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Analysis of Wrist and Elbow Muscle Activity in Compound versus Traditional Bows with Experienced Archers

Stacey Fuhrer
University of North Dakota

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Analysis of Wrist and Elbow Muscle Activity in Compound Versus Traditional Bows with Experienced Archers

by

Stacey Fuhrer
Bachelor of Science in Physical Therapy
University of North Dakota, 2000

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
2001
This Independent Study, submitted by Stacey Fuhrer, 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.

(Chairperson, Physical Therapy)

(Faculty Preceptor)

Graduate School Advisor)

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Title Analysis of Wrist and Elbow Muscle Activity in Compound Versus Traditional Bows with Experienced Archers

Department Physical Therapy

Degree Master of Physical Therapy

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Signature Stacey Fuhrer
Date 11-13-00
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ABSTRACT

Archery is becoming more popular as a recreational sport, so it is likely that physical therapists will be seeing more archery-related injuries and will need to know how to treat these athletes. Few studies available specify which muscles are used when shooting compound or traditional bows. The purpose of this study is to identify the muscles around the wrist and elbow that are recruited from draw to release, the specific timing of this recruitment, and the differences in recruitment and muscle activity when using a compound bow compared to a traditional bow.

Six males between the ages of 37 and 51 were selected for this study. They were recruited from the Red River Archer’s Club and had at least three years of archery experience. Electromyography and motion analysis equipment provided by the University of North Dakota Physical Therapy Department was used to collect the data. The subjects performed approximately 4 to 6 draw and release movements with each bow, shooting at a target approximately 5 feet away. Reflective markers were attached to the bow at three locations and video analysis was used to record bow string angles.

The results of our study indicated that the traditional bow overall required more muscle activity to shoot for both the draw and bow hands as compared to the compound bow. This is due to the presence of the let-off mechanism in the compound bow. Included in this study is an example of a protocol that archers can use for strengthening muscles around the shoulder and wrist.
CHAPTER 1
INTRODUCTION

Background

Originally used for hunting and warfare, archery was one of the earliest weapons used by man, dating back over 20,000 years.\textsuperscript{1,2} Ancient Egyptians first established the long bow as their main weapon of war around 3500 B.C.\textsuperscript{1} In 1800 B.C., the Assyrians developed the recurve bow, which was more accurate than the Egyptian’s long bow. In the 11\textsuperscript{th} century, the English began using the long bow in place of the bow they had been using. King Henry VIII established the first archery society in 1537. In 1900, archery became an Olympic sport. It was also in the 1904, 1908, and 1920 Olympic games, but it did not reenter the Olympics again until 1972.\textsuperscript{1}

The compound bow was developed in the late 1960s and early 1970s.\textsuperscript{3} The recurve and long bows almost disappeared from use by the 1970s, but began to reappear in the 1980s.

This study is based on a previous study done by Brodina and Vagle,\textsuperscript{4} which investigated the muscles located around the shoulder and upper arm that are recruited during the use of compound and traditional bows. This study expands on Brodina and Vagle’s\textsuperscript{4} study by investigating the muscle recruitment and activity around the wrist and elbow.

Definitions

There are terms used in archery that need to be understood for this study. The bow hand/arm holds the bow during shooting.\textsuperscript{5} The draw hand/arm performs the action of drawing. For the purpose of this study, the left hand is the bow hand and the right
hand is the draw hand. **Draw** is the process of pulling the bow string back into a position to release the arrow. **Full Draw** is the maximal draw length of the bow string. **Hold/anchor** involves steadily keeping an arrow at full draw before release. During **release**, the fingers slip off the fully drawn bow string, sending the arrow away.

**Draw Length** is the distance between the bow string and handle when holding at full draw and is usually measured in inches.\(^3\) It is determined by the length of the archer’s arm and the width of the shoulders.

**Draw Weight** is the maximal amount of force needed to pull the bow string to full draw and is usually measured in pounds.\(^6\) With traditional bows, peak weight is reached at full draw. With compound bows, draw weight peaks near mid draw, and then the amount of weight is reduced.

**Holding weight** refers to the amount of poundage held at full draw.\(^3\) **Let-off** is the reduction in weight at full draw in a compound bow and is usually between 50% and 80%. Let-off allows the compound bow to be held at full draw much longer than with traditional bows.

For the purpose of this study, recruitment is defined as which muscles are activated. Activity is the amount of electromyographic voltage used in each muscle.

**Problem Statement**

Previous research of muscles recruited during archery is limited, and few articles in the literature compare traditional bows to compound bows in muscle activity. Treatment protocols used to treat archery-related injuries are also limited.
Purpose of Study

The purpose of this study is to identify the muscles around the archer’s wrist and elbow that are recruited from draw to release, the specific timing of this muscle recruitment, and the differences in the muscles recruited and the amount of muscle activity when using a compound bow compared to a traditional bow.

Significance of Study

Archery is becoming more popular as a recreational sport, so it is likely that physical therapists will be seeing more archery-related injuries and will need to know how to treat these injuries. As a result of this study, information that may enhance the treatment of patients with archery-related injuries of the wrist and elbow will be provided.

Archery is also becoming more popular in rehabilitation for people with paraplegia. It develops and strengthens muscles needed for those with paraplegia to perform at higher functioning levels. These muscles include those of the shoulder, back, elbow, and wrist.

Research Questions

1) What muscles around the wrist and elbow are recruited from draw to release in the compound bow?

