2000

An Electromyographic and Video Motion Analysis Study of the Drawback and Hold Phases of a Compound Bow versus a Traditional Bow in Experienced Archers

Andrea L. Vagle
University of North Dakota

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AN ELECTROMYOGRAPHIC AND VIDEO MOTION ANALYSIS STUDY OF THE DRAWBACK AND HOLD PHASES OF A COMPOUND BOW VERSUS A TRADITIONAL BOW IN EXPERIENCED ARCHERS

by

Andrea L. Vagle
Bachelor of Science in Physical Therapy
University of North Dakota, 1999

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

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

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title An Electromyographic and Video Motion Analysis Study of the Drawback and Hold Phases of a Compound Bow versus a Traditional Bow in Experienced Archers

Department Physical Therapy

Degree Master of Physical Therapy

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Signature

Date 12-9-99
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ACKNOWLEDGEMENTS

First, I would like to thank Tom Mohr for his assistance in completing this project and his dedication to the Physical Therapy students at the University of North Dakota. I would also like to thank my partner in this project, and my future partner in life, Jason Brodina. Our ability to support each other through the past two years and complete this project together only strengthens my faith in our future as husband and wife. Thank you.

A sincere appreciation also goes out to the members of the Red River Archers who donated their time to be subjects for this study. Without them, this is just a literature review.

To Dustin, thank you for all your patience during the hours spent hooked up with electrodes in a small, hot room...You're the best! Also, thanks to Marc Sondreal for helping us with running our subjects and for being such a wonderful friend the past three years.

Thanks to Scheels and Jesse Berthold who allowed us to utilize the bows for our study. And, thank you to David Cole, creator of Bowfit, who further inspired and motivated us to pursue this study.

And finally, a special thank you to Mom and Dad for unconditionally supporting all my dreams and goals. Without your love, encouragement, and guidance I would not have made it this far. Thank you.
ABSTRACT

Background/Purpose: Archery is quickly becoming an increasingly popular sport, with limited research in the training and rehabilitation of archers. The purpose of this study is to identify the major muscles and timing of recruitment during the drawback and hold of a bow, and to determine the presence of differences in this recruitment between a compound and traditional bow. Subjects/Methods: Seven males between the ages of 36 to 51 years of age completed 6 drawbacks each with a compound bow and a traditional bow. Surface electrodes on the subjects and reflective markers on the bow were used to analyze electromyographic activity of 12 muscles and calculate bowstring angles during the drawback and hold phases of shooting a bow. The following muscles were analyzed: 1) right posterior deltoid, 2) right middle deltoid, 3) right teres major, 4) right triceps brachii, 5) right biceps brachii, 6) right brachioradialis, 7) left middle trapezius, 8) right middle trapezius, 9) left middle deltoid, 10) left posterior deltoid, 11) left triceps brachii, and the 12) left brachioradialis. A descriptive analysis was then performed comparing the two bows. Results: 1) The compound bow requires the greatest muscle activity during the middle of the drawing phase. 2) The traditional bow requires the greatest muscle activity following the point of full draw. Conclusion: Most muscles demonstrated a considerable distinction between the two bows. Decreased muscle activity was generated following let-off to full draw in the compound bow when comparing it to a traditional bow. The traditional bow required heightened activity during full draw.
CHAPTER I
INTRODUCTION

Archery has been in existence for many centuries, dating back to the Ancient Egyptians\(^1\). Being used in wars, hunting, and as a recreational sport, it has grown increasingly popular, established as an Olympic sport in 1972\(^{1,2,3}\). Since then, technology has increased the sophistication of archery equipment. Each year more efficient and advanced bows are designed and manufactured. The compound bow is the most popular bow utilized. However, many archers continue to practice with the traditional bows, referred to as the recurve or longbow. Because the act of shooting a bow requires significant upper extremity activity and strength, patients with shoulder problems may have pain or difficulty when drawing the bow.

Definitions

For the purpose of this study, the following terms are defined.

**Draw (Drawback):** The term used for pulling the bowstring back.

**Draw Length:** Measurement of the distance an archer draws the bow.

**Full Draw:** The maximum draw length of the bow, before the release of the arrow.

**Holding Weight:** The weight or poundage the archer holds at full draw. Measured in pounds.

**Let-off:** The reduction in holding weight when compared to the peak weight. Measured as a percentage of the peak weight. (usually 50-80%)
Peak Weight: The amount of force it takes to pull the bowstring back to a full draw position. Measured in pounds.

Problem Statement

To our knowledge, there have been limited scientific studies regarding the muscles that are recruited in archery. In addition, no studies are available comparing the recruitment of musculature between the draw back and hold of the compound versus a traditional bow. It is our hope that by identifying these muscles and their varying recruitment, injured archers and physical therapists will be able to work together to more effectively and efficiently rehabilitate. Also, engineers designing new bows will have a better understanding of the human musculature as it correlates with the shooting of a bow.

Purpose

The purpose of this study is to: 1) identify the major muscles recruited, 2) the specific timing of this recruitment, during the drawback and hold of a bow, and 3) to determine the presence of differences in this recruitment between a compound and a traditional bow.

