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

Michelle L. Ballan

University of North Dakota

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

by

Michelle L. Ballan
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 Michelle L. Ballan 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.

David Kelling
(Faculty Preceptor)

Peggy Mohr
(Graduate School Advisor)

Thomas Mon
(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  12/14/99

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ACKNOWLEDGEMENTS

I want to start by thanking Mr. Dave Relling for all his help and understanding throughout this whole process. Without his knowledge and expertise this study would not have been possible. A big hand goes out to Christine Wellner, Katie Glessing and Nicole Garrett for being my partners and supporters. It made it so much more enjoyable to complete this study with friends I respect and care for. It also made it a little easier being able to laugh at ourselves in those times of frustration.

My parents and sisters have been a vital part of my success in life. Their support, advice, and understanding have helped guide me down a road in life I have been able to enjoy. I have also gained an extended family in all the amazing friends I have been blessed with over the years. They are people with whom I am constantly learning, laughing, and growing. I feel very lucky and thankful for all the gifts I have been given throughout my life.
ABSTRACT

The purpose of this study is 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 obliques 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. The results will attempt to provide information on 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

Golf is a game once thought of for white upper-class males. Today it is a sport played by up to 10% to 20% of the overall adult population in countries worldwide. People enjoy the game for its exercise benefits found in walking up to 10km along with the relaxation of being out in nature.¹

An increase in popularity has also brought an increase in injury. It is estimated that 10% to 33% of professional players are touring injured at any one time.² McCarroll² reported 45% of amateurs and 54% of professionals would classify their injury as chronic, causing them to lose 5 weeks of playing time a year. Excluding freak accidents, overuse injuries developed over a long period of time are the most common cause of such golf injuries.²

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 the 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 Questions

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

Null Hypotheses

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

LITERATURE REVIEW

Previous studies and articles have covered topics of muscle fatigue, EMG analysis of the golf swing, and golf injuries. Very few studies have been done on muscle fatigue as a possible precipitating factor of golf injury. This review will attempt to pull these three separate areas together demonstrating why it is essential for injury prevention to identify fatigue in the trunk musculature as a risk factor in golf.

Analysis of the Golf Swing

A golf swing is a request of the body to put itself through an unusual range of motion involving a significant rotatory torque. The modern swing utilizes a large shoulder turn with restricted hip turn. This builds torque in the back and shoulders leading to greater angular club head velocity in the downswing. The follow through is ended with the golfer in a "reverse C" position, back hyperextended, right shoulder lower than left and hands high over head. This pattern produces a more powerful yet stressful swing. Large lateral bending, shear, compression, and torsional forces have been found to be of greater impact on the lumbar spine of amateurs during the golf swing.

EMG analysis of the golf swing has been used to identify which muscles contribute to the swing, when they are active, and also help in identifying their potential for injury. The swing can be broken down into five phases: 1) take away= ball address to end of back swing, 2) forward swing= end of back swing until horizontal club,
3) acceleration= horizontal club to ball contact, 4) early follow through= ball contact to horizontal club, and 5) late follow through= horizontal club to end of motion.\textsuperscript{9,10} Watkins et al\textsuperscript{10} utilized the phases noted above and tested the following trunk musculature bilaterally for EMG analysis of the golf swing: erector spinae, upper gluteus maximus, abdominal obliques, and upper and lower rectus abdominis (See Table 2.1)

**Table 2.1: The 5 phases of the golf swing and muscle activity in a right-handed golfer.**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Take Away Activity</th>
<th>Forward Swing Activity</th>
<th>Acceleration Activity</th>
<th>Early Follow Through Activity</th>
<th>Late Follow Through Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Muscle Activity</strong></td>
<td>bilateral abdominal obliques, right erector spinae</td>
<td>right gluteus maximus, erector spinae, abdominal obliques</td>
<td>all muscles, especially right external oblique</td>
<td>overall decrease in all muscles</td>
<td>left abdominal oblique</td>
</tr>
</tbody>
</table>