2) What muscles around the wrist and elbow are recruited from draw to release in the traditional bow?

3) What is the specific timing of the muscle recruitment?

4) Is there a difference in the muscles recruited and the amount of muscle activity between the compound and traditional bows?
Hypotheses

Null: There is no significant difference in muscle recruitment, timing, and muscle activity when using a compound bow compared to a traditional bow.

Alternative: There is a significant difference in muscle recruitment, timing, and muscle activity when using a compound bow compared to a traditional bow.
CHAPTER 2
LITERATURE REVIEW

There are two basic types of bows, compound and traditional. The major difference between the two is that the compound bow has cams and cables, which causes a reduction in force when drawing the bow string back to full draw. Because of this let-off, an archer is able to hold longer at full draw with a compound bow than with a traditional bow.

The traditional bow consists of the long bow and the recurve bow. The traditional bows are lighter in weight and have a smoother draw than the compound bows, but they require more force to maintain full draw. The recurve bow has limbs that curve back toward the front of the bow. Most long bows have limbs that form a smooth curve toward the string. Recurve bows are normally smoother when drawing than the long bows. The long bows have less torque following release, but require more practice to become a talented archer. Figures 1-2 display the compound and recurve bows with the components labeled.

**Bow Stages**

In archery, there are general forms and styles that most archers follow, but each individual makes variations in order to fit his/her needs. The following positions discussed will be referring to a right-handed archer. There are five basic stages when shooting a bow. The first stage is getting into the shooting position. Receiving the bow and gripping the handle is the second stage. The third stage is receiving and positioning the arrow and positioning the hand on the bow string. The fourth stage is drawing the
Figure 1. Traditional bow
Figure 2. Compound bow
bow string, and the fifth stage is releasing the arrow. The grip of the left hand on the bow is maintained from receiving the bow until after release.

**Joint Position**

The shoulder girdle adducts bilaterally and provides stabilization throughout the draw stage. The shoulder requires full range of flexion (0-180 degrees), abduction (0-180 degrees), and rotation (0-90) bilaterally. The left elbow requires 20 degrees of flexion (from anatomical position) and the right elbow needs full range of flexion and extension (0-150 degrees). In the left forearm, there needs to be full range of pronation and supination (0-80), but in the right forearm only 45 degrees is required from full supination to mid-position.

Twenty degrees of extension (from the anatomical position) is required in both wrists. The left hand uses a cylindrical grip with the long finger flexor group, lumbricals, and adductor pollicus being the most active. Forty-five degrees of range of motion is required at all joints in the hand except the second through fifth metacarpophalangeal (MCP) joints, which require only 40 degrees and the second through fifth proximal interphalangeal (PIP) joints, which require 90 degrees. In the right hand, the second and third fingers are primarily used.

The muscle grade required for archery is generally a fair plus. A “good” grade is only needed during draw. The above muscle grading scale has five levels, which are absent, trace, poor, fair, good, and normal.

**Shooting Techniques**

The hand that holds the bow is normally relaxed and in a neutral position before shooting the bow. There are three different hand positions in which to hold the bow.
These are 1) low wrist, 2) high wrist, and 3) straight wrist. Figures 3-5 depict these positions. In the low wrist position, the lateral border of the wrist is lower than the lateral border of the first finger. The high wrist position is opposite to the low wrist hand. In the straight wrist position, the lateral borders of the wrist and first finger are level.

The handle should be aligned with the center of the left forearm during draw. This decreases the torque and muscle work required. During draw, the bow is pulled back into the hand if the bow is in alignment with the forearm. This allows the bow hand to relax. At release, the fingers lightly hold the bow to prevent it from falling.

In the draw hand, the Mediterranean grip is the most common string grip. The index, middle, and ring fingers hold the string with the arrow placed between the index and middle fingers as shown in Figure 6. The fifth finger is not involved and rests against the hypothenar eminence, and the thumb rests on the thenar eminence. The distal interphalangeal (DIP) and PIP joints are flexed and the MCP joints remain in neutral.

There are two different positions for placing the string on the fingers. The shallow hook position consists of placing the string distal to or on the DIP crease. This is the most common. The deep hook position consists of placing the string between the DIP and PIP creases. Beginning archers most often use this position. A release aide can also be used to hold the string during draw. This device utilizes a switch or lever to release the string. Using a release aide causes the draw length to be approximately 1 inch shorter than when using finger release.

During draw, the shoulder and back muscles produce the majority of the forces required to pull back the string. The fingers act as hooks to hold the string. The most
Figure 3. Low wrist holding position
Figure 4. Straight wrist holding position
High wrist holding position
Mediterranean string grip
pressure is usually on the middle finger.\textsuperscript{6} Figure 7 illustrates the compound bow at full draw. During release, the fingers relax and let the string slip away. Other archers may use active extension of the PIP and DIP joints to release the string.

\textbf{Related electromyographic archery studies}

Few studies about electromyographic activity in muscles around the wrist and elbow in archery can be found in the scientific literature. Hennessy et al\textsuperscript{10} studied the flexor digitorum superficialis and the extensor digitorum of the draw arm, and the flexor carpi ulnaris, extensor carpi radialis, biceps, and triceps of the bow arm. They found an increase in muscle activity from negligible to significant in the wrist flexors 60 milliseconds before release. The activity lasted until after release for both archers in this study. The wrist extensors had moderate activity, which rose to marked activity 60 milliseconds before release and lasted until after release. The flexors had a significantly greater percentage increase of electromyographic (EMG) activity than the extensors. The extrinsic flexors and extensors of the fingers of the draw arm had a sharp increase in muscle activity which began 60 milliseconds before release.\textsuperscript{10}

Hennessy et al\textsuperscript{10} also found that before release, there was a static equilibrium of the muscles at the wrist and elbow of the bow arm. The co-contraction of the flexors and extensors prior to release helped keep the bow in a stable position. The authors believed that the co-contraction of muscles at release of the draw hand was due to the change from flexion needed to hold the string at full draw to extension to allow the release of the string.