Significance

Many injuries have been documented to result from or be aggravated by participation in archery\(^1,2\). Physical therapists employed in communities supporting archery have an increased probability of coming into contact with such injuries. We hope the results of this study help physical therapists develop a training protocol for archers who have upper extremity weakness and who require a program as a part of their rehabilitation.
Research Questions

1.) “What are the major muscles recruited from the upper arm and shoulder during the draw back and hold phases of a compound bow?”

2.) “What are the major muscles recruited from the upper arm and shoulder during the draw back and hold phases of a traditional bow?”

3.) “At what point during the draw back and hold phases are these muscles recruited using a compound bow?”

4.) “At what point during the draw back and hold phases are these muscles recruited using a traditional bow?”

Hypotheses

Null hypothesis: “There is no significant difference in muscle activity between a compound bow and a traditional bow.”

Alternate hypothesis: “There is a significant difference in muscle activity between a compound bow and a traditional bow.”
CHAPTER II

REVIEW OF THE LITERATURE

Although the Ancient Egyptians and Native Americans were proficient in its use for hunting and weaponry, only in recent decades has archery become well known. As a result, research and literature consisting of scientific rationale and explanation regarding muscular activity is quite limited.

The compound bow is the most frequently used bow in the present literature. The compound bow works on cam wheels called eccentrics, with an off center axle. These wheels make the bow easier to draw. During the draw of the bow, the peak weight is transferred from the bowstring to the cables, creating the let-off, and decreasing the holding weight to less then the peak weight. Another bow used by many archers is the recurve, a traditional type bow. The recurve grants no mechanical assistance to the archer, causing the holding weight to equal the peak weight (Figures 1 and 2).

There are four recognized and briefly researched grips utilized in archery. Of the more customary is the 3 finger grip (index, long, and ring finger) with the forearm in neutral. The two finger grip employs the long and ring fingers to draw. Symptoms of pain in the bilateral medial epicondyles were present in a 34 year old hobby archer who frequently used the two finger grip. Using the three finger grip instead of two may decrease the concentrated force on this area. In addition, grips referred to as the thumb...
Figure 1. Compound bow. Circles indicate the placement of the reflective markers.
Figure 2. Traditional bow. Circles indicate the placement of the reflective markers.
grip and reversed grip, although rarely utilized and difficult to master, may decrease the force in the area of the medial epicondyle.

Motions for proper shooting form traditionally begin with raising the bow to the target, resulting in $90^\circ$ of drawing arm shoulder abduction and $135^\circ$ of horizontal adduction of the drawing arm$^2$. At this moment, the tendons of the subscapularis and long head of the biceps brachii are compressed under the coracoacromial arch. The infraspinatus and teres minor are on stretch. The draw should be straight back, into horizontal abduction, maintaining the drawing arm parallel to the ground. As a result, the supraspinatus and long head of the biceps brachii are in contact with the inferior surface of the coracoacromial arch. At full draw, the tendon of the supraspinatus is increasingly vulnerable to impingement under the coracoacromial arch. Also, during horizontal abduction, strain is imposed upon the external rotators of the shoulder girdle, namely the infraspinatus and teres minor. During a four day tournament, one-third of all archers exhibited a tenderness to palpation of the posterior shoulder, which includes this musculature.

At the point of full draw there is a combined push-pull contraction of the muscles in and stabilizing and drawing arm$^5$. Figures 3-5 illustrate the beginning and full draw of each bow, accomplished by the stabilizing arm pushing and the drawing arm pulling, until the release. Note that the end position (full draw) of the two bows is approximately the same. In seven male varsity archers the mean power frequency (MPF) of the deltoid was found to decrease during the prolonged push-pull, assumed to be caused by muscular fatigue, leading to injury and diminishing performance. This is due to the deltoid’s proposed responsibility for shoulder joint stability. Three solutions were proposed for
Figure 3. Beginning of the draw phase of the compound bow.
Figure 4. Beginning of the draw phase of the traditional bow.
Figure 5. The end of the draw phase; full draw (compound bow shown).
improving performance and reducing injury: 1) decreasing the bow’s power, 2)
improving maximum force of the archer through appropriate training, and 3) dampening
the bow’s vibration caused by the muscle tremor on fatigue. It was noted that many of the
top archers reduce fatigue by minimizing the push-pull duration.

One must differentiate between acute and chronic injuries in archery. Common
acute injuries have been described as lacerations, contusions, and compression
neuropathy. Chronic injuries include medial epicondylitis, DeQuervains tenosynovitis,
Median nerve compression, impingement syndrome, rotator cuff tendonitis, bicipital
tendonitis, bursitis, recurrent subluxation, and dislocation disorders. Much of the
blame for chronic injuries lies in a lack of neuromuscular training and prevention. As a
result, the timing and intensity of muscle recruitment is important to research in order to
properly treat, educate, and prevent these disorders.

