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Electromyographic and Motion Analysis of the Trunk and Pelvis during the Golf Swing

Torin Berge
University of North Dakota

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ELECTROMYOGRAPHIC AND MOTION ANALYSIS OF THE TRUNK AND PELVIS DURING THE GOLF SWING

by

Torin Berge
Bachelor of Science in Physical Therapy
University of North Dakota, 1998

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
1999
This Independent Study, submitted by Torin D. Berge in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
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Date 12-16-98
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ABSTRACT

The purpose of this study was to analyze and compare the trunk muscle activity and range of motion in male and female golfers. With the use of surface electrode electromyography and motion analysis we evaluated three male and three female Division II collegiate golfers. The EMG activity of the erector spinae, gluteus maximus and external oblique muscles was measured bilaterally during the golf swing. The main emphasis in analyzing the trunk range of motion was comparing relative pelvis to shoulder rotation (X-factor) throughout the swing. The researchers found definitive differences in the patterns of muscle activity and range of motion between male and female golfers. The male golfers muscle activity occurred slightly earlier in the swing than the female golfers. The males also had a greater X-factor by about 10° and a faster swing by ~.20 seconds than the females. These findings demonstrate the importance of the trunk and pelvic muscles in stabilizing and initiating motion in the spine during the golf swing. This study, along with previous studies, provides the framework for developing rehabilitation and training programs for the golfer stressing stability, strength, and mobility of the trunk.
CHAPTER 1
INTRODUCTION/LITERATURE REVIEW

The sport of golf is seen by many, including those who play the sport, as a non-strenuous leisure activity that requires technique more than it requires power or stresses the body physically. However, research has shown that the golf swing is a very taxing and physically demanding activity that does transfer tremendous loads onto the body. These stresses are large enough that they can potentially cause injury to a golfer’s back, shoulder, elbow, wrist, and almost every other part of the body. When these stresses are repeated numerous times, as is the case in a round of golf, the potential for injury is further increased. Since the sport of golf is seen as so non-strenuous emphasis is not placed on training and conditioning programs for the golfer. However, golfers who have inadequately trained bodies with or without poor mechanics put themselves at a greater risk for injury. Thus, to prevent injury, golfers of all levels need to have a training regime to strengthen, stretch, and prepare their bodies for the stresses of a day on the golf course.

Purpose of the Study

The purpose of this study is to examine the trunk ROM, muscle activity, and subsequent power of the swing measured in club-head speed (i.e. speed of the club head at impact with the ball) in collegiate male and female golfers. This data will be used to develop a specific low-back training regime to prevent injury without sacrificing power.
We also hope to determine if a difference exists in the mechanics of the golf swing between the male and female collegiate golfer.

Significance of the Study

The theory of specificity of exercise states that by training the elements directly involved in an activity we can get the most desired results from our training program. In order to develop an effective training program for golfers we need to examine the biomechanics, range of motion (ROM), and muscle activity during the golf swing itself.

Research Questions

Through this study we hope to answer a few questions about the golf swing in collegiate-level players: 1) Is there a difference in EMG activity of the trunk and hip muscles between men and women during the different phases of the golf swing? 2) Is there a difference in trunk range of motion (ROM) between men and women during the golf swing? 3) Do ROM and EMG activity have an effect on club-head speed generated by men as compared to women?

Hypotheses

Our null hypotheses state that: 1) There is no significant difference in trunk EMG activity between men and women during the phases of the golf swing. 2) There is no significant difference in trunk ROM between men and women during the golf swing. 3) There is no significant difference between men and women in the effect EMG activity and ROM have on club-head speed.

Golf Participation

The sport of golf is quickly becoming a favorite activity for many Americans of all ages and abilities. According to a recent survey by the National Golf Foundation, 26.5
million golfers over the age of 12 played at least one round of golf in 1997. That was a dramatic increase of over seven percent from 1996. In addition, the number of junior golfers (age 12-17) who played in 1997 rose 33.8% over 1996, and the number of beginners who played rose 51.2% over the same period. Another source stated that in 1995 approximately 25 million people played over 500 million rounds of golf. They also stated that the percent of the American population that plays golf rose from 8.1% in 1980 to 13.5% in 1990 and has continued to rise.

Prevalence of Injury

While the number of golfers, and especially the number of beginner golfers, continues to increase, so does the number of golf-related injuries. It has been estimated that 10-33% of the touring professionals are playing injured at one time and that approximately 50% of them will develop chronic problems. This growing concern over injuries has lead to the formation of a fitness center that follows the Professional Golfers Association (PGA) and Ladies Professional Golfers Association (LPGA) Tour to every tournament, and is staffed by certified athletic trainers and Physical Therapists.

The most commonly injured area of the body from the golf swing is the trunk. During the 1990 Professional Golf (PGA) Tour season, 59% of all injuries were to the trunk. In a review of over 1400 letters sent to the nationally publicized magazine *Golf Digest* about golf injuries, over half of them were concerning the low back. An often sited study by McCarroll and Gioe shows the prevalence of golf injuries in professional and amateur golfers. According to this study the low back is the most often injured area of the body in professional men (25% of all injuries) and amateur men (36% of all injuries). The low back, however, is only the second most often injured in both
professional women (22% of all injuries) and amateur women (27% of all injuries). The most often injured body part is the left wrist in professional women (31% of all injuries) and the elbow in amateur women (36% of all injuries).\textsuperscript{6,7,8} This shows that the prevalence of low-back pain is greater in the male golfing population than in the female population. No possible causes for the differences in injury incidences between men and women were mentioned in this article.

A 1-year follow-up study done in the Netherlands of men taking up the game of golf measured the incidence of recurring and new back pain. This showed that 63\% of the men taking up the sport have had previous episodes of back pain and after 1 year of playing golf 45\% had recurrence of their back pain. Of the group that had never had back pain 8\% developed new symptoms. The conclusions of this study were that taking up golf is more likely to aggravate pre-existing back pain than cause episodes of new back pain in male golfers.\textsuperscript{9}

Mechanisms of Injury

There are several theorized causes of injuries in golfers. The golf swing requires a large amount of rotatory force in the trunk and shoulders through a large range of motion.\textsuperscript{6,7} This in itself will put a lot of stress on many areas of the body. One source states that irregardless of mechanics, the forces of the golf swing alone “predisposes the entire golfing population to muscle strains, discogenic lower back pain, spondylolysis, and facet joint arthritis.”\textsuperscript{10} Professional golfers, in order to remain competitive, spend a significant amount of time each day swinging a golf club and subjecting their bodies to the tremendous loads inherent in the golf swing. This puts them at risk for overuse injuries to their shoulder and back muscles.\textsuperscript{3,4,6}
Amateur golfers may also be at risk for these overuse injuries but are more likely to become injured from other factors. Amateur golfers often have a poor and inconsistent swing technique. This may lead to improper and differing muscle firing patterns on every swing. Which in turn may cause an increased loading to these muscles and/or supporting tissues.\textsuperscript{3,4} In addition to their unpolished swings, recreational golfers also play less often than professional golfers, often with improper warm-up. Lack of play may lead to injuries because these golfers lack the strength, coordination and flexibility necessary to perform the golf swing correctly.\textsuperscript{10} A proper pre-round warm-up is vital to injury prevention because, as in any other sport, stressing muscles that aren’t prepared to work predisposes those muscles to injury.