Martin et al\textsuperscript{11} studied the flexor digitorum superficialis (FDS) and the extensor digitorum (ED) of the draw arm and found variation between subjects for the amount of
Figure 7. Full draw with the compound bow
activation of the muscles. During full draw, the FDS and the ED had activity well above resting levels, which demonstrated that there was co-activation occurring. The FDS had a constant level of activity for the first 900 milliseconds. There was a decrease in activity for the 100 milliseconds before release, which was followed by a continued decrease in activity throughout the remaining time. The results of this study indicated that the fingers of the draw arm were held in a flexed position to maintain a hold on the string as it was drawn back and held at full draw.

The extensor digitorum had two patterns in the subjects occurring from start to after release. In the first, there was little change in activity until 100 millisecs prior to release. Then the activity decreased throughout release and the time that followed. The second pattern consisted of a short, large increase in activity before release. After this increase, there was a rapid reduction in muscle activity following release.

Clarys et al found that the muscles having the greatest variability between experienced and novice archers were the biceps at full draw and the extensor digitorum during release. The pattern of the muscle recruitment in the draw arm stayed consistent between novice and experienced archers.

Clarys et al tested the ED, FDS, biceps, and brachioradialis of the draw arm and the ED, triceps, and brachioradialis of the bow arm. The authors found that with an increase in shooting distance, the muscular pattern did not change, but the intensity of the muscle activity did increase.

Archery-related injuries

There are injuries that can occur in archery. Arrow injuries usually involve penetrating wounds of the upper extremities or vital structures. Bow-related injuries are
caused by repetitive motions of the neck, shoulder, and upper extremity. The FDS can receive abnormal stress and cumulative trauma during archery. The median nerve can also become compressed where it runs beneath the FDS, especially if the archer only uses the middle and ring fingers to draw the bow string. A significant amount of force can become concentrated at the medial epicondyle.

Some acute injuries include digital nerve and artery laceration, forearm skin and subcutaneous tissue contusion, and compression neuropathy of the four digital nerves. Chronic injuries include bilateral medial epicondylitis (usually more severe on the draw arm), deQuervain’s tenosynovitis, median nerve entrapment by the FDS at the elbow, and bilateral median nerve compression at the wrist due to flexor tenosynovitis.

Many of these injuries are preventable if certain steps are taken. Archers should wear protective gear such as arm and chest guards, shooting gloves or use a bow string release with a grip. Using a lightweight bow, modifying the drawback of the string, and conditioning the forearm flexor muscles can also prevent injuries. This is why it is important for physical therapists to be able to prescribe exercise programs for archers to strengthen muscles to prevent injury.
CHAPTER 3
METHODS

Subjects

Six males were selected for this study. All of the subjects were part of the Red River Archers club and had participated in the study conducted by Brodina and Vagle. The subjects had at least three years of archery experience, no major arm injuries in the last year, were right handed, and had competed in at least three tournaments in the last year. Ages of the subjects ranged from 37 to 51 (X=44.8), weight ranged from 194 to 254 pounds (X=228.2), and height ranged from 69 to 75 inches (X=70.8). Each subject read and signed the consent form before participating in the study. An example of the consent form is included in Appendix A.

Instrumentation

Bows

The traditional bow used in this study was the 1999 Martin Hatfield Takedown, a recurve bow, which had a draw weight of 55 pounds at a draw length of 28 inches. The compound bow used was the 2000 Hoyt Raider Intruder, which had a variable draw weight of 55-70 pounds with a 75% let-off and a variable draw length of 28.5 to 32 inches. A shooting glove and arm guard were provided for the participants.

Electromyography

The Noraxon Telemyo 8 telemetry unit (Noraxon USA, 13430 North Scottsdale Road, Scottsdale, AZ 85254) was used to record data which was sent to the Noraxon Telemyo 8 receiver. An analog digital interface board in the Peak Analog Module (Peak Performance Technologies, 7388 S. Revere Parkway Suite 601, Englewood, CO 80112-9765) digitized the information. The Peak Event Synchronization unit synchronized the
electromyographic (EMG) and video data. A Noraxon switch placed on the middle finger was used to trigger the synchronization unit to begin recording the EMG data.

**Video**

A two-dimensional system utilizing one camera was used in this study. The Peak High Speed Video 60/120 Hz camera (Peak Performance Technologies, 7388 S. Revere Parkway Suite 601, Englewood, CO 80112-9765) filmed the subjects while they shot the bows. A lamp was set up next to the camera to provide light for marker reflection. Three reflective markers were attached to each bow and are depicted in Figures 8-9. Markers were placed over the upper cam for the compound bow and at the point where the bow string and upper limb meet for the traditional bow. The upper limb pockets and the bow string parallel to the upper limb pocket were also used as sites for both bows. The markers were used to determine bow and bow string position throughout each trial.