Limited studies utilizing electromyographic (EMG) analysis have been done
regarding archery injuries and muscular recruitment. In a study of 21 male and female
elite archers, a questionnaire and physical exam were used to investigate past and present
archery related shoulder injuries. Women were found to present with more injuries to
their drawing arm shoulder than men. The overall injury rate was 26% with females
demonstrating a 56% injury rate. To explain this, it was suggested that it was because the
strength of women was 67% that of men. Although eight out of the nine females tested
claimed regular participation in an archery specific exercise program, it was uncertain
whether the exercise program was adequately designed or performed properly. Lower
poundage or progressive resistive strength training designed and correctly performed
specific to archery was recommended.
Mann and Littke² examined the posterior girdle of both archers and cadaver specimens. The cadavers were manually brought through the range of motion necessary for archery and the pertinent structures were examined. Following the examination, the posterior shoulder girdle was found to be the most common problem area in the cadavers and in archers. The muscles involved were the infraspinatous and teres minor. A rotator cuff injury or deficiency can cause instability and other insufficiencies that may lead to continued weakness and re-injury. Prevention was the best treatment choice. Prevention can be achieved via instruction on proper technique, which includes avoiding any extra elbow/shoulder movement during drawing. Such actions aggravate structures under the coracoacromial arch. Muscular conditioning is also important. A proposed weight program, previously successful in professional baseball, should focus on strengthening the supraspinatous, infraspinatous, and teres minor. The distinct and repetitive force is focused at the shoulder and forearm flexors (at their origin or medial epicondyle) of the drawing arm¹,². These muscles are vulnerable to cumulative stresses and trauma, as is the median nerve to compression under the origin of the flexor digitorum superficialis¹.

In a study comparing the muscular activity of Olympic athletes, national competitors, and beginners, ten muscles in the upper extremities were monitored via EMG⁴. One of the major factors in discriminating performance was found to be the ability to reproduce identical muscle patterns at the time of release; the stability and neuromuscular control of the trapezius during the initial draw, biceps brachii during full draw, and extensor digitorum in the release phase. The trapezius is responsible for initial draw to elevate the arm and scapula and upwardly rotate the scapula. The importance of the deltoid and trapezius have been emphasized in a number of studies⁴,⁵,⁶. In addition to
being activated at the time of release, the extensor digitorum has been found to be active in full draw\textsuperscript{3}. Discrepancies in muscle intensity were found between the Olympic archers and the other two groups (beginners and national archers)\textsuperscript{4}. These intensities differed significantly in the trapezius, extensor digitorum, and biceps brachii of the drawing arm. Additional results of muscular analysis in archery by various authors and a pilot study by the current authors, are outlined in Tables 1 and 2.

Clarys et al.\textsuperscript{4} set out to determine the level of muscular activity represented with increased shooting distance. Following integrated EMG analysis of both extremities at varying distances, the brachioradialis was found to be the most consistent in intensity. This brachioradialis muscular activity was found to significantly decrease in a reversed grip with the forearm pronated. A confirmation of shoulder muscles initiating draw movement was solidified by the trapezius, revealing the earliest contraction in both extremities. Overall, each of the six upper extremity muscles tested showed a specific pattern, unaffected by increased shooting distance.

**Present Study**

The intent of this research and analysis is to ascertain the muscle activity present in archery and display the distinction of such activity between two styles of bows. In addition, I intend to educate those involved in the prevention or rehabilitation of injuries resulting from archery, and prompt further research in the sport. In anticipation of the results, I expect there to be significant differences in muscle timing and intensity, however, few differences in the actual muscles recruited, between a compound and traditional bow. As a result, it is presumed that, although the same muscles must be
trained for archery, the method in which to properly accomplish this is unique to each bow.
Table 1. Previous findings in literature of muscles utilized in stabilizing (left) arm.

<table>
<thead>
<tr>
<th></th>
<th>Middle Trapezius</th>
<th>Lower Trapezius</th>
<th>Serratus Anterior</th>
<th>Anterior Deltoid</th>
<th>Pectoralis Major</th>
<th>Middle Deltoid</th>
<th>Posterior Deltoid</th>
<th>Teres Minor</th>
<th>Infra-spinatus</th>
<th>Triceps Brachii</th>
<th>Brachioradialis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountsford S, Ainsley J.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>NT</td>
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<td>Clarys et al.</td>
<td>NT</td>
<td>X</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>X</td>
<td>X</td>
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<td>Zipp</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
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<td>Y</td>
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<td>X</td>
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</tr>
<tr>
<td>(Traditional Bow)</td>
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</tr>
</tbody>
</table>

Legend:
X = maximum recruitment
Y = minimum recruitment
0 = no significant recruitment
NT = not tested
Table 2. Previous findings in literature of muscles utilized in the drawing (right) arm.