Many golfers also neglect the importance of aerobic conditioning and strengthening the muscles used during the golf swing. It has been shown that the abdominal and low back (erector spinae) muscles remain active throughout the entire golf swing. The more active a muscle is, the more fatigued that muscle will become. Inadequately trained muscles become fatigued faster and easier than strengthened muscles. Fatigued muscles take longer to accommodate to changes in loads. This leads to compensation by other muscles as well as potential increases in loads on the joints around the muscles. Non-fatigued muscles fire synchronously which is necessary for the precise timing of the golf swing. Thus, we can say that strengthened muscles can decrease the risk of injury to both muscles and the joints around those muscles.\textsuperscript{5}

The average golf course measures about 6500-7000 yards for 18 holes not including the distances between holes. This converts to about 4 miles a round plus the
distance walked between holes and around the green. A golfer who walks this
distance carrying a bag of clubs on a summer day will definitely feel the effects of
fatigue. Even riding in a cart will require a golfer to walk a significant distance on the
golf course. The fatigue felt from walking a golf course alone may lead to reduced
coordination and strength resulting in an improperly performed golf swing.
Cardiovascular or aerobic conditioning may also help to reduce the amount of fatigue a
golfer experiences from walking on the golf course and improve the coordination of the
golf swing, which in turn reduces the risk for injury.

Swing Mechanics/Loads on the Spine
The basic mechanics of the golf swing have evolved throughout the past several
decades. With development of new equipment and a desire by those who play golf to hit
the ball farther and straighter came a new style of swing. The new “modern swing”
differs from the old “classic swing” in several distinct ways. The classic swing had a
relatively flat backswing and used a large degree of hip and shoulder turn to take the club
away from the ball. The classic swing also ended with the body in a straight vertical and
relaxed position of the golfer after the follow-through. The modern swing, on the other
hand, uses a large shoulder turn but restricts the hips from turning thus creating a large
torque force in the trunk and shoulders. This torque force is utilized during the forward
swing to accelerate the club through the ball with a larger angular velocity creating longer
shots. This technique does create significantly more power in the swing but also puts a
large stress on the tissues of the lower back. The follow-through of the modern swing
also ends in a position where the back is in an arched or extended position. Thus, injuries
occur in the back due to a twisting of the lumbar spine followed by derotation at very high speeds and then hyperextension throughout the follow-through.\textsuperscript{3,4}

This new modern swing also accentuates the need for flexibility in the low back. As shown above the increased trunk rotation creates a larger swing arc, which in turn creates more club-head speed and increased distance of the shot. However, if the trunk is unable to rotate as far as necessary, muscle substitution patterns are used to accelerate the club-head, which in turn puts these muscles and the other tissues of the low back at greater risk for injury.\textsuperscript{5}

Four different forces on the lower back have been measured during the golf swing.\textsuperscript{3,4} These are lateral bending, shear forces (anterior-posterior direction), compression, and torque forces. These four forces were measured at the L\textsubscript{3-4} level. The measured shear force was 560 N in amateurs and 329 N in professionals. A squat lift has been measured at 690 N of force. It has been shown that in cadavers prolonged shear forces of 570 $\pm$ 190 N caused a fracture of the pars interarticularis (spondylolysis). Thus the shear component of the swing put considerable stress on the bony elements of the spine which may, over time, lead to injury. The compression loads of the golf swing were measured at 6000-7500 N. One cadaveric study produced disk prolapse with compression forces of 5448 N.\textsuperscript{11} However, the speed at which the golf swing occurs limits this extreme force to a fraction of a second and this protects the disk. Although, over time this load may eventually cause injury to fatigued, aged, or already weakened tissues in the back. The torque loads were measured at 85.3 Nm in the amateur and 56.8 Nm in the professional. No other studies have measured torque forces in the back so
these numbers cannot be compared to other activities. Overall, these loads, when combined with the muscle forces, may predispose golfers to many back pathologies including muscle strains, disk lesions, and bony and/or joint problems. Thus a proper warm-up, strengthening, and stretching program are necessary for a golfer for the maintenance of a healthy back.

Golf EMG Studies

There have been several electromyographic (EMG) studies done on various parts of the body during the golf swing. These include analysis of the shoulder muscles, scapular muscles, hip and leg muscles and trunk muscles. All of the studies have used motion analysis cameras to break up the golf swing into five separate stages:

1. Takeaway (TA): from address to the end of the backswing
2. Forward swing (FS): from the end of the backswing to the point where the club is horizontal on the downswing.
3. Acceleration (A): from the point where the club is horizontal to ball contact.
4. Early follow-through (EFT): from ball contact to the point where the club is horizontal in the follow-through.
5. Late follow-through (LFT): from the point where the club is horizontal to the end of the motion. (Figure 1)

While these studies used motion analysis to break up the golf swing into distinct phases for analysis of the EMG data, none of them used the motion analysis to measure and compare range of motion or club-head speed to the EMG data.
The muscles studied in the shoulder studies included infraspinatus, supraspinatus, subscapularis, latissimus dorsi, pectoralis major, and the three portions of the deltoid. These studies showed there were no significant differences in shoulder muscle activity between men and women and were able to combine the data to get a larger sample size. The results of these studies showed that these muscles work together using force couples to provide some power while keeping the humeral head directly in its place. The rotators (infraspinatus and supraspinatus) were more active during the takeaway and follow-through to stabilize the gleno-humeral joint, while the larger muscles (latissimus dorsi and pectoralis) were more active from acceleration through early follow-through to provide power to the swing.\textsuperscript{12,13}

The scapular muscles were measured only in male professional golfers and included the levator scapulae, rhomboids, three portions of the trapezius, and the upper and lower serratus anterior. These muscles weren’t used to create power to the swing but were largely responsible for stabilizing the scapula so that the larger muscles of the
shoulder could efficiently accelerate the arms through impact. These muscles required
delicate timing in the firing of each muscle as manifested by very reproducible patterns in
the muscle activity. Anything that disrupts this delicate timing (i.e. fatigue, injury) sets
up these and the other muscles about the shoulder for injury.

The hip and leg muscles were measured in both male and female golfers with
handicaps under 5 and included: upper and lower gluteus maximus, gluteus medius,
adductor magnus, biceps femoris, semimembranosis, and vastus lateralis. Again, there
was no difference noted between the male and female golfers and the results were
combined. The results of this study showed that the hip and leg muscles had their peak
muscle activity (forward swing - acceleration) before the shoulder muscles do
(acceleration - early follow through). This shows us that the hips initiate the uncoiling of
the trunk at the top of the backswing, and the shoulder muscles follow this to accelerate
the arms through impact.