A frequency of 60 Hz and shutter speed of 1/250 of a second was used. The archers were taped on a JVC Model BR-S3780 videocassette recorder (JVC of America, 41 Slater Drive, Elwood Park, NJ 07407). A SMPTE time code generator was encoded on the videotape.

Selfe\textsuperscript{14} studied the validity of the Peak 5 motion analysis system. The author found a high level of agreement in static angular measurements between the goniometer and motion analysis system. Overall, this study indicated that the Peak 5 system is valid for angular position and angular velocity data.

After filming the subjects, the Peak Motus Software Package was used to digitize the video while the tapes were played on the Sanyo Model GVR-S955 VCR (Sanyo, 1200 W. Artesia Boulevard, Campton, CA 90220).
Figure 8. Reflective marker placement on traditional bow
Figure 9. Reflective marker placement on compound bow
Procedure

Each subject read and signed the consent form. His age, weight, and height were then recorded. All subjects performed warm-up exercises consisting of 10 repetitions of drawing motion using blue resistive elastic theraband. Standard electrode placement charts were used to determine the location of the motor points for each muscle as shown in Figure 10. The area where the electrodes were placed was shaved of excess hair and then cleansed with rubbing alcohol before the self-adhesive electrodes were applied.

The muscles used include: flexor carpi ulnaris (FCU), flexor carpi radialis (FCR), extensor carpi ulnaris (ECU), extensor digitorum (ED), extensor carpi radialis longus/brevis (ECRL/B), and the flexor digitorum superficialis/flexor digitorum profundus (FDS/FDP). The flexor digitorum superficialis and profundus and the extensor carpi radialis longus and brevis can not be differentiated when using surface EMG electrodes, and thus were considered as one muscle. The ground electrodes were placed on the superior aspect of the left and right acromion.

The compound bow was set at 55 pounds and adjusted to each subject’s reported normal draw length. An on/off switch was attached to the middle finger of the right hand between the proximal and distal finger crease. Each subject performed isometric contractions of each muscle while the raw EMG signal was observed to determine if the electrode placement was accurate. Muscle activity of the draw arm was recorded first. The first bow used was randomly selected for each subject. Each subject wore a shooting glove on his draw hand and an arm guard on his bow arm.

The subjects were instructed to use normal shooting motion and stance for both bows, with the exception that they use three fingers to draw the string and apply even
**Flexor Carpi Radialis** - over the muscle belly, ½ the distance on a line drawn from the lateral biceps in the cubital fossa to the pisiform

**Flexor Carpi Ulnaris** - over the muscle belly, 1/3 the distance on a line drawn from the medial epicondyle to the pisiform

**Flexor Digitorum Superficialis/Profundus** - ½ the distance on a line drawn from the medical epicondyle to the midline of the wrist joint

**Extensor Carpi Ulnaris** - over the muscle belly, 1/3 the distance from the lat. Epicondyle to the ulnar styloid

**Extensor Carpi Radialis Longus/Brevis** - over muscle belly, 1/3 the distance from the lat. Epicondyle to the midline of the wrist

**Extensor Digitorum** - over the muscle belly, on a line ¼ the distance from the lat. Epicondyle to a point midway between the radial and ulnar styloids

*Figure 10. Electrode placement chart*
force throughout the three fingers. The subjects all used the low wrist position. Each subject performed an average of 4 to 6 draw and release movements for each bow. They shot at a target approximately 4 feet off the ground and 5 feet away. The subjects held at full draw for 3 seconds with the compound bow and 1 second with the traditional bow, using a metronome set at a one second interval. The subjects came to full draw with the compound bow. With the traditional bow, the subjects drew back until the arrow rest touched a mark on the arrow indicating 28 inches, which was considered full draw.

Data Analysis

A meter stick was filmed before the trials began to use for calibration. Each trial was calibrated, cropped, and digitized. Then event markers were added, which included start, full draw, and release. Full draw was determined by the largest bow string angle. Release was determined by when the arrow left the hand so that muscle activity could be studied at or slightly after release.

The software package calculated two dimensional bow string angles and scaled/matched analogue data for each trial. The trials for every subject were averaged together for the right and left hands for both compound and traditional bows. The data was then plotted on a line graph for visual representation of each muscle. Refer to Figures 11-14 for illustration of this data.

The average scaled/matched analogue data was exported to a Microsoft excel spreadsheet (Microsoft Corporation, One Microsoft Way, Redmond, WA 98052-6399). Then the mean for each muscle was calculated. Bar graphs were constructed to compare the muscle activity between the two bows as shown in Figures 15-16. The percent difference in average muscle activity between the compound and traditional bows for the
left and right hands was calculated. The average EMG activity for all muscles tested in the left and right hands, using compound and traditional bows, was also calculated. Tables 1-2 list this data.
Figures 11-14 depict bow angles and the average electromyographic activity for all muscles tested in the draw and bow hands of the compound and traditional bows. Figures 15-16 display the average muscle activity comparing the two bows for the draw and bow hands. Full draw occurred at an average of 98% of the total time from start until release for the compound bow and at 96% for the traditional bow. Release occurred at 100%.

As seen in Figure 11, the ECRL/B had a gradual rise and fall in muscle activity between 4% and 40% of the total time for the compound bow in the draw hand. With the traditional bow, the ECRL/B gradually increased activity from start until 97% where the activity dropped off. The ED and ECU in the compound bow had a peak in activity between 10% to 20% followed by a baseline level until 96% where the activity increased dramatically. The ED and ECU in the traditional bow had a rise and decline in activity between 25% and 42% followed by a constant level of activity until 96% where there was a sharp rise in activity.