<table>
<thead>
<tr>
<th></th>
<th>Middle Trapezius</th>
<th>Lower Trapezius</th>
<th>Serratus Anterior</th>
<th>Anterior Deltoid</th>
<th>Middle Deltoid</th>
<th>Posterior Deltoid</th>
<th>Triceps Brachii</th>
<th>Brachioradialis</th>
<th>Teres Major</th>
<th>Biceps Brachii</th>
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<tbody>
<tr>
<td>Mountford S. Ainsley J.(^7)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>Zipp(^6)</td>
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<tr>
<td>Pilot Study (Traditional Bow)</td>
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<td>NT</td>
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<td>X</td>
<td>X</td>
<td>Y</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Legend:
X = maximum recruitment
Y = minimum recruitment
0 = no significant recruitment
NT = not tested
CHAPTER III
METHODS

Subjects

Seven men ranging in age from 36 to 51 (X = 44.9) were selected for this study. Heights ranged from 69” to 74” (X = 70.4”) and weights from 195 to 270 lbs. (X = 225.9 lbs.). All subjects competed in 3 archery tournaments in the previous 12 months, have had no major upper extremity injury within the last 12 months, are experienced in both compound and traditional bow, and are right handed. The subjects were selected based on their membership in the Red River Archers archery club and their participation in state and national competition. Each subject in this study signed a consent form verifying their willingness and ability to participate.

Instrumentation

Electromyography

The electromyographic information was collected by a Noraxon Telemyo 8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ 85254). This information was then sent to a Noraxon Telemyo 8 receiver and then digitized by an analog digital interface board in the Peak Analog Module (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO 80112-9765). The video data and the electromyographic data were synchronized using the Peak Event Synchronization Unit. To start the EMG data collection, the synchronization unit was
triggered by a switch on the palmar surface of the middle and distal phalanx of the third digit.

**Video**

Three reflective markers were placed on each bow to represent various axes in the sagittal plane. The exact placement of each marker is detailed depicted in Figures 1 and 2. The camera used to film the archery activity was a Peak High Speed Video 60/120 Hz camera (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO 80112-9765). A camera frequency of 60 Hz was utilized during the trials with a shutter speed of 1/250 of a second. The trials were taped on a JVC model BR-S378U video cassette recorder (JVC of America, 41 Slater Drive, Elmoood Park, MF 07407). The video tape was encoded with a SMPTE time code generator. A two dimensional system was used, with one camera. In a study driven by J. Selfe, it was suggested that the Peak 5 provides valid angular and angular velocity data when compared to other measuring devices. Bratton and Ross found interoperator error to be very low on the Peak 5 system. Between two examiners, measurements were highly correlated ($r = 0.991$).

After recording all the trials, the subjects' movements were digitized using the Peak Motus Software package. The tapes were played back on a Sanyo Model GVR-S955 (Sanyo, 1200 W. Artesia Boulevard, Campton, CA 90220) video cassette recorder for the purpose of digitization.

**Bows**

The compound bow utilized was a 1999 Hoyt Raider Powerflex with a variable draw length of 28” to 31.5” and variable draw weight of 55 to 70 lbs. The percent let-off
for this bow is 75%. The traditional/recurve bow used was a 1999 Martin Hatfield Takedown with a 55 lb. draw weight at a 28” draw length. A shooting glove and arm guard were provided with the subjects being given the option to use their own glove or tab.

Procedure

Initially, the subjects were brought to the preparatory area. The consent forms were reviewed and signed and the age, height, and weight of each subject was recorded. As a warm-up exercise, ten repetitions of the draw movement of a bow were performed by all subjects with a blue theraband for resistance. The subjects’ draw length for the compound bow was measured and adjusted accordingly. The compound bow draw weight was then set to 55 lbs. The subjects’ recurve draw length was measured and recorded. The skin attachment sites for the ground and surface electrodes were shaved (if necessary) and thoroughly cleaned with rubbing alcohol. The EMG electrodes were placed on the muscles shown on Figure 6. Electrode placement was verified by isometric contraction of each muscle and by observing the raw EMG signal when the subject performed an isometric contraction. The ground electrodes were placed on the superior aspect of the left and right acromion. Finally, an on/off switch was applied on the middle and distal phalanx of the third digit. All subjects completed approximately six drawbacks and releases with each bow, utilizing a foam target at approximately five feet. The subjects were instructed to hold the compound bow at full draw for three seconds and the recurve bow for one second using a metronome, which was set at a one second interval, for reference. They were also reminded to use their normal shooting motion and stance for both bows.
**Biceps Brachii** - over the muscle belly, 1/2 distance up from the bottom of a line drawn from the acromion to cubital fossa

**Brachioradialis** - over the muscle belly, with hand pronated, 1/4 of the distance from the elbow crease to the radial styloid process

**Triceps Brachii** - over the muscle belly, 1/3 the distance up on a line drawn from the olecanon to the acromion process

**Posterior Deltoid** - over the muscle belly, 1/5 the distance from the acromion to lat. Epicondyle of humerus

**Middle Deltoid** - over the muscle belly, 1/4 the distance from the acromion to the lateral epicondyle

**Middle Trapezius** - over the muscle belly, midway between the scapula and thoracic spine, 1/2 the distance from T1 to T7

**Teres Major** - over the muscle belly, 1/2 half the distance between inferior angle of the scapula and mid-axilla

---

**Figure 6. Electrode placements.**
Data Analysis

Prior to videotaping, the camera was calibrated by videotaping a meter stick. Then the video footage for each archery trial was calibrated in meters, cropped to the first trial, and digitized using the Peak system. The software calculated the bow angle and segmental motion. The raw analog EMG data was scaled and matched to the video. Reports were then generated to show bowstring angle and matched integrated EMG data for each trial.