Golf EMG Studies—Trunk Musculature

The studies that specifically researched trunk musculature, came up with similar
results. The study by Pink et al. used surface electrodes to measure the EMG activity in
the erector spinae and abdominal oblique muscles bilaterally in 23 right handed golfers
with handicaps under 5. All measurements were compared to a maximal manual
contraction (MMT). The results showed that the erector spinae muscles were relatively
inactive during the takeaway phase with a peak activity of less that 30% MMT. The right
erector spinae had its overall peak activity during the forward swing phase with 75%
MMT, while the left erector spinae had its peak activity during the acceleration phase
with 50% MMT. Both sides then decreased steadily through follow-through with a peak
activity of 28% MMT. (Figure 2) The abdominal oblique muscles were also relatively inactive during the take-away phase with activity at 20-22% MMT. The activity then increased through acceleration peaking in the 50-60% MMT range and then also steadily decreased through the follow-through. (Figure 2)

![Graphs showing muscle activity](image)

**Figure 2:** Erector spinae and abdominal oblique activity.

Another study by Watkins et al.\(^{10}\) measured muscle activity in the abdominal obliques, gluteus maximus, erector spinae, and upper and lower rectus abdominis muscles bilaterally in 13 male professional golfers. During the take-away phase all muscles showed their lowest activity during the swing. This has been explained since the muscles are merely responsible for positioning the body for the forward swing and not needed for accelerating any body segments. During the forward swing phase all muscles had significantly higher activity with the abdominal oblique muscles reaching their peak activity and a tremendous spike in right gluteus maximus activity. This significant increase in the right gluteus maximus demonstrates the initiation of the power portion of the swing begins in the hips and progresses upward throughout the swing. The other muscles, erector spinae, rectus abdominis, and left gluteus maximus all demonstrated a
similar pattern of activity. This is a gradual increase in activity from take away through
acceleration where it reaches a peak and then a gradual decline throughout the follow-
through. All the muscles show the most activity in the forward swing and acceleration
phases when the trunk muscles are actively accelerating and derotating the body from the
top of the backswing through impact with the ball. The activity in the follow-through
phases is mainly the muscles decelerating the body.

A study by Bechler et al.\textsuperscript{15} that looked at hip muscles during the golf swing
included analysis of the upper and lower gluteus maximus muscles. Both the upper and
lower portions of the muscle showed similar patterns of activity. This study also showed
a significant spike in the right, or trail leg, gluteus maximus muscle during the forward
swing phase followed by a decrease in activity through the follow-through phase. The
left, or lead, gluteus muscle showed a fairly constant activity level from forward swing
through early follow-through and then a decrease in activity in late follow-through.

Golf Motion Analysis--Trunk

One study by McTiegue et al.\textsuperscript{16} specifically discusses the range of motion of the
lower back during the golf swing. This study however did not correlate this data with
muscle activity or EMG data. This study measured 51 PGA Tour players, 46 Senior
PGA Tour players, and 34 amateur players. They measured, among other things, hip and
torso rotation at address, at the top of the backswing and at impact. They were
comparing the amount of hip rotation with the amount of torso rotation measured at the
mid-thoracic spine, a measure of the torque built up within the low back. They termed
this measurement the “X-factor” as the lines used to measure these angles crossed to form
an “X”. The rotation at the top of the back swing is facing away from the target and is
considered closed. The rotation at the time of impact is facing the target and considered open. By definition hip rotation at address is 0. There was no significant difference in the total measurement of rotation in the professional and amateur golfers. The results are summarized in Table 1:

**Table 1: X-factor summary**

<table>
<thead>
<tr>
<th>Group</th>
<th>Torso Rotation</th>
<th>Hip Rotation</th>
<th>Difference (X-factor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of swing:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professionals</td>
<td>87°</td>
<td>55°</td>
<td>32° (closed)</td>
</tr>
<tr>
<td>Amateurs</td>
<td>87°</td>
<td>53°</td>
<td>34° (closed)</td>
</tr>
<tr>
<td>Impact:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professionals</td>
<td>26°</td>
<td>32°</td>
<td>6° (open)</td>
</tr>
<tr>
<td>Amateurs</td>
<td>27°</td>
<td>35°</td>
<td>8° (open)</td>
</tr>
</tbody>
</table>

*a. Adapted from McTeigue et al. 16*

This study also measured time from the initiation of take-away until impact. This measurement was significantly different between the amateurs and the professionals. It took the professionals on the average 1.09 seconds from take-away to impact while the amateurs took an average of 1.28 seconds. By combining these pieces of data we can see that the professional golfer’s torso rotates from 0 degrees to 87 degrees closed back to 0 degrees and then to 26 degrees open in 1.09 seconds. This subjects the body, particularly the lower back, to significant amounts of movement in a relatively short period of time.

**Injury Prevention/Rehabilitation**

So far we have looked at the biomechanics of the swing and some of the causes for injury that can occur from the sport of golf. What can we do to prevent or minimize these injuries? If golfers have adequate flexibility their body can perform the normal
swing arc which decreases the need for substitution from other muscles and decreases the risk of those other muscles from becoming injured. Adequate trunk strength increases the stability of the lower back which allows the extreme range of motion necessary for the golf swing to be achieved without compromising stability. Also, the stronger the muscles are the less fatigued they become, thus the muscles can fire synchronously which minimizes the risk for muscular injury. Other important things that can be done to prevent injury include patient education in regards to strength, flexibility, and proper warm-up as well as encouraging the golfer to seek instruction to improve swing mechanics. One source gave an example of an appropriate 10-minute warm-up prior to playing a round of golf. This includes stretching, practice shots on the driving range, putting, and then practice swings immediately before teeing off.

We hope this study will add to the body of information regarding the mechanics of the golf swing by comparing the EMG activity in the trunk muscles with trunk rotation data and club head speed (a measure of power) in order to more specifically design a conditioning or rehabilitative program for the golfer.
CHAPTER 2

METHODOLOGY

Prior to initiation of this study, the project was reviewed and approved by the University of North Dakota Institutional Review Board (Appendix A). The methods used in this study are detailed below.

Subjects

Six volunteer subjects (three male and three female) participated in this study. All subjects met specific limitations set by the researchers which included: no previous or current back injuries, 18 years of age or older, not pregnant, and currently a member of a NCAA Division II golf program. The purpose and procedures of the study were explained to each subject prior to their signing a statement of informed consent. EMG and motion analysis data were collected from each subject.