During the take away phase all muscles tested produced their lowest amount of activity.\textsuperscript{9,10} The trailing erector spinae and bilateral abdominal oblique muscles produced the highest EMG activity in this phase.\textsuperscript{6,9,10} The highest activity during the forward swing was shown by the trailing right gluteus maximus. The erector spinae and abdominal oblique muscles were also very active. These findings are consistent with the need for hip stabilization as the golfer moves into the acceleration phase.\textsuperscript{9,10} In the acceleration phase all trunk musculature is relatively active. The right external oblique fires maximally to produce maximum power at the point of ball contact.\textsuperscript{2,9,10} During the forward swing peak muscle forces occur in unison with peak spinal loading of shear, lateral bending, and torsional forces. The right and left paraspinals demonstrate their spine stabilizing action during the swing by firing nearly simultaneously throughout the phase.\textsuperscript{2}
Early follow through shows an overall decrease in the activity of the trunk musculature. In the late follow through phase total activity continues to decrease with the exception of the left abdominal oblique demonstrating its importance in decelerating the trunk at the end of the swing.\textsuperscript{9,10}

During all phases of the swing, the abdominal and erector spinae muscles remained consistently active. This shows not only their importance in the golf swing but also their potential to fatigue.\textsuperscript{9} Muscle activity overall in amateurs during the golf swing can reach 90\%\ of their maximum voluntary contraction (MVC) compared to the 80\% of MVC found in professionals. The poor swing mechanics in amateurs results in larger spinal loads and thus produces these higher myoelectric activities.\textsuperscript{2,8} These fatigued muscles are slower and take longer to accommodate to changes in load. This leads to compensation by secondary muscle groups and abnormal loading of joints and muscles, resulting in injury.\textsuperscript{9}

Golf Injury

Golf is a game requiring great skill that comes as a result of practice. The prolonged practice necessary to attain such skills may be what leads to many of the musculoskeletal injuries sustained by players. In both professional and amateur golfers, too much play or practice was the most common cause of injury with poor swing mechanics the second most leading mechanism of injury.\textsuperscript{3}

It is reported that low back injuries are the most common area of injury in professional players and male amateur golfers.\textsuperscript{2,3} Touring professionals sustain an average of two injuries per year with competitive demands requiring continuous play
leading to overuse syndromes. In amateur golfers, two main causes of injury include technical deficiencies and excessive time spent golfing, both leading to overuse injuries.¹

Technical errors during the swing are encountered among amateur golfers and rank among the leading causes of golf injuries as mentioned above. They tend to have lower levels of physical preparation and altered mechanics compared to professionals. In order to compensate, many players attempt to reach professional performance by dorsolumbar and abdominal muscular overload. This "muscling" of the club leads to fatigue, muscular compensation and, eventually, to injury. Injuries to the musculoskeletal structures can be caused by excess tension, twisting of the tissue or the stress of the physical impact upon ball contact.¹

Injury to the low back can occur at ball address and back swing if the upper body is flexed anteriorly instead of at the hips, potentially causing vertebral hypermobility and abnormal muscular tension. A leftward spinal tilt instead of a perpendicular posture to the ground during the back swing also increases your chance of injury by putting the body in position to finish with a "reverse C" posture at the end of the follow-through. Forward swing and acceleration phases can produce abdominal muscular strain with vigorous trunk rotation. Lumbar spine injury can occur during follow through if deceleration is too brisk or the "reversed C" lordotic spinal curvature is experienced.¹

Although golf is thought of as a relaxing low risk sport one can see there is potential for injury. In rehabilitation of such injuries described above it is important to consider muscular endurance training along with strengthening activities to aid in prevention of fatigue.¹¹
Muscle Fatigue

"Muscle fatigue is a decrease in the peak tension and power output resulting in a reduced work capacity." Power, the indicator of fatigue, is a combination of force and velocity. Muscle fatigue is dependent upon three factors: 1) the person's state of fitness, 2) the muscle fiber type composition, and 3) the sport or activity that person is performing. One can also distinguish between central and peripheral fatigue. Peripheral fatigue occurs at the neuromuscular junction. The mechanism starts with the process of excitation-contraction (E-C) coupling, which involves the surface membrane, the propagation of that activation down the T-tubules, which brings the activation into the depth of the cell, the release of calcium and, finally, the activation of the contractile elements involved in the generation of force and power. The main features of fatigue are the drop in twitch tension and a slowing of the contraction and relaxation time due to a slower re-uptake of calcium by the sarcoplasmic reticulum.

The first parameter to change in muscle fatigue is relaxation rate. A decrease in force and reduction in the velocity a muscle fiber can shorten also accompany fatigue. Force must drop at least 10% before there is any change found in velocity. Peak power is normally found at 30% to 40% of maximal load. As fatigue sets in, there is a large drop in power and the power-force relationship shifts to the left. Thus in a fatigued muscle, peak power is achieved at 15% of the peak force-generating ability. It has been shown type I muscle fibers are more fatigue resistant than the fast type IIA fibers.