The integrated EMG data was quantitatively processed using the Peak Motus software program. An ensemble average was computed for two drawing cycles for each subject shooting with each bow. The ensemble average was computed by sampling the EMG activity of an drawing cycle at 0.5 percent intervals. The ensemble average was computed for one cycle, for each subject, with the averaged curves for each subject added together to yield a grand mean curve representative of all the subjects. The qualitative analysis and timing of the muscle activity was determined from the grand mean, ensemble average curves for each muscle.

The EMG scaled matched data was exported for further quantitative analysis to MyoResearch Software (Noraxon USA, 13430 N. Scottsdale Rd., Scottsdale, AZ, 85254). The MyoResearch software was used to calculate an average of the EMG activity over the time period (i.e. start to release or start to full draw). This average activity was then exported to Excel (Microsoft Corp, One Microsoft Way, Redmond, WA, 98052). The Excel spreadsheet program was used to construct bar graphs showing the average activity and percent differences for the trials.
The Excel spreadsheet was also used to calculate the presence of maximal activity in each of the muscles during the trials. The muscle activation was graded as maximal, in relation to the peak level of averaged EMG activity that occurred during the drawing cycle. Maximal activation was defined as 66.6-100% of peak muscle activity.

The bow angle was processed similar to the EMG data. That is, an ensemble average was computed for one drawing cycles for each subject, and then averaged to compute a grand mean ensemble average for all of the subjects. Due to the small sample size, statistical testing was not performed.
CHAPTER IV

RESULTS

Ensemble averaged EMG activity for all twelve muscles with the compound and traditional bow are shown in Figures 7-10 and 12-15. Figures 11 and 16 display a mean of muscle activity, in microvolts (µV), for each stage of the draw back and hold phases of the bow.

The muscle activity in figures 7-10 depict the entire action from start to release of both bows. Full draw of the two bows differ in relation to percentage of time. The compound bow's full draw is at 29% and full draw of the traditional bow is at 59%. Overall, the muscle activity in all twelve muscles is greater in the traditional bow when compared to the compound bow. When each muscle is compared individually, using the compound and traditional bow, the muscle activity in the initial stages of the drawback are similar. An exception is apparent in the right brachioradialis, with the traditional bow showing more activity at initiation of the drawing phase. Figure 11 shows that the overall largest muscle activity difference (in percent difference) between the two bows, from start to release, was in the right brachioradialis, right teres major, and left triceps brachii and the least was in the left brachioradialis and left middle deltoid. The compound bow muscle activity appears to peak in the early to middle stages of start to release cycle, whereas the traditional bow appears to show peak muscle activity from the middle to late.
stages. Further results regarding peak muscle activity periods for each muscle of the two bows are illustrated in Table 3.

Figures 12-15, depicting start to full draw, show that following let-off of the compound bow, most of the muscles show a gradual decrease in activity. However, with the left brachioradialis, there is no activity change evident at let-off in the compound bow.

Table 3. Period of peak activity for each muscle tested during start to release of the compound and traditional bows. Period expressed as a percentage of time.

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Compound Bow</th>
<th>Traditional Bow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Posterior Deltoid</td>
<td>10-39%</td>
<td>65-98.5%</td>
</tr>
<tr>
<td>Right Biceps Brachii</td>
<td>5-17.5%</td>
<td>None</td>
</tr>
<tr>
<td>Right Triceps Brachii</td>
<td>4-24.5%</td>
<td>None</td>
</tr>
<tr>
<td>Right Brachioradialis</td>
<td>6.5-24.5%</td>
<td>22-97.5%</td>
</tr>
<tr>
<td>Right Teres Major</td>
<td>9-33%</td>
<td>51.5-99%</td>
</tr>
<tr>
<td>Right Middle Deltoid</td>
<td>8-36%</td>
<td>43-100%</td>
</tr>
<tr>
<td>Left Brachioradialis</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Right Middle Trapezius</td>
<td>12.5-53%</td>
<td>43-98.5%</td>
</tr>
<tr>
<td>Left Middle Trapezius</td>
<td>5.5-28%</td>
<td>53-99%</td>
</tr>
<tr>
<td>Left Triceps Brachii</td>
<td>2.5-23.5%</td>
<td>41-99.5%</td>
</tr>
<tr>
<td>Left Posterior Deltoid</td>
<td>9-26%</td>
<td>64-99%</td>
</tr>
<tr>
<td>Left Middle Deltoid</td>
<td>12.5-30.5%</td>
<td>27-98.5%</td>
</tr>
</tbody>
</table>
bow. The greatest muscle activity difference from 0%-20% between the two bows was in the right brachioradialis and the smallest amount of difference was in the left brachioradialis. From 70% to 100% the largest muscle activity difference was in the right brachioradialis and Left Triceps and the least amount of difference was in the left brachioradialis. Figure 16 shows activity from start to full draw. When compared to the traditional bow, greater muscle activity of the compound bow was evident in the right triceps brachii, left brachioradialis, left middle trapezius, left posterior deltoid, and left middle deltoid. In the case of all other muscles, the traditional bow required more activity from start to full draw. The greatest percentage difference in average muscle activity of the drawing phase between the two bows was in the right middle trapezius, and the least was in the left middle trapezius.