Instrumentation

Surface electrodes were placed on the subjects to record EMG activity. The EMG activity was transmitted by a Noraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ 85254) and collected by the Noraxon Telemyo8 receiver. The Peak Motus5 system (Peak Performance, Englewood, CO) was used to store and analyze the EMG data. Three high-speed video cameras (Peak Performance High-Speed Video System, Englewood, CO, and Pulnix TM-640 Sequential Scanning
Camera, Sunnyvale, CA) operating at 60 frames per second were set up to tape the
golfers' swings. Three hi-fi videocassette recorders (JVC BR-S3784 Hi-Fi VCR)
recorded the swings onto super VHS tape. The Peak Calibration Frame (Peak
Performance, Englewood, CO) was used to calibrate the cameras before the subjects were
run for the study. According to research, the Peak Motus system has been found to be
both reliable and valid\textsuperscript{17,18}, the Noraxon EMG measurement system has been found to be
"reasonably" reliable in determining parameters of neuromuscular performance.\textsuperscript{19}

Procedure

Subjects were tested at the University of North Dakota Physical Therapy
Department in Grand Forks, ND. Cameras were set up at approximate 45-degree angles
from the right shoulder anteriorly and from the right and left shoulder posteriorly, at a
height of approximately eight feet. (Figure 3) Lights were attached to each of the
cameras to illuminate the golfer.

![Camera Set-up](image)

\textbf{Figure 3: Camera Set-up}
The 25 point Peak Calibration Frame was used to calibrate the three-dimensional area in which the golfer would be swinging the golf club for motion analysis. EMG equipment was tested by the researchers for appropriate signal transmission and reception prior to placement on the subjects.

The procedure and the purpose of the study were first explained to the subjects, after which they were asked to sign a statement of informed consent. Female subjects were asked to wear athletic shorts and sports bras; males were asked only to wear athletic shorts. Subjects were shaved as needed and the skin was cleaned with rubbing alcohol prior to electrode placement in order to maximize signal conduction. Pre-gelled, silver-silver chloride, self-adhesive, surface electrodes (Multi Bio-Sensors, El Paso, TX 79913) were used. The electrodes were placed bilaterally according to the following landmarks: five centimeters superior to the ASIS for the abdominal oblique muscles, horizontally aligned with the L3-4 interspace and four centimeters lateral to midline for the erector spinae muscles, and at the midpoint of a line running from the inferior lateral angle of the sacrum to the greater trochanter for the gluteus maximus muscle. (Figure 4) A ground electrode was placed on the ASIS. Leads from the electrodes were connected to a transmitter, which was attached to each subject's leg in a manner that would not impede the golf swing.

Subjects were asked to perform maximal manual muscle tests (MMT) bilaterally. The muscle test for the abdominal oblique was performed supine with legs flexed approximately 5-10° at the hips with resistance provided on the distal lower extremity for 5 seconds. To test the erector spinae, subjects were positioned in prone and instructed to raise their trunk off the plinth, holding an isometric contraction against resistance for 5
18 seconds. The gluteus maximus test was also performed in prone; subjects were asked to contract their gluteal muscles for 5 seconds. Each subject's EMG activity for each muscle tested was recorded as the subject's 100% MMT.

**Figure 4:** Electrode placements for gluteus maximus, external oblique, and erector spinae (Adapted from Basmaijian et al. 20)

Reflective markers were attached to the subjects using double-sided tape to the following landmarks bilaterally: lateral malleolus, lateral femoral epicondyle, top of the iliac crest, acromion process, lateral humeral epicondyle, and radial styloid process. Additional markers were attached to spinous processes at the T12 and S1 level. Reflective tape was also attached to the subjects club and to the tee for a total of 16 points. (Figure 5)
Subjects were allowed to warm up as desired to stretch their muscles and to get accustomed to swinging with the EMG equipment and reflective markers in place. Subjects stood on an astro-turf mat with bare feet and were asked to hit a rubber tee when swinging (no ball was used). A microphone was placed near the tee in order to trigger an event marker when the club struck the tee; this was done for the purpose of determining club head impact. Each subject used his or her own driver and performed three or four "normal" swings. The EMG activity was recorded simultaneously as the swings were videotaped.

Figure 5: Set-up and reflective marker placements

Data Analysis

Swings from the three female and three male subjects were trial averaged using the PEAK Motus system trial averaging software at a sampling rate of 0.5%. This was
done to produce an "ensemble average" incorporating all of the subjects. This data was separated into male and female groups. The trial averaged EMG activity of the six total muscles and trial averaged shoulder to hip angle (X-factor) was used for qualitative analysis.

The EMG activity was divided into the five phases of the golf swing described earlier using set event markers. Qualitative analysis of the "ensemble average" muscle activity was operationally defined as one of three levels:

1. **No or minimal EMG activity**: muscle activity less than 33% of the maximal EMG activity within that muscle during the golf swing.
2. **Moderate activity**: muscle activity between 33 and 66.5% of the maximal EMG activity for that muscle during the golf swing.
3. **Maximal activity**: muscle activity greater than or equal to 66.6% of the maximal EMG activity within that muscle during the golf swing.

Each muscle had to be active for 3% of the swing to be classified at a level of minimal, moderate or maximal EMG activity. In order for the classification to be changed to a higher or lower level a 3% duration at the different activity level was required.

This method of using the ensemble average to analyze EMG data has been shown to have several advantages over other methods of analysis. According to Yang and Winter\textsuperscript{21} the normalization method of using a peak or mean ensemble average for EMG activity significantly reduces intersubject variability in normal subjects and thus improves the sensitivity of surface EMG. In previous research, Yang and Winter also stated that the method of normalizing EMG data using 100% of a maximal voluntary contraction is
not a very reliable method. This research, in addition to the number of subjects we ran led us to conclude that qualitative analysis using an ensemble averaged EMG activity and ROM was the most desirable way to analyze this data.
CHAPTER 3

RESULTS

During data analysis the EMG activity of the trunk muscles for the men and the women were divided into the five phases of the swing as per specific event markers. For the women, the takeaway phase lasted the first 52.5% of the swing, the forward swing phase lasted from 52.5-66.5% of the swing, the acceleration phase lasted from 66.5-69% of the swing, early follow through lasted from 69-72% of the swing and the late follow through phase lasted from 72-100% of the swing. The men had a longer takeaway phase and a shorter late follow through phase but all other phases remained comparable in duration. The takeaway phase lasted the first 67% of the swing, the forward swing phase lasted from 67-80% of the swing, the acceleration phase lasted from 80-83% of the swing, the early follow through lasted from 83-85.5% of the swing, and late follow through lasted from 85.5% until the end of the swing. (Figure 6,7)

The EMG data was classified as minimal activity, moderate activity or maximal activity and described in terms of percentages of total swing. The data was then converted to percentages within each phase of the golf swing so that men and women could be more accurately compared.