Figure 12 depicts the FCR of the draw hand having a gradual rise and fall of activity from start until 45% for the compound bow. A baseline level was maintained throughout the remaining time. The FCR and finger flexors (FDS/FDP) of the traditional bow had a gradual rise from start until 97% where the activity dropped off. The finger flexors and the FCU of the compound bow had a slow rise from start until 40% where the activity maintained baseline until 98% where there was a sharp rise in activity followed
by a drop at release. The FCU of the traditional bow had a gradual incline from start until prior to release, with a spike in activity at 96%.

As shown in Figure 13, the ECRL/B of the bow hand of both the compound and traditional bows had near baseline levels until 98% and 94%, respectively where there was a sharp rise in activity. The ED of the compound bow had a large amount of activity from start until 30% followed by a drop in activity to baseline until 98% where the activity rose sharply. The ED and the ECU of the traditional bow had a gradual increase in activity from start until release for the ECU and at 98% for the ED where there was a spike in activity. The ECU of the compound bow had a large amount of activity from start until 20% where the activity began to decrease back to baseline throughout the remaining time.

In Figure 14, the FCR of the compound bow had a small rise in activity from 25% to 35% and a sharp rise in activity at 98%. The FCR of the traditional bow stayed at baseline until 97% where there was a sharp rise in activity. The finger flexors (FDS/FDP) and the FCU for both bows maintained baseline until 97% where there was an increase in muscle activity.

As shown in Figures 15-16, the traditional bow required greater mean activity in both the right and left hands than the compound bow. In Table 1, the difference in average muscle activity is compared between the compound and traditional bows for both the bow and draw hands. Table 2 displays the muscle activity for all muscles averaged together.
Figure 11. Average kinematic and electromyographic data from start to release for the extensors of the draw hand for the compound (blue) and traditional (red) bows.
Figure 12. Average kinematic and electromyographic data from start to release for the flexors of the draw hand for the compound (blue) and traditional (red) bows.
Figure 13. Average kinematic and electromyographic data from start to release for the extensors of the bow hand for the compound (blue) and traditional (red) bows.
Figure 14. Average kinematic and electromyographic data from start to release for the flexors of the bow hand for the compound (blue) and traditional (red) bows.
Figure 15. Mean muscle activity from start to release of the draw hand of the compound and traditional bows.
Figure 16. Mean muscle activity from start to release of the bow hand for the compound and traditional bow.
<table>
<thead>
<tr>
<th>Muscle</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCR</td>
<td>89.80%</td>
<td>15.00%</td>
</tr>
<tr>
<td>FDS/FDP</td>
<td>78.10%</td>
<td>39.60%</td>
</tr>
<tr>
<td>FCU</td>
<td>71.30%</td>
<td>47.90%</td>
</tr>
<tr>
<td>ECRL/B</td>
<td>85.50%</td>
<td>20.00%</td>
</tr>
<tr>
<td>ED</td>
<td>61.00%</td>
<td>38.96%</td>
</tr>
<tr>
<td>ECU</td>
<td>47.80%</td>
<td>64.60%</td>
</tr>
</tbody>
</table>

Table 1. Difference in average muscle activity of traditional and compound bows in the left and right hands. Percentages reflect muscle activity greater in the traditional bow compared to compound bow.

<table>
<thead>
<tr>
<th>Hand/bow</th>
<th>Average EMG (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Compound</td>
<td>0.091</td>
</tr>
<tr>
<td>Left Traditional</td>
<td>0.133</td>
</tr>
<tr>
<td>Right Compound</td>
<td>0.134</td>
</tr>
<tr>
<td>Right Traditional</td>
<td>0.231</td>
</tr>
</tbody>
</table>

Table 2. Average EMG activity for all muscles tested in the left and right hands using compound and traditional bows.
CHAPTER 5
DISCUSSION AND CONCLUSION

As stated in the results, full draw occurred at an average of 98% for the compound bow and at 96% for the traditional bow. We did not expect full draw to occur so close to release, but we hypothesize that this was caused by the subjects pulling back further prior to releasing the arrow. Once the subjects reached full draw, they had actually been holding the string for an extended period of time.

Let-off in the compound bow started at approximately 20% and lasted until 46%, which was evident by the decrease in muscle activity of the draw hand muscles at this time. Let-off was also visible in the bow hand. With the traditional bow, the muscle activity increased until release indicating that the longer the subjects held at full draw the more muscle activity they required.

In the traditional bow, the ECU of the draw hand had a rise in activity from 22% to 40% of the total time. In the compound bow, the increase in activity occurred at 10% to 20%. We believe that this brief activation of the ECU was needed to help stabilize the wrist. We also theorize that the ED worked more with extending the wrist than extending the fingers during draw.

In the compound bow, the FCU, FDS/FDP, FCR, and ED of the bow hand and the ED, ECU, FCU, and FDS/FDP of the draw hand all had an increase in activity prior to release. In the traditional bow, the ED, ECU, and FCU of the draw hand and ECRL/B, ED, FCR, FDS/FDP, and FCU of the bow hand also had an increase in activity prior to release.
In the draw hand for the traditional bow, we theorize that there was an increase in muscle activity at release in the ED to extend the fingers allowing the release of the arrow. We believe the ECU and FCU were also active to promote ulnar deviation at release. The FDS/FDP had a decrease in activity at release, presumably allowing the fingers to let go of the string. In the bow hand, there was an increase in activity of all muscles, except the ECU, to most likely promote stabilization of the bow at release. We suggest the FDS/FDP needed to increase at release to increase the grip on the bow handle.