Overall, from start to release, the compound bow's greatest activity level was from 0% to 20-26% of the drawing phase, decreasing following the point of let-off. In contrast, the muscle activity in the traditional bow was highest during the hold phase.
Figure 7. Ensemble averaged kinematic and electromyographic data from start to release of the drawing and hold phases; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and release of both bows.
Figure 8. Ensemble averaged kinematic and electromyographic data from start to release of the drawing and hold phases; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and release of both bows.
Figure 9. Ensemble averaged kinematic and electromyographic data from start to release of the drawing and hold phases, compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and release of both bows.
Figure 10. Ensemble averaged kinematic and electromyographic data from start to release of the drawing and hold phases; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and release of both bows.
Figure 11. Average muscle activity from start to release of the compound and traditional bow. Percentages reflect the activity difference between the bows.
Figure 12. Ensemble averaged kinematic and electromyographic data from start to full draw of the drawing phase; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and full draw of both bows.
Figure 13. Ensemble averaged kinematic and electromyographic data from start to full draw of the drawing phase; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and full draw of both bows.
Figure 14. Ensemble averaged kinematic and electromyographic data from start to full draw of the drawing phase; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and full draw of both bows.
Figure 15. Ensemble averaged kinematic and electromyographic data from start to full draw of the drawing phase; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and full draw of both bows.
Figure 16. Average muscle activity from start to full draw of the compound and traditional bow. Percentages reflect the difference in muscle activity between the bows.
Chapter V

DISCUSSION

Due to the presence of let-off in the compound bow and its absence in the traditional bow (peak weight equals holding weight), higher muscle activity was expected throughout the activity, from start to release, with the traditional bow. It was also expected, due to the let-off of the compound bow, that after this portion of the drawing phase, the musculature activity in the compound bow would decrease in comparison to the traditional bow musculature, which would increase or stay constant throughout the entire hold phase.

Start to Release

When comparing the brachioradialis muscle activity on the left and right, the right brachioradialis shows a greater increase in muscle activity than the left brachioradialis, from start to release. The only substantial activity of the left brachioradialis found in the present study was seen at release where its peak activity occurred. We propose that the actual moments of peak activity occur at the release to prevent the bow from falling toward the ground. See Figure 17 for further discussion of this hypothesis. In relation to this concept, the traditional bow's left brachioradialis fires more than the compound bow's left brachioradialis at the point of release. This is presumed due to the increased energy produced by the flexible limbs of the traditional bow. The limbs of the traditional bow recoil with more force than the compound bow. This places a higher degree of quick stretch on the left brachioradialis, incorporating more activity from this muscle to keep
Figure 17. Model of left brachioradialis peak muscle activity at release. Two theories to explain this activity. 1) As the arrow is released, the resultant force and direction of rotation provided by the force from the arrow, causes a quick stretch to the elbow flexors, in this case, the left brachioradialis. This stretch stimulates the left brachioradialis to contract to prevent the bow from falling toward the ground. 2) At release, the elbow flexion moment is lost. Yet, the left triceps brachii continues to contract, pulling the left elbow into extension. This causes a quick stretch on the left brachioradialis, causing it to contract.
the traditional bow upright. The minimal overall muscle activity apparent in the left brachioradialis may be due to the theory of reciprocal inhibition. Because the elbow extensors are firing to extend the left arm, the elbow flexors (left brachioradialis) are, in effect, inhibited.

The greatest percent difference in muscle activity from start to release between bows was in the right teres major, right brachioradialis, and left triceps brachii. The right teres major showed the greatest percent difference between bows, from start to release, at 119.6%. An explanation for this might have to do with the teres major's role in stabilizing the scapula with the upper extremity in abduction, and the fact that it is active as a shoulder extensor. Its activity is consequently decreased as a result of the diminished holding weight in the compound bow. The right brachioradialis showed a 116.9% difference in average muscle activity between bows, most likely due to the let-off of the compound bow and the resultant decrease in elbow flexion force required after let-off. The left triceps brachii also displays a considerable percent difference in average muscle activity between the two bows, at 111.9%. Our assumption is that the traditional bow requires more activity from the left triceps brachii due to the push-pull theory described by Leroyer, Van Hoecke, and Helal. In order to prevent extraneous movement of the bow, the left triceps brachii must extend the arm with a force equal and opposite to that of the right arm, which is pulling back on the bowstring. As a consequence, the decrease in the draw weight following let-off of the compound bow results in the diminished muscle activity in the left triceps brachii.

The smallest percent difference in average muscle activity between the two bows was in the left middle deltoid, from start to release, at 30.9%. Although this muscle is
active in holding the bow up and stabilizing the shoulder with the arm in abduction, it may play a decreased role in the push-pull mechanism of drawing the bowstring.

The middle and posterior deltoid of the drawing arm also play a role in stabilizing and horizontally abducting the shoulder during the draw back. Their activity also illustrates the presence of let-off in the compound bow. Muscle activity increases in both bows until let-off, when the muscle activity with the compound bow decreases. We propose that increased muscle activity is required with the traditional bow due to the absence of let-off.