Takeaway phase

The men’s right external oblique was minimally active during the first 39.2% of the takeaway phase, moderately active through 60%, minimally active through 73.9%,
and moderately active for the remainder of this phase. The left external oblique was active at a minimal level during the first 23.1% of this phase, moderate through 87.3%, and maximally active through the remainder of the phase. The right erector spinae produced a minimal level of activity for the first 79.1% of the phase, moderate through 97%, and maximal for the remainder. The left erector spinae was minimally active through the first 82.8% of the phase, moderate through 90.3%, maximal through 98.5%, and minimal for the remainder. The right gluteus maximus showed minimal activity through 70.1% of the phase, moderate through 84.3%, minimal through 97.8%, and moderate through the end of the phase. The left gluteus maximus had minimal activity through 37.3% of the phase, moderate through 76.1%, dropped back to minimal until 82.8% of the way through the phase, maximal through 97%, and moderate for the rest of the phase. (Figure 8)

The women’s right external oblique showed minimal activity for the first 57.6% of the phase and moderate for the remainder. The left external oblique and right and left erector spinae all produced minimal activity throughout this phase. The right gluteus maximus showed minimal activity through 92.8% and moderate for the remainder. The left gluteus maximus was minimally active through the first 71.9% of the swing and moderate for the remainder. (Figure 9)

Forward Swing

The men’s right and left external obliques showed moderate levels throughout this phase. The right erector spinae continued maximal levels of activity for the first 7.7%, dropped to moderate through 65.4%, and was minimal for the remainder. The left erector spinae was minimally active throughout. The right gluteus maximus was moderate for
the first 26.9% and minimal for the remainder. The left gluteus maximus showed moderate activity through the first 42.3% of forward swing and dropped to minimal for the remainder of the phase. (Figure 10)

The women’s right external oblique produced moderate activity throughout the forward swing phase. The left external oblique was minimally active for the first 12.5% and moderate for the remainder. The right erector spinae showed minimal activity through 16.1%, moderate through 39.3%, maximal through 85.7% of the phase, and back to a moderate level for the remainder. The left erector spinae produced minimal activity for the first 16.1% of the phase, moderate through 71.5%, and maximal for the remainder. The right gluteus maximus was moderately active through the first 23.2% of the phase, maximally through 87.5%, and moderately for the remainder. The left gluteus maximus was moderate throughout. (Figure 11)

Acceleration

The men’s right and left external obliques showed moderate activity throughout. Both erector spinae and both gluteus maximus muscles were minimally active throughout the acceleration phase. (Figure 12)

The women’s right and left external obliques were moderately active for the entire phase. The bilateral erector spinae muscles were minimally active throughout this phase. The right gluteus maximus was moderately active through the first 70% of the phase and minimal for the remainder. The left gluteus maximus was moderately active throughout. (Figure 13)
Early Follow Through

The men’s right and left external obliques were moderately active throughout. The bilateral erector spinae and gluteus muscles showed minimal activity for the duration of this phase. (Figure 14)

The women’s right external oblique was maximally active throughout this phase. The left external oblique showed moderate activity throughout. Both erector spinae muscles were minimally active during this phase. The right gluteus maximus was minimally active throughout, while the left gluteus maximus was moderately active for the entire phase. (Figure 15)

Late Follow Through

The men’s right external oblique was moderately active for the first 46.6% of late follow through, and minimally active for the remainder. The left external oblique produced moderate activity throughout. Both erector spinae and gluteus maximus muscles were minimally active throughout this phase. (Figure 16)

The women’s right external oblique remained maximally active through 32.1% of this phase, and then became moderately active for the remainder. The left external oblique was moderately active for the entire phase. The bilateral erector spinae and right gluteus maximus were minimally active throughout. The left gluteus maximus remained moderately active through 2.7% of this phase, and was then minimally active for the remainder. (Figure 17)

Peak Activity

Peak activity of the men’s right external oblique occurred at 7.7% of forward swing, left external oblique at 97.8% of takeaway, right erector spinae at 3.8% of forward
swing, left erector spinae at 98.5% of takeaway, right gluteus maximus at 91% of 
takeaway, and left gluteus maximus at 89.6% of takeaway.

Peak activity of the women’s right external oblique occurred at 71.5% of early 
follow through, left external oblique at 78.6% of forward swing, right erector spinae at 
64.3% of forward swing, left erector spinae at 78.6% of forward swing, right gluteus 
maximus at 32.1% of forward swing, and left gluteus maximus at 20% of acceleration.

Table 2 summarizes the stage at which the peak muscle activity occurred for each of the 
muscles for this study as well as previous studies.

**Table 2.** Peak Muscle Activity by Stage and Study

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Take Away</th>
<th>Forward Swing</th>
<th>Acceleration</th>
<th>Early Follow Through</th>
<th>Late Follow Through</th>
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<tbody>
<tr>
<td>R External Oblique</td>
<td>1</td>
<td>2,4,5</td>
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<tr>
<td>L External Oblique</td>
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<td>1</td>
<td>2,4,5</td>
<td></td>
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<td>R Erector Spinae</td>
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<td>1</td>
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<tr>
<td>L Erector Spinae</td>
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<td>2</td>
<td>2,3,5</td>
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<td></td>
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<tr>
<td>R Gluteus Maximus</td>
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</tr>
<tr>
<td>L Gluteus Maximus</td>
<td>1</td>
<td>2</td>
<td>2,3,5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Male subjects in this study
2. Female subjects in this study
3. Subjects from Bechler et al.\(^{15}\)
4. Subjects from Pink et al.\(^{5}\)
5. Subjects from Watkins et al.\(^{10}\)

X-Factor

At address, the men showed an X-factor of approximately 18° with shoulders 
closed relative to the hips. This angle increased to a maximal excursion of approximately
48° as they neared the top of backswing. By impact, the shoulders had moved past the hips to an angle of 14°.

Women showed an X-factor of approximately 19° at address with the shoulders open relative to the hips. Toward the end of backswing the X-factor was 37.8° with the shoulders in a position closed relative to the hips. At impact the shoulders were closed relative to the hips approximately 2°.

Duration of swing

The duration of the men’s swings averaged .94 seconds while the women’s swings averaged 1.13 seconds.
Figure 6. Integrated, "Ensemble" averaged EMG activity of male golfers during a full swing cycle.

2-3 Takeaway; 3-4 Forward Swing; 4-5 Acceleration; 5-6 Early Follow Through; 6-7 Late Follow Through
Figure 7. Integrated, "Ensemble" averaged EMG activity of female golfers during a full swing cycle.

2-3 Takeaway; 3-4 Forward Swing; 4-5 Acceleration; 5-6 Early Follow Through; 6-7 Late Follow Through
Figure 8. EMG activity during takeaway in male golfers
Figure 9. EMG activity during takeaway in female golfers
Figure 10. EMG activity during forward swing in male golfers
Figure 11. EMG activity during forward swing in female golfers
Figure 12. EMG activity during acceleration in male golfers
Figure 13. EMG activity during acceleration in female golfers
Figure 14. EMG activity during early follow-through in male golfers
Figure 15. EMG activity during early follow-through in female golfers
Figure 16. EMG activity during late follow-through in male golfers
Figure 17. EMG activity during late follow-through in female golfers
CHAPTER 4

DISCUSSION

Several previous studies that looked at EMG activity during the golf swing used both male and female golfers.\textsuperscript{13,12,15} These studies stated that there was no significant difference between male and female golfers' EMG activity in the shoulder, hip and knee muscles. In looking at the EMG activity found in this study, there were noticeable differences between the male and female golfers. For the males, the EMG activity peaked consistently at the end of the takeaway phase or the very beginning of the forward swing phase for all the muscles studied. Following the peak activity the muscles then showed an immediate drop in activity to moderate or minimal levels throughout the remainder of the swing. The females' muscle activity peaked mainly during the middle to late forward swing phase with the exception of the right external oblique muscle and the left gluteus maximus. The right external oblique peaked late in the early follow through phase and the left gluteus maximus peaked during the acceleration phase. While the peak muscle activity of the males occurred slightly earlier than the females, for the majority of the muscles there was a very similar pattern of muscle activity between men and women.