Proprioception is a factor known to be important in motor control, coordination and timing. In a study done on shoulder proprioception it was found that detection of motion occurred at .92° prior to exercise and increased to 1.59° following fatiguing
exercise. This effect was found statistically significant (p < .001). It can then be hypothesized that if fatigue interferes with position sense, joint function may be impaired by loss of the normal muscle coordination and injury can result.  

EMG Analysis  

Studies have looked at different ways of testing reliability of EMG analysis in detecting fatigue of the trunk musculature. The Sorenson endurance test, a static endurance test, used in conjunction with EMG power spectral analysis has proved a reliable evaluation method of fatigue performance of back muscles. The subject is placed prone and stabilized at the hips, knees and ankles by straps while keeping the upper body in a horizontal position for two minutes. Very rarely are the sustained contractions used in such studies functional for everyday life.

One’s day-to-day activities are mostly dynamic in nature and dealing with light loads. One study took this into consideration and used repeated light load dynamic testing to measure fatigue. The subjects were mechanically restricted below the third lumbar vertebrae while performing repetitive upper trunk extension. The subject’s load depended on their upper body mass, sex and age. This isoinertial extension test showed a progressive decline of median frequency (MF) and mean power frequency (MPF) in the lumbar paraspinals. Many believe that MF and MPF are the best way to measure EMG power spectral shifts. It has been well documented that the rate of decrease in spectral indices is correlated with endurance time. MPF is also more sensitive to fast twitch (type II) motor unit fatigue and a reliable way to measure performance. The individuals with chronic low back pain demonstrated decreased endurance and force production of the
lumbar paraspinal musculature. However, it is unknown if such changes are the primary or secondary cause of such pain.\textsuperscript{5}
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.

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, and 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
Figure 3.1: Electrode placement for abdominal oblique, erector spinae and gluteus maximus (Adapted from Basmaiyan and Blumenstein\textsuperscript{12}).
EMG data allowing comparison and 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>
</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 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 173.75lbs. 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) all muscles, individual subjects Pre vs Post round, 3) individual muscles, all 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.
Dependent Variable: Time

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<th>Source</th>
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<th>df</th>
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<th>F</th>
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<td>6.233E-04</td>
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<td>.970</td>
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<td>28</td>
<td>.439</td>
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Table 4.2: Scheffe’s post hoc analysis of swing time among subjects.
Dependent Variable: Time

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<tr>
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<th>Subject</th>
<th>Mean Difference</th>
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*The mean difference is significant at the .05 level
CHAPTER V
DISCUSSION

Fatigue of the trunk musculature was defined as a significant shift in median frequency of EMG data collected from the subject group. Significant fatigue of the trunk musculature following a simulated 9 hole round of golf was found in the subject group. When each muscle was looked at individually only the left abdominal oblique failed to show significant fatigue. The swing was looked at as a whole component and not broken down into the five phases discussed earlier. Pink et al\textsuperscript{9} reported the abdominal and erector spinae muscles remained consistently active throughout all the phases of the golf swing. It would seem safe to assume that this constant activity would result in fatigue and thus substantiate the results in our study.

The failure of the left abdominal oblique to show significant fatigue may be due to many factors. The researchers placed the electrodes over a point covering the internal and external abdominal obliques. This electrode placement could result in overflow from surrounding musculature or activity from the external abdominal oblique picked up less than the internal abdominal oblique on one side versus the opposite side.

The external oblique was shown to be active in all phases of the golf swing with the left external oblique maximal activity occurring during late follow through.\textsuperscript{9,10} The internal oblique was also shown to be active in all phases of the swing with the right side showing maximal activity during acceleration.\textsuperscript{2,9,10} If electrode placement targeted the
internal oblique more than the external oblique, the right obliques may show fatigue due to it’s activity during the forward swing. The left oblique may fail to show significant fatigue due to the reduction in activity of the internal oblique during follow through.

Many believe that MF and MPF are the best way to measure EMG power spectral analysis. It has been well documented that the rate of decrease in spectral indices is correlated with endurance time. MPF is also more sensitive to type II motor unit fatigue and a reliable way to measure endurance. It was proposed by Arendt-Nielsen, Gantchev and Sinkjaer that stretching a muscle causes thinning of the tissue between the electrode and muscle causing an increase in the MPF as that muscle is stretched under the electrodes. This could also cause an insignificant drop because MPF goes up with stretch and decreases with shortening of the left abdominal oblique during the golf swing.