**Start to Full Draw**

Higher average muscle activity from start to full draw was observed in the left middle trapezius, left brachioradialis, right triceps brachii, left middle deltoid, and left posterior deltoid with the compound bow. Although the percent differences are small, they were not anticipated. Excluding the left brachioradialis and its relative inactivity, the remaining four muscles exhibit a decrease in muscular activity with the compound bow, from let-off to full draw. Throughout start to full draw the apparent similarity in uV of activity between both bows in the left brachioradialis is likely due to its primary role in maintaining neutral position of the forearm, having little to do with the effect of let-off. All four of the remaining muscles elicit a higher muscular activity from approximately 30% of the drawing phase to let-off, when compared to the traditional bow. This is probably due to the peak weight of the compound bow occurring during the previously mentioned phase, 30% to let-off.

The right brachioradialis was the muscle that showed the greatest difference in activity at initiation of the draw phase, between bows. A potential rationale for this
finding could be related to the start position of the bows, as discussed in the literature review (See figures 3 and 4). In the case of the traditional bow, the right brachioradialis is in a more advantageous position to initiate and achieve elbow flexion, as the forearm begins in a more neutral posture in relation to the upper arm. With the compound bow, the forearm begins in supinated position in relation to the upper arm, decreasing the mechanical advantage of the right brachioradialis and likely increasing the recruitment of the right biceps brachii to initiate elbow flexion.

The right middle trapezius produced the greatest percent difference in average muscle activity during start to full draw, at 16.5%. The main function of the right middle trapezius is to adduct the scapula. We suggest that this muscle must stabilize the scapula in adduction in response to the peak draw weight of the bow. Because the compound bow's holding weight (holding weight less than peak weight) is less than that of the traditional bow (holding weight equals peak weight), it requires less force from the right middle trapezius to stabilize the scapula at the end of drawing phase, at full draw. The smallest percent difference in average muscle activity from start to full draw was in the left middle trapezius, at 1.4%. The middle trapezius adducts the scapula. Since the goal of the stabilizing arm is to brace the scapula in slight abduction, avoiding scapular adduction, we believe that it is relatively insignificant. It is affected very little by the difference in the two styles of bows.

Limitations

There are a number of limitations which may have influenced the results of this study. First, the small number of subjects participating in this study may not sufficiently represent all trained archers experienced with the traditional and compound bow.
Secondly, reaching a conclusion regarding the most active muscles in archery is not possible because the maximum voluntary contraction (MVC) for each muscle was not determined. Therefore, we were unable to state whether a muscle was maximally active, and whether one muscle was more active than another, during the drawback and hold phases. A solution for this problem would be to record a baseline of muscle activity and MVC in future studies. This leads us to the third limitation. We were unable to adequately compare our findings to the previous literature. All the previous literature have compared muscles and their relative activity in archery. There are no studies that we know of which have compared the muscle activity between a compound bow and traditional bow.

A two-dimensional, one camera view was used in this study for motion analysis. A second camera from above may have allowed us to relate the muscle activity to the movement of the upper extremity, rather than the bow itself. The trials of each bow differed in the amount of time elapsed from start to full draw and start to release. As a result, there was increased variability when the trials from each subject were averaged. And finally, because of the many muscles involved in the trunk and upper extremity in archery and the inability to sufficiently record specific muscular activity without interference from other musculature (rhomboids, supraspinatus, serratus anterior), the potential need for adequately analyzing additional muscles is suggested in future research.

Conclusion

The compound bow requires the greatest muscle activity during the middle of the drawing phase. The traditional bow requires the greatest muscle activity following the

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point of full draw, the hold phase. Most muscles demonstrate a considerable distinction between the two bows during the hold phase. The left brachioradialis is only slightly affected by the variations of the two styles of bows.

**Clinical Implications**

The results of this study indicate that decreased muscle activity is generated following let-off to full draw in the compound bow when comparing it to a traditional bow. Although both bows require sufficient musculature for an isometric hold at full draw, it is apparent that the traditional bow requires heightened activity during this period. This suggests that, when strengthening for the use of a compound bow, a training program for the involved muscles should occur at ranges of motion mimicking start to let-off. Training for a traditional bow may also involve strengthening during the initial draw but may stress isometric strengthening of the involved muscles at the end range of movement. This training should be included as a critical component in archery instruction or rehabilitation to strengthen, prevent injury, and enhance accuracy in the beginning or experienced archer.
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

DATE: May 7, 1999  PROJECT NUMBER: IRB-9905-235

NAME: Jason Brodina  DEPARTMENT/COLLEGE: Physical Therapy

PROJECT TITLE: An Electromyographic Analysis of the Drawback and Hold of a Compound Bow
Versus Traditional Bow in Experienced Archers

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on May 10, 1999 and the following action was taken:

☒ Project approved. EXPEDITED REVIEW No. 1
☒ Next scheduled review is on May 2000

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

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

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

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

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

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

Please indicate on p. 1 whether this is dissertation or thesis research (under Type of Project).