When the results of this study are compared with previous trunk EMG studies, there are some interesting similarities and differences. Consistently the muscle activity
that was measured in the males of this study peaked one stage earlier than the muscle activity analyzed in the other studies. However, the females in this study showed a pattern of muscle activity that more closely resembled the results of the previous studies which used men or a combination of men and women.

In comparing the X-factor, or hip to shoulder angle, measured between male and female collegiate golfers there was also some noticeable differences. At address, the females were at a position with the shoulders in an open position, or facing more towards the left at an average angle of 19° while the males started their swing in a closed position, or facing more toward the right at an average angle of 18°. The greatest X-factor measurement was achieved near the top of the backswing for both males and females with the females averaging 37.8° and the males averaging 48°. This position is considered closed since the shoulders are pointing further right than the hips. This shows that the men produce a greater overall X-factor. However, at address the men are starting in a more closed position and thus do not have to rotate as far during the takeaway phase to achieve the extreme rotated position. At impact the men had reduced the X-factor past a neutral measurement and were now open 14°. This means that in the short time from the top of backswing until impact their trunks had rotated, or uncoiled, a total of 62°. The women at impact were still 2° short of a neutral position and thus during the forward swing and acceleration phases only rotated, or uncoiled, a total of 36°. This difference may be a reason why low back injuries are more prevalent among male golfers than female golfers.

The study by McTeigue\textsuperscript{16} that originally looked at the X-factor measurement compared professional and amateur golfers. That study found that the professional and
amateur golfers started out in an open position of 5°. This is closer to the position the women golfers in this study were initially positioned. The greatest point of excursion at the top of backswing measured 32° for the professionals and 34° for the amateur level golfers. The results of this study show higher X-factor numbers than the results of the McTeigue study, especially with the male golfers.

As stated earlier, the muscle activity of the male golfers peaked near the end of the takeaway phase or at the beginning of the forward swing phase. This is also the point in the swing where the greatest shoulder to hip angle (X-factor) is being attained. Also as stated earlier, the X-factor attained by the male golfers in this study exceeded the previous measurements by McTeigue by 14°. This shows that the trunk muscles such as the external obliques are working hard to rotate the trunk to achieve a large shoulder to hip angle setting up a large amount of potential energy to be released when the body uncoils during the next 2 phases of the swing. The other trunk muscles, such as the erector spinae and the gluteus maximus, are working hard to stabilize the spine while in a position of extreme rotation that is not inherently stable. Without a stable low back and trunk the muscles providing the rotation forces, including the shoulder and upper trunk muscles, will not be able to effectively impart their pull on the trunk during the forward swing and acceleration phases thus reducing the amount of power generated during the swing.

The focus of young, male golfers with a driver in his hand is to create as much power and club-head speed as possible. In order to create the power of the swing that they desire, the male golfers have learned that by creating a large X-factor, and thus increasing muscle activity at the top of the backswing, they can produce a lot of rotational
energy in the forward swing and acceleration phases merely from the uncoiling of their trunk. This may be why the trunk muscle activity is occurring earlier in the male subjects and their X-factor is so much larger than the prior studies. Another factor may be that the study by McTeigue in regards to the X-factor was done sometime prior to 1994. That study has been utilized in many newer teaching programs implemented in the last few years that may have been the basis of what these younger golfers have been taught. This means that the younger golfers may have been taught that an increased X-factor may lead to increased power, while those originally studied did not know this and thus were not trying to produce a large X-factor.

The professional and women golfers on the other hand may not be focusing on power as much as they are focusing on accuracy and control. Thus, the majority of the focus for muscle activity is during the forward swing and acceleration phase to control and place the club in a proper position rather that to rotate the body to an extreme position to produce a powerful but more inaccurate motion. For this reason the X-factor numbers may not have been as high and the EMG activity peaked later in the swing for the professionals studied in previous studies and by the female golfers in this study.

Another piece of data that fits into this pattern is the duration of the golf swing. The average duration of the swing was measured to be 0.94 seconds for the male golfers, 1.13 seconds for the female golfers and 1.09 seconds for the professional golfers as stated by McTeigue. While there may not be a substantial difference in the numbers, the male golfers in this study did have a faster swing time than the women or the previously studied professionals. An increase in the power of the golf swing is attained by an increase in club head speed. The faster a swing is completed the faster the body and club
head is traveling. Thus, by having a smaller duration of the swing it follows that the club head is traveling faster and the golfer is trying for a more powerful swing. This is what we see in the male golfers of this study compared to the female golfers and previously studied professional golfers.

Limitations of Study

There were a few limitations to this study, that if overcome in future studies could lead to better, more reliable data. There were only three male and three female golfers used to compute the ensemble average for male and female golfers. This may not be a true representative sample of golfers, or even of collegiate-level golfers.

Partially due to the number of subjects, we decided to use a qualitative-type analysis instead of a more valid form of quantitative analysis. Thus, we were unable to utilize any type of statistical test that could be show significant differences between men and women or to prove or disprove our initial hypotheses. In addition, we instead had to look at patterns of activity rather than amounts of activity when looking to compare the men with the women.

Originally we had also planned to obtain measurements in regards to club head speed and correlate that data with both the X-factor data and the EMG data. The club head speeds that were computed did not match golfer reported club head speed and were thus not reported. This may be due to a limitation in the computer program, the knowledge of the computer operator, or a possible source of error in the present study.

We also obtained some data from the external oblique muscles that was difficult to explain in regards to the motions that were occurring at that time of the swing. This led us to believe, in addition to problems experienced by previous studies, that there was
no way to truly distinguish just external oblique activity from internal oblique, and
transverse abdominis muscle activity. This overflow of muscle activity from underlying
muscles could help explain the discrepancies. Thus, it may be more accurate to describe
the activity as coming from the abdominal oblique muscles rather than just from the
external oblique musculature.

The golfers were also required to swing a club barefooted, without a ball to hit,
with 14 reflective markers, EMG electrodes, and a transmitter unit all attached to his/her
body somewhere. This may have impeded the swing in some way, however the subjects
did not report a significant hindrance in the feel of their swing due to the apparatus they
had to wear.

Clinical Implications

The low back is the most often injured body part in male golfers and the second
most injured body part in female golfers. In reviewing the extreme range of motion and
muscle activity during the golf swing it is easy to see that the unconditioned golfer is at
risk for a low back injury. There are two uses for a low back training program for the
golfer: as a preventative training program and as a rehabilitative program following
injury.