In the bow hand for the compound bow, there was an increase in 5 out of 6 muscles at release to presumably promote stabilization as with the traditional bow. In the draw hand, the ED was active at release to seemingly extend the fingers. We theorize the ECU and FCU were also active at release for ulnar deviation of the wrist. The finger flexors of the draw hand had a small rise and then drop in activity.

Overall, the traditional bow required more muscle activity than the compound bow. In the draw hand, the average difference in muscle activity between the two bows was the greatest in the FCR, ECRL/B, FDS/FDP, and FCU. In the bow hand, the greatest difference in average activity was in the ECU and FCU.

In the compound bow, the most muscle activity was required at the beginning of draw and just before release. In the traditional bow, the muscle activity continued to increase until release.

Findings from this study are difficult to compare to other researchers, as they did not specify which bow was being used in their studies. Our results are similar to the
findings by Hennessy et al. The authors found an increase in wrist flexor and extensor activity prior to release as we did.

Martin et al. found that the FDS had a constant level of activity for the first 900 msec followed by a decrease in activity through release, which was similar to our findings for the compound bow of the draw hand. The authors also noted co-activation of the FDS and ED of the draw hand as we did in our study. We noted that the ED followed the second pattern identified in the research by Martin et al. where there was active extension of the fingers to release the arrow.

Limitations

The limitations of this study include a small sample size, which could have led to an increase in variability for our study. Future studies should be performed with a larger sample size. A second limitation was that we used two types of bows in our study, but there are different styles and brands of bows that may require different shooting techniques, which would make it more difficult to generalize the bows we used to all bows. The muscles around the wrist and elbow are small and close together, so the third limitation was there could have been interference between the muscles even though we used standard electrode placement.

A fourth limitation was that the trials were not exactly the same length for every archer. This would increase the variability when the trials were averaged together. The fifth limitation is that the maximal voluntary contract (MVC) was not recorded for each muscle, so we could not compare the bow hand to the draw hand. We could only compare the muscle activity between the compound and traditional bows. Future studies
should look at the torque produced by the bow following release to see the effects on the draw and bow arms.

**Conclusion**

The traditional bow overall required more muscle activity to shoot for both the draw and bow hands as compared to the compound bow. This is due to the presence of the let-off mechanism in the compound bow.

**Clinical Implications**

Physical therapists may tend to spend more time strengthening the shoulder muscles in archers, but the muscles around the wrist are also important to strengthen. With the compound bow, strengthening should concentrate on the drawing motion to reach full draw. With the traditional bow, it is important to work on the drawing motion along with isometrics for the hold phase to prevent fatigue. The bow hand for either bow also needs to be strengthened for stabilization. Exercises need to be activity-specific, which means that exercises should simulate the draw motion. Training is important for preventing injuries and increasing strength for all archers. An example of a protocol to be used with archers is listed in Appendix B.
Consent Form

Analysis of Wrist and Elbow Muscle Activity in Compound versus Traditional Bows with Experienced Archers.

Principal Investigators: Jesse Fuhrer, Stacey Fuhrer, and Dr. Peggy Mohr from the Department of Physical Therapy at the University of North Dakota

You are being invited to participate in this study of muscle activity during the drawback and hold phases of archery. The purpose of our study is to identify the muscle activity at the wrist and elbow recruited during drawback and hold phases of shooting, the specific timing of this recruitment, and the differences between compound and traditional bows in muscle activity. We hope that the results of this study will aid physical therapists in the rehabilitation and training of archers.

Five to ten subjects will be selected for this study. You were selected for this study because of your experience in archery (three archery tournaments over the past year), you have greater than five years of archery involvement, you are male, you have had no major arm injuries in the last year, and you are experienced with the equipment (compound bow with release aide and traditional/recurve bow).

Your participation in the study will take place at the UND Physical Therapy Department located in the Medical Science North Building and will last approximately two hours. Your age, height, and weight will be recorded. Electromyography and motion analysis will be used to collect the data. Electromyography involves using surface electrodes on the skin that are connected to a computer that records muscle activity. You will be asked to remove your shirt for the application of electrodes. The self-adhesive electrodes will be placed on the skin of your left and right arms. Excess hair on the arms will need to be clipped and the skin rubbed with an alcohol swab. Bow string angles will be video taped, and the video information will be converted to stickman diagrams. You will shoot six times each with the compound and traditional bow at a target.

Although the process of physical performance testing always involves some degree of risk, we feel that because of your prior training, the risk of injury or discomfort is minimal. Minor muscle soreness may result following the repeated activity. You will perform a brief warm-up prior to the testing procedure to decrease this risk. Arm protectors and shooting gloves will be available for your use or you have the option of
using your own gloves or tabs. Researchers will have been trained and have demonstrated competency in the use of standard EMG electrode protocol.

Your name will not be used in any results of this study. Any information that is obtained in this study and that can be identified with you will remain confidential. Only the investigators of this study will have access to the records. The data will be identified by numbers known only to the investigators. Records will be kept in a locked storage cabinet for three years following completion of the study, after which they will be destroyed. Your decision whether or not to participate won’t change your future relations with UND Physical Therapy Department. If you decide to participate, you may discontinue participation without prejudice at anytime until all data has been collected. You may stop the experiment if you experience pain, discomfort, fatigue, or any other symptoms that may be detrimental to you health. If it is determined that you have health issues that put you at risk for injury or you do not meet the inclusion criteria, you may be excluded from the study.

