-isometric contractions. However, there was a greater reduction in median frequency at the shortest muscle length compared to the longest. As players try to muscle the club through the swing they may actively contract the trunk musculature more and achieve a shortened muscle length sooner. This increased time in a shortened position may cause a median frequency shift to lesser values in these muscles.

When analyzing each individual muscle, all the tested muscles except the left abdominal oblique demonstrated a significant shift in median frequency to a lesser value. According to Pink et al the left abdominal oblique shows less activity throughout the forward swing to late follow through than the right abdominal oblique. This decreased output by the left oblique may represent minimal activation and force when compared to the right oblique. Therefore the left oblique may be less likely to fatigue. The lack of a significant shift in median frequency by the left oblique could also be explained by the large amounts of overflow activity from underlying and neighboring muscle groups. The signal from the obliques cannot be discerned as coming from the internal or external group because of the use of surface electrodes. Electrodes placed over the left obliques may have been positioned in such a manner that would receive more activity from the external oblique rather than the internal during the forward swing and follow-through phase of the golf swing.
Study Limitations

The first and foremost limitation of this study was the number of subjects. More subjects would have provided more concrete results and conclusions. Another limitation was that the rest period following the simulated round of golf was not equal for each subject. Each subject did rest approximately 5 minutes before taking 5 post-round swings but some unforeseen complications were experienced with certain subjects in connecting them to the EMG equipment. A greater rest period may have allowed the trunk musculature to recover from the simulated round of golf. Also, our study's round of golf only took 20-30 minutes where a real round of golf takes 90-120 minutes. Conclusions made about muscle fatigue from our study may not correlate to fatigue experienced by trunk musculature during an actual round of golf. During an actual round, the golfer may have ample time to fully recover between swings. Our study also did not include the aerobic component of walking which may fatigue musculature more. Recommendations for future studies include more accuracy in determining and allowing rest periods for the subjects. It also may be helpful for a simulated round of golf to resemble more closely an actual round of golf. This would allow greater ease in relating the results from the studies to real life. This study also did not control the swing times among subjects. Many studies investigating muscle fatigue in dynamic contractions used isokinetic equipment in order to control the speed of movement and muscle contraction. A better relationship between swing time and muscle fatigue may be demonstrated if swing velocities were controlled among each subject and comparing the results from specific swing velocities.
Clinical Implications

A common site of injury among amateur and professional golfers is the low back.\textsuperscript{1,2} Many amateur players will overload their dorsolumbar and abdominal musculature in order to increase power generated from the swing.\textsuperscript{1} This increased muscle activity may lead to early fatigue and injury resulting from muscle compensation patterns. Fatigue does occur in trunk musculature during repetitive dynamic activities.\textsuperscript{9} Increasing strength and flexibility of trunk muscles may decrease the fatigue experienced by an average golfer during a nine hole round of golf. The increased strength will allow muscles greater endurance and ability to maintain proper swing mechanics. Increasing flexibility of the spine may increase trunk rotation during a golf swing eliminating the need for a harder, more powerful swing to achieve distance.
CHAPTER VI

CONCLUSION

The purpose of this study was to determine if muscle fatigue, as measured by a shift in median frequency, occurs in the trunk musculature following a nine hole round of golf among amateur golfers. This data could then help provide training protocols for golfers in order to prevent or rehabilitate low back injuries. The results showed a significant shift in median frequency for all six muscles grouped together in 2 of the 4 golfers. These 2 golfers also had fast swing times when compared to the 2 other subjects suggesting a possible relationship between faster swing times and increased force output by trunk muscles during the golf swing. When looking at each individual muscle among the 4 subjects grouped together all muscles showed a significant shift in median frequency except for the left oblique.

Limitations to this study included the small sample size, the inconsistent amount of rest experienced by each subject, the differences between our simulated round of golf and a real round of golf and inability to control or normalize swing times between subjects. In future studies data could be collected before and after an actual golf game to make the results more comparable to actual fatigue experienced by trunk musculature. Discovering if muscles fatigue during a real round may assist in developing specific training activities and exercises for prevention of golf related injuries in the future.
APPENDIX A
EXPEDITED REVIEW REQUESTED UNDER ITEM 3 (NUMBER[S]) OF HHS REGULATIONS

EXEMPT REVIEW REQUESTED UNDER ITEM _____ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL
INVESTIGATOR: Dave Reiling, Michelle Ballan, Katie Glessing, 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

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):

- NEW PROJECT
- CONTINUATION
- RENEWAL
- THESIS RESEARCH
- STUDENT RESEARCH PROJECT
- CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSEMINATION/THESIS ADVISER, OR STUDENT ADVISER: David Reiling, 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
- UNO 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 ____________________

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 to 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 5 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 psycho-logical, 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 Relling 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.
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 4-8-99 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 4-8-99
UND's Institutional Review Board

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)
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
Paired T-Test of Left Oblique for all subjects and swings

Paired Samples Test

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

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

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

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

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<td>11</td>
<td>.000</td>
</tr>
</tbody>
</table>

### Paired T-Test of Subject #4 for Pre-Round and Post-Round Median Frequency

**Paired Samples Test**

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td>7.3888</td>
<td>12.8960</td>
<td>3.7227</td>
<td>1.985</td>
<td>11</td>
<td>.073</td>
</tr>
</tbody>
</table>
Paired T-Test of Pre-Round and Post-Round Median Frequency of all subjects combined

Paired Samples Test

<table>
<thead>
<tr>
<th>Pair 1</th>
<th>FREQ1 - FREQ2</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>12.1829</td>
<td>13.8555</td>
<td>1.9999</td>
<td>6.092</td>
<td>47</td>
<td>.000</td>
</tr>
</tbody>
</table>
REFERENCES