The focus of a low back training program must be on increasing or maintaining
mobility of the spine and strengthening the low back muscles that support the spine in it’s
most vulnerable positions and forcefully uncoil the trunk during the downswing portion
of the swing. The spine needs to be mobile enough to allow proper rotation to occur and
thus avoid potentially dangerous or ineffective substitution patterns. General mobility
can be obtained through straight plane flexion and extension stretching exercises. The
focus of the stretching exercises however needs to be in the direction of rotation. This is the direction most desired and most likely most restricted in unconditioned golfers.

Since the golf swing requires a stable spine even in extreme postures, adequate strength of the trunk muscles is necessary for a safe and proper golf swing. Strengthening exercises for the low back can be done in traditional neutral positioning as with dynamic lumbar stabilization exercises which may be very beneficial as a portion of the training program. However, as our results showed, the highest muscle activity in the trunk occurs while the trunk is in an extremely rotated position or in the process of uncoiling. Thus, to maximize the effects of a strengthening program some exercises must be done with the trunk in a rotated position. Such exercises may include resisted bilateral upper extremity Proprioceptive Neuromuscular Facilitation (PNF) patterns (i.e. lift and chop) emphasizing the trunk rotation element, throwing a medicine ball to the side using trunk rotation as the driving force (not shoulder motions), and diagonal crunches for the abdominal oblique muscles.

Another potential sport specific exercise for strengthening and timing of the golf swing is the performance of a plyometric golf swing. To accomplish this the golfer swings a normal club slowly to the top of the backswing thus putting a stretch on the trunk muscles. The golfer then waits at that position for a few seconds, then quickly rotates a little further to initiate a stretch reflex in the trunk muscles before performing a normal downswing and follow through.

Following a low back injury the focus of the rehabilitation program will depend on the type of injury. If the injury was muscular in nature the focus will be first to regain the mobility in the spine that may have been lost following the injury. The focus may
then shift to properly strengthening not only the injured muscle, but also the rest of the trunk muscles that may be weak or compensating for the injured muscles. Initial strengthening exercises should be performed in a neutral back position. Once adequate strength is achieved, progression to more extreme ranges of motion (especially rotation) and faster movements is needed to mimic the forces required on the golf course.

If the initial injury was non-muscular (ligamentous or discogenic) the focus needs to start with attaining a stable spine. Areas of hyper- or hypomobility should be addressed with strengthening or mobilization techniques respectively. Once a stable back is achieved in a neutral position, progression to regaining lost mobility and strengthening the muscles in a non-neutral position should be initiated. Previously stated exercises may be used as well as any number of other stretching and strengthening exercises commonly used for the low back. Once an injury has been rehabilitated it is necessary to maintain mobility and strength to prevent repeated injuries.

No matter the cause or type of injury, the only way to end a comprehensive training or rehabilitative program is to perform sport specific activity. It may be necessary to begin with the golfer performing just partial swings to limit the range of motion required and progressing to full swings, plyometric swings, and full swings with a weighted club.

Another important aspect of both the training and rehabilitative programs is the need for a proper pre-round warm-up and aerobic conditioning. Prior to swinging a club at full speeds during a round of golf, the golfer should perform 10-15 minutes of light aerobic activity including stretching exercises for his low-back, neck, shoulder, and arm muscles to prepare them for the upcoming stresses in the round of golf. Walking the four
miles or more required during a round of golf also may lead to general fatigue increasing the risk for improper swing mechanics and increasing the risk for injury. By performing 20-30 minutes of moderate aerobic activity such as walking, riding a bike or swimming three times a week will prepare the golfer for the aerobic demands of walking a golf course.

Overall, any comprehensive low-back exercise program for the golfer must include mobility exercises emphasizing rotation, strengthening of the stabilizers of the spine and trunk rotators, aerobic conditioning, and a proper pre-round warm-up.

Additional exercises for the shoulders, arms, and legs may be included in any exercise program as needed.
CHAPTER 5

CONCLUSION

The purpose of this study was to examine the differences between male and female collegiate level golfers in the amount and timing of muscle activity in the low back and the range of motion of the trunk during a golf swing. This data was then to be used to provide the basis for a training program in a preventative and rehabilitative fashion for the golfer. There was some prior research on the biomechanics and muscle activity of the trunk during the golf swing but none of them included a training program.

The results of this study found a slight difference in muscle activity patterns between men and women with the men’s muscles more active at the end of the takeaway phase and the very beginning of the forward swing phase when the trunk is maximally rotated. The women’s muscles were more active during the forward swing and acceleration phases to accelerate the trunk through impact. In comparison to prior studies the female golfers showed similar results to the prior research while the men’s muscles were active consistently earlier.

There were several limitations to the study including number of subjects, type of analysis, type of data collected, and the set-up of the subject prior to testing. One other difficulty that could be avoided in the future was in regards to the reflective markers used for digitizing the golf swings. Increasing the contrast of the markers, i.e. light markers on
dark clothing or dark markers on light clothing, would have made the digitizing process much easier and perhaps more accurate.

Finding the range of motion necessary and the amount and timing of muscle activity during the golf swing is necessary for developing a comprehensive training program for the golfer. This author recommends further studies that increase the baseline of information started with this study, or that look at the effectiveness of a training program as both for healthy golfers and as a rehabilitative program for injured golfers. Future studies should also utilize a method to increase the contrast of the reflective markers and some sort of external device to measure club head speed.
UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Dave Reiling, Torin Berge, Chris Lugibihl, James Simmons, James Vranna
TELEPHONE: (701) 777-4091 DATE: April 1, 1998
ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 501 N. Columbia Road, P.O. Box 9037, Grand Forks, ND 58202-9037

PROPOSED SCHOOL/COLLEGE: Medicine DEPARTMENT: Physical Therapy
PROJECT DATES: April 1998 – April 1999

PROJECT TITLE: Electromyographic and Motion Analysis of the Trunk and Pelvis During the Golf Swing

FUNDING AGENCIES (IF APPLICABLE): ________________________________________________________

TYPE OF PROJECT (Check ALL that apply):

  - [X] NEW PROJECT
  - [ ] CONTINUATION
  - [ ] RENEWAL
  - [X] THESIS RESEARCH
  - [ ] STUDENT RESEARCH PROJECT

  - [ ] CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

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

INVESTIGATOR:

  - [X] INVOLVES NON-APPROVED

PROPOSED PROJECT:

  - [X] 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
  - [X] UND STUDENTS (>18 YEARS)

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

IF YOUR PROJECT HAS BEEN WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S): Red River Valley Sports Medicine Institute, Fargo, ND

Status: Submitted; Date__ Approved; Date__ Pending

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

According to a recent survey, 26.5 million golfers played at least one round in 1997, which is a seven percent increase from 1996. As the popularity of golf increases in the United States, so does the rate of golf-related injuries. Low back injury is the most
common affliction of male golfers; it is the second most common injury among female golfers. For this reason, research analyzing the motion and the muscles involved in the golf swing is essential. However, in reviewing the literature analyzing the golf swing, it is found that relatively few studies of this subject have been completed. The purpose of this study is to determine specific trunk musculature activity and to analyze trunk and pelvis range of motion during the different phases of the golf swing.