When each subject was looked at individually for fatigue, subjects 2 and 3 showed significance. They also displayed the fastest mean swing times. To create speed in the club head on the downswing the body begins to uncoil starting at the lower body. This uncoiling comes from the energy built up by the turning of the hips and shoulders on the back swing. Technically less skilled players have up to 50% less trunk rotation than those with excellent technical skills. This larger trunk rotation seen in more skilled players may have been evident in subjects 1 and 4. Larger trunk rotation may result in a longer swing time and decreased EMG output due to momentum built up by a more efficient swing. Subjects 2 and 3 may have been at the higher end of the 40-50 stroke range set as criteria by the researchers. This may result in decreased trunk rotation by less skilled players and increased dorsolumbar and abdominal musculature activity in
order to reach increased swing performance. The increased muscle activity would lead to earlier fatigue and thus explain the difference among the subjects.

Limitations

There are many unanswered questions as to why the results came out the way they did. A larger subject group would be more appropriate if the results were to be inferred to a population. The criteria for inclusion could have been more precise. There may be a large difference in swing mechanics of a golfer who consistently shoots 40 on 9 holes and a golfer who shoots 50 on 9 holes. It has been shown that swing mechanics are related to the occurrence of fatigue in muscles.

The study was set up where there was approximately a five minute rest period between the simulated round and the post-round EMG data collection. The five minutes was an approximate time because of the inexperience of the researchers with EMG equipment use. The round we simulated was also anywhere from 30 to 45 minutes whereas a real 9 hole round is 90 to 120 minutes in length. The five minutes between our simulated round and the post-round EMG collection may have been a long enough time for muscle recovery to begin to occur. The increased time between swings in a real round of golf may be enough for recovery to occur also.

We did not take into account the aerobic component of walking which may be looked at by future researchers for its contribution to possible fatigue in trunk musculature. A study utilizing more subjects with narrower criteria for inclusion should be conducted with motion analysis and EMG to determine if swing mechanics and the amount of trunk rotation are related to the amount of fatigue shown in the trunk.
musculature. It would also be ideal for data to be collected after an actual 9 hole round of
golf so that the results could be better applied to the golf community.
CHAPTER VI
CONCLUSION

This study showed that significant fatigue was present in the trunk musculature following a simulated 9 hole round of golf. When each muscle was looked at individually, all trunk muscles examined showed significant fatigue with the exception of the left abdominal oblique. Each subject was looked at individually with subjects 2 and 3 showing significant fatigue along with the fastest mean swing times.

Endurance and flexibility programs need to be looked at as important measures to aid in reduction of fatigue in trunk musculature. Skilled golfers show greater trunk flexibility and display a decreased amount of muscle activity overall as compared to unskilled golfers. The increased flexibility may allow for better swing mechanics and the use of momentum rather than muscle strength to attain speed of the club head. Muscle fatigue has been shown to lead to faulty swing mechanics that often results in injury. The information collected in this study can be used to develop prevention and rehabilitation programs. Trunk strengthening programs are present and recommended in the golf community today. The absolute cause or primary cause of injury has yet to be identified. One may question if the cause of injury is unknown, how can a prevention program be appropriately implemented?

Further research should be done to look at comparing those golfers utilizing exercise programs and those who do not. Do exercise and training programs really result
injury prevention or does injury occur regardless due to the repetitive stresses placed on the spine throughout the swing? A study could also look at the swing in regard to the amount of muscle activity at different degrees of trunk rotation. Isokinetic testing of the golf swing could be done to identify if different swing speeds result in differing degrees of fatigue in the trunk musculature. With the development of appropriate prevention programs proper swing mechanics may be displayed throughout a round of golf with greater ease and thus decrease the amount of muscle compensation patterns and possible injury.
APPENDIX A
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 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 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.
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

NAME: Dave Relling, Michelle Ballan, Katie Glessing, Nicole Garrett, Christine Wellner

DEPARTMENT/COLLEGE: Physical Therapy

REVIEW BOARD:
University of North Dakota Institutional Review Board

PROJECT NUMBER: IRB-9904-205

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
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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### 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

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

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Paired T-Test for 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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Paired Samples Test

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REFERENCES