The investigators involved are available to answer any questions you may have concerning the study. You are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Dr. Peggy Mohr at 777-2831 or Jesse Fuhrer at 772-4347. At your request, you will be given a copy of this form for future reference. In the event that research activity results in physical injury, medical treatment will be available to you as it is to the general public. Payment for any such treatment must be provided by you and your third party payer.

All of my questions have been answered and I have been encouraged to ask any questions that I may have concerning the study in the future. I have read all of the above and willingly agree to participate in this study.

________________________________________
Signature                                      Date
APPENDIX B
SHOULDER - 47
Strengthening Activities: Active Resisted Horizontal Abduction

Using tubing, start with elbow straight and arm elevated parallel to floor. Pull arm across body through pain-free range of motion.

Repeat _____ times.
Do _____ sessions per day.

SHOULDER - 49
Strengthening Activities: Active Resisted Diagonal

Using tubing, start with arm across body, palm facing backward. Pull arm across body and over head so palm now faces forward.

Repeat _____ times.
Do _____ sessions per day.

SHOULDER - 88
PNF Strengthening with Tubing or Resistive Band

Standing with tubing or resistive band around each hand, bring one arm up and away with thumb pointing backward.

Repeat _____ times per set.
Do _____ sets per session.
Do _____ sessions per day.

SHOULDER - 89
PNF Strengthening with Tubing or Resistive Band

Standing with tubing or resistive band around each hand, bring one arm up and across body.

Repeat _____ times per set.
Do _____ sets per session.
Do _____ sessions per day.

HAND - 35
Active Resisted Elbow Flexion

With tubing wrapped around fist and other end secured under foot, curl arm up as far as possible. Lower slowly.

Repeat _____ times.
Do _____ sessions per day.

Using tubing, start with elbow straight and arm elevated parallel to floor. Pull arm across body through pain-free range of motion.

Repeat _____ times.
Do _____ sessions per day.
HAND - 30
Active Resisted Wrist Extension

With tubing wrapped around fist and other end secured under foot, bend wrist up (palm down) as far as possible. Lower slowly, keeping forearm on thigh.

Repeat _____ times.
Do _____ sessions per day.

HAND - 29
Active Resisted Wrist Flexion

With tubing wrapped around fist and other end secured under foot, bend wrist up (palm up) as far as possible. Lower slowly, keeping forearm on thigh.

Repeat _____ times.
Do _____ sessions per day.

HAND - 31
Active Resisted Radial Deviation

With tubing wrapped around fist and other end secured under foot, bend wrist up (thumb side up) as far as possible. Lower slowly, keeping forearm on thigh.

Repeat _____ times per session.
Do _____ sessions per day.

HAND - 32
Active Resisted Ulnar Deviation

With tubing wrapped around fist and other end secured under foot, bend wrist up (thumb side down) as far as possible. Lower slowly, keeping forearm braced on knee.

Repeat _____ times.
Do _____ sessions per day.
APPENDIX C
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

Date: May 9, 2000

Name: Peggy Mohr, Jesse Fuhrer, Stacey Goodman

Department/College: Physical Therapy

Project Number: IRB-200005-216

Project Title: Analysis of Wrist and Elbow Muscle Activity During Drawback and Hold in Compound Versus Traditional Bows in Experienced Archers

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on 5-11-00, and the following action was taken:

☑ Project approved. EXPEDITED REVIEW Category No. 4

Next scheduled review is on: 5-16-01

☐ Project approved. EXEMPT REVIEW 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: Peggy Mohr, Adviser
Chair, Physical Therapy
Dean, School of Medicine

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.
The purpose of our study is to identify the specific timing and the major muscles of the wrist and elbow recruited during drawback and hold phases of compound and traditional bows. We also want to see if there are differences between the two bows in this muscle recruitment. Electromyography and motion analysis provided by the Physical Therapy Department at the University of North Dakota will be used to collect the data. We expect to find differences in the timing of muscle activity between the two bows with the most activity occurring during the middle of the draw phase for the compound bow and following full draw for the traditional bow. Human subjects are required for us to determine which muscles are used during archery. There are few studies available that specify which muscles are used when shooting compound or traditional bows. As a result of this study, we hope to increase the effectiveness of treating patients with archery related injuries of the wrist and elbow.
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. Attach any surveys, tests, questionnaires, interview questions, examples of interview questions [if qualitative research], etc., the subjects will be asked to complete.)

Subjects:

 Five to ten males between the ages of 18 and 55 will be selected for this study. They will be recruited from the Red River Archer’s Club, experienced with both compound and traditional bows, have greater than five years of archery involvement, have no major arm injuries in the last twelve months, and have competed in three tournaments in the past year. Participation will be voluntary. The subjects will be given a consent form to read that contains information on what the study entails. Written consent will be obtained prior to subjects’ participation in the study.

Methods:

 The study will take place at the UND Physical Therapy Department. Prior to starting the trials, the subjects’ age, height, and weight will be recorded. Then they will perform a warm-up of ten repetitions of the draw movement using a resistive elastic band. The draw length for the compound bow will be measured and adjusted for each subject to ensure appropriate positioning. The subjects’ traditional bow draw length will also be measured and recorded. To record the EMG activity, self-adhesive electrodes will be placed on the skin over each muscle to be tested. Muscles of the wrist and elbow of the left and right arms will be recorded. Standard electrode placement charts will be used to determine the location. Researchers will have been trained and have demonstrated competency in the use of standard EMG electrode protocol. The area where the electrode will be placed may need to be clipped to remove excess hair and then cleansed with alcohol before the electrodes are placed on the skin.