The results will attempt to provide information on establishing training programs targeting the trunk with the purpose of reducing golf-related injuries to this area. This information will be beneficial to physical therapists working with professional, amateur, and recreational golfers, both in training and in rehabilitation of low back injuries. Normal, trained, healthy subjects will be used in this research. Human subjects are needed for this research study in order to determine which muscles are active and when they are active while performing the golf swing.

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

Subjects
The sample will consist of 10 female and 10 male University of North Dakota golf team members voluntarily recruited for this study. Subjects must be healthy and without existing trunk pathology. Subjects’ age will be 18 or older. We will not accept subjects who are pregnant. All participants will sign the appropriate human subject consent forms.

Procedure
The study will be conducted at Red River Valley Sports Medicine Institute in Fargo, ND. Upon entering the facility, subjects will be given verbal instructions on purpose and procedure of the experiment and then will be asked to sign a consent form. EMG electrodes will be placed over the erector spinae, rectus abdominus, external obliques, internal obliques, gluteus maximus, and latissimus dorsi muscles bilaterally. Surface electrodes will be placed over motor points of the above muscles. If necessary, the skin may have to 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 and then fed into a computer for display and recording of data. Maximum voluntary contractions of the aforementioned muscles will be measured using manual muscle testing techniques administered by the testers. The muscle activity recorded during the maximal voluntary contraction will be considered as 100 percent activity level. This procedure is done to normalize the EMG data for later analysis.

Video analysis will be used to measure trunk range of motion during the activity. Reflective markers will be attached to the trunk and shoulders using double-sided tape. Video cameras will be placed around the subject and will film the subject’s trunk movements during the golf swing. This will be recorded on videotapes and will be
transferred to a computer for analysis.

Subjects will be allowed to warm up and to take practice swings with electrodes in place to ensure that the swing will not be impeded. Each subject will take five swings with a driver, hitting golf balls into a net. EMG and motion analysis data will be recorded of each swing. Subjects will be asked to take their normal golf swing with a driver. Club head speed will be measured at impact with a separate piece of equipment provided by Red River Valley Sports Medicine Institute and correlated with EMG and motion analysis data.

Data collection will consist of measurements of muscle activity and trunk range of motion focusing on the rotational component of the trunk and pelvis. Statistical analysis of the mean activity of each monitored muscle will be performed. 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. The video image will be converted to a stickman-like figure, from which we can determine trunk and pelvis range of motion and rotational velocity. The EMG data will be synchronized with the video data to determine the level of EMG activity during the various stages of the golf swing.

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

The possible benefits of this study will include obtaining information on the golf swing that may lead to the development of training programs to prevent golf-related trunk injuries. By identifying specific trunk muscles active during the golf swing, a training program may be developed to specifically train these muscles so they are strengthened at the appropriate stages of the swing. By establishing normative data on muscle activity and trunk and pelvis motion during the various stage of the golf swing, we will provide information that could be used in future golf studies.

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 in this study are minimal. EMG and motion analysis equipment poses no risk of injury to the subjects. The possibility of muscle strains exists, but this risk should be minimal due to the condition of the athletes involved in the study and the warm-up period allowed. Light-weight plastic golf balls will be used to further reduce the risks of injury.

Data will be collected in a confidential manner and the collected data will be kept confidential. Names will not be used for any reason in this study and subjects will be assigned code numbers to ensure strict confidentiality. Participation in this study is voluntary and subjects are free to withdraw at any time and for any reason without fear of
retribution. Data will be kept for a minimum of 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.

The signed consent forms will be kept by David Relling in the University of North Dakota Physical Therapy Department for a period of three (3) years. A copy of the consent form is attached.

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 _____________________.

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

Consent required by 20 U.S.C. 1232g.
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

DATE: April 15, 1998

PROJECT NUMBER: IRB-9804-265

Dave Relling, Torin Berge, Chris Lugibihl,
NAME: James Simmons, James Vranna

DEPARTMENT/COLLEGE: Physical Therapy

PROJECT TITLE: Electromyographic and Motion Analysis of the Trunk and Pelvis During the Golf Swing

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on April 17, 1998 and the following action was taken:

☑ Project approved. EXPEDITED REVIEW No. 3
☐ Next scheduled review is on April 1999

☐ 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.

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)
April 14, 1998

Mr. Dave Relling, M.S. PT  
UND School of Medicine  
Department of Physical Therapy  
501 N. Columbia Road  
P.O. Box 9037  
Grand Forks, ND 58202-9037

Dear Mr. Relling,

I have had the opportunity to review the research proposal “Electromyographic and Motion Analysis of the Trunk and Pelvis During the Golf Swing”. As the Medical Director of the Red River Valley Sports Medicine Institute, I approve and fully support this research endeavor. We look forward to working together with you.

Sincerely,

Mark A. Lundeen, MD  
Medical Director RRVSMI
APPENDIX B
INFORMATION AND CONSENT FORM

TITLE: Electromyographic and Motion Analysis of the Trunk and Pelvis During the Golf Swing.

You are being invited to participate in a study conducted by Dave Relling, a physical therapy instructor, and Torin Berge, Chris Lugibihl, James Simmons and James Vranna, physical therapy students at the University of North Dakota. The purpose of this study is to study muscle activity and range of motion in your trunk and pelvis during different phases of the golf swing. The results will attempt to provide information on creating training programs targeting the trunk with the purpose of reducing golf-related injuries to this area. Only normal, healthy subjects will be asked to participate in this study.

You will be asked to make five swings with a driver while connected to the EMG apparatus and motion analysis cameras videotaping the swings. Club head speed at impact will also be analyzed for each swing. You will be given a few minutes to warm up prior to performing the actual trials. You will be given a short rest period between trials.

The study will take approximately one hour of your time. You will be asked to report to the Red River Valley Sports Medicine Institute in Fargo, North Dakota 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, range of motion (via motion analysis cameras), and club head speed while swinging the golf club.

Although the process of physical performance testing always involves some degree of risk, 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 electrodes on your trunk and pelvis. The recording electrodes are attached to the surface of the skin with an adhesive material. If necessary we may have to shave the hair from the area where the electrode will be placed. These devices only record information from your muscles and joints, they do not stimulate the skin. We will also attach some reflective markers to certain landmarks on your body for the motion analysis cameras. The amount of exercise you will be asked to perform will be minimal.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical
Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. 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.

In the event that this research activity (which will be conducted at Red River Valley Sports Medicine Institute) 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 in similar circumstances. Payment for any such treatment must be provided by you and your third party payor, if any.

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 and willingly agree to participate in this study explained to me by Dave Relling, Torin Berge, Chris Lugibihl, James Simmons, or James Vranna.

Participant's Signature Date

Witness (not the scientist) Date
RELEASE STATEMENT

I hereby give my permission to the University of North Dakota, its agents, successors, assignees, clients and purchasers of its services and/or products, to use my photograph (whether still, motion or television)

Name: _____________________________

Signed: ____________________________

Date: ______________________________

Address: __________________________

City: ______________________________

State and Zipcode: __________________
REFERENCES