 The EMG signals from the muscles will be transmitted to a receiver unit and then fed into a computer for display and recording of data. Video analysis will be used to record bow string angles. Reflective markers will be attached to the bow at different places to represent various axes in the sagittal plane.

 An on/off switch will be placed on the third finger of the draw arm. The subjects will be instructed to use normal shooting motion and stance for both bows. They will perform six drawback and release movements with each bow, shooting at a target approximately five feet away. Each subject will hold for three seconds with the compound bow and one second with the traditional bow. The bow weight will be set at fifty-five pounds for both bows which will facilitate injury prevention.

Data Analysis:

 An average of the EMG activity for a given time period will be calculated which will then be used to construct bar graphs that will show the average activity and percent differences for the trials. The presence of maximal muscle activity will be determined. An ensemble average will be computed for one drawing cycle for each subject, and then averaged to compute a grand mean ensemble for all of the subjects.
3. **BENEFITS:** (Describe the benefits to the individual or society.)

The study will help the investigators identify which muscles are used most during the “drawback and hold” component of the shooting process and how that differs with different bows. As a result of this study, we hope to provide information that may enhance the treatment of patients with archery related injuries of the wrist and elbow. The subjects of this study will benefit by learning which muscles must be trained for them to become better archers.

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, debriefing procedures, etc.)

Potential risks subjects may experience are minor muscle soreness and an adverse reaction to electrode application. All of the subjects in this study are experienced archers so there is minimal risk of an overuse injury. The participants will also be required to perform a warm-up prior to starting the trials to help decrease any risk of injury. Shooting gloves and arm protectors will also be available to the participants. Procedures to minimize adverse reaction to electrode application will be implemented, such as asking if the subjects are allergic to alcohol or latex.

The video information will be converted to stickman diagrams, so the actual subject’s video will not be used in data reporting. Data retrieval will be made only by the researchers of this study and assurance of confidentiality was stated in the consent form. The subjects’ names will not be used in any reports of the results of this study. Any information that is obtained with this study and that can be identified with the subject will remain confidential. The data will be coded with numbers known only by the investigators. Consent forms and data collected will be locked in Dr. Peggy Mohr’s office for a period of three years after the completion of the study and then will be shredded. Only the researchers of this study will have access to the records.
5. **CONSENT FORM:** Attach a copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject. 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 and data will be kept for the required 3 years, including plans for final disposition or destruction.

Consent forms will be kept in Dr. Peggy Mohr’s office for a period of three years after the completion of the study. After this time, they will be destroyed.

6. For **FULL IRB REVIEW** forward a signed original and fifteen (15) copies of this completed form, including fifteen (15) copies of the proposed consent form, questionnaires, examples of interview questions, 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 off at Room 105 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original, including a copy of the consent form, questionnaires, examples of interview questions, 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:**

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jesse Turkes</td>
<td>4/19/00</td>
</tr>
<tr>
<td>Shelly Goodman</td>
<td></td>
</tr>
<tr>
<td>Peggy Mohr</td>
<td>4/19/00</td>
</tr>
<tr>
<td>(Project Director or Student Adviser)</td>
<td></td>
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Training or Center Grant Director

(Revised 4/1998)
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 Analysis of Wrist and Elbow Muscle Activity During Drawback and Hold in Compound Versus Traditional Bow in Experienced Archers.

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: 4-13-00

Signature of Student Researcher: [Signature]

1Consent required by 20 U.S.C. 1232g.
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 Analysis of Wrist and Elbow Muscle Activity during Drawback and Hold in Compound versus Traditional Bows in Experienced Archers.

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4/13/00
Date

Sally Goodman
Signature of Student Researcher

1Consent required by 20 U.S.C. 1232g.
APPENDIX D
You have our permission to use the pic of our Hatfield Take Down from the Martin archery website.

George D. Ryals IV
Advertising Director
Product Development
Martin Archery
Jesse and Stacy,

Thank you for your e-mail. Sounds like a fun Thesis project. First of all we appreciate you contacting us to make sure it would be okay to use our bow. I give you full permission to use any images you need off of our website for your thesis project.

Best of luck with the project!

Mike

-----Original Message-----
From: jfuhrer@medicine.nodak.edu [SMTP:jfuhrer@medicine.nodak.edu]
Sent: Friday, September 01, 2000 1:33 PM
To: msl@hoytusa.com
Subject: bow

September 1, 2000

Dear Mike Luper,

We are writing our masters thesis for physical therapy on the muscles used while drawing a compound and traditional bow. The compound bow that we used in our study was a 2000 Hoyt Raider Intruder. We are requesting your permission to use a picture of this bow from your website at www.hoytusa.com/products/compound/raider.htm.

We would like to label the picture with the different parts of the bow, such as limb, cam, and string. The picture would be included in our final thesis which will be reprinted and placed in the Medical Library here at the University of North Dakota.

Thank you for your consideration in this matter.

Sincerely,

Jesse Fuhrer, SPT  jfuhrer@medicine.nodak.edu
Stacey Fuhrer, SPT
REFERENCES