cc: T. Mohr, Adviser
Dean, Medical School

Signature of Designated IRB Member
UND's Institutional Review Board

Date

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.
The purpose of this study is to identify the timing and recruitment of the major muscles during the drawback and hold of a bow, and to determine the presence of differences in this recruitment between a compound bow versus a traditional bow. The data will be collected using electromyographic and motion analysis equipment provided by the Physical Therapy Department at the University of North Dakota. To achieve our results, human subjects must be used to evaluate and describe which muscles are used during the activity. We hope to use the results of this study to develop a training protocol for archers who have upper extremity weakness and require a training program as part of their rehabilitation. Because there are few studies presently available which have described the major muscles used in archery, this study will provide a basis for developing exercise protocols which would be of use to physical therapists involved in rehabilitating patients with upper extremity dysfunction.
PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

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

Subjects:
It is anticipated that we will recruit 5 male subjects between the ages of 18 and 55. Subjects for this study will be experienced archers selected based on the following criteria: 1) competed in three archery tournaments over the last twelve months and 2) greater than five years of archery involvement. To reduce variability of the study, only male subjects with no history of major upper extremity injury within the last twelve months will be tested. These archers must be experienced with their respective equipment, i.e.: compound bow with release aid and traditional/recurve bow.

Methods:
Prior to running the trials, each subject's age, height, and weight will be recorded. During the trial we will measure electromyographic (EMG) activity in selected upper extremity and shoulder muscles. We will measure activity in the following muscles while the subjects are using a bow: 1) deltoid, 2) triceps, 3) trapezius, 4) teres major, 5) infraspinatus, 6) biceps brachii, 7) brachioradialis, and 8) latissimus dorsi.

To record EMG activity, adhesive electrodes will be placed on the skin over the respective muscles. The electrode locations will be determined using standard electrode placement charts. The skin, where the electrode is placed, will be prepared by cleansing the skin with alcohol before attachment of the EMG electrodes. 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. Prior to beginning the experimental trial, the researcher will apply manual resistance to the subject's upper extremity and shoulder muscles in order to elicit a maximal voluntary contraction from each muscle being monitored in this study. The muscle activity recorded during the maximal voluntary contraction will be considered as a 100% EMG activity level to which the EMG activity during the actual bow shooting can be compared. This procedure is done to normalize the EMG data for later analysis.

Video analysis will be used to measure upper extremity range of motion during the activity. Reflective markers will be attached to the upper extremity using double sided adhesive tape. We anticipate placing markers on the shoulder, elbow, and wrist. Video cameras will be placed above and on the side of the subject and will film the subject’s upper extremity markers and motion during the experimental trial. This will be recorded on videotape and will be transferred to a computer for analysis.

Each subject will perform two drawbacks, a three second hold, and release of the arrow. The subject will perform this activity with both pieces of equipment, i.e.: a compound bow with release aid and a traditional/recurve bow. The bows will be set at a specific poundage for all subjects. Both the compound bow and the traditional bow will be set at 45 pounds. The subject will shoot an arrow at a traditional padded target. The study will be performed at the physical therapy department at UND.

Data Analysis:
Descriptive statistics describing the subjects' anthropometric profiles will be provided. The mean activity of each monitored muscle will be calculated. The EMG data collected during the experimental trials will be expressed as a percentage of the EMG activity recorded during the maximal contraction prior to the experimental trials (i.e. normalized). The video image will be converted to a stickman-like figure, from which we can determine joint angles and limb velocity. The EMG data is synchronized with the video data to determine the level of EMG activity during the various shooting trials.
3. BENEFITS: (Describe the benefits to the individual or society.)

This study will potentially lead in the advancement of archery through an improved understanding of the muscles utilized in the drawback and hold of a bow. The results of this study will also aid archers, in a rehabilitative setting, by allowing the physical therapist to develop an exercise protocol for a patient who is an archer and who has upper extremity and shoulder weakness. The subjects in this study will benefit by gaining a better understanding of which muscles must be trained in order 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, including plans for final disposition or destruction, debriefing procedures, etc.)

Potential risks subjects may experience could be minor muscle soreness and an adverse reaction to electrode application. However, all of the subjects in this experiment are experienced archers and so the risk of any muscle overuse is remote. To further minimize any risk of injury each subject will perform a brief warm-up range of motion and stretching prior to the trials.

Because the video information is converted to stickman-like diagrams, the actual subject's video is not used in data reporting. Therefore, the subject is not recognizable. Data retrieval will be made only by the researchers directly involved and assurance of confidentiality is stated on the informed consent form. The subjects' names 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 the subject will remain confidential and will be disclosed only with the subject's permission. The data will be identified by a number known only by the investigator.

Data will be stored in the office of Dr. Tom Mohr for a period of three years.
5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject’s rights will not occur.

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

Consent forms will be kept in the Physical Therapy department at the University of North Dakota for a period of three years.

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:**

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**Principal Investigator**

**Project Director or Student Adviser**

**Training or Center Grant Director**

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5-6-99  
5/6/99
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 Boards access to those portions of my educational record which involve research that I wish to conduct under the Boards 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:

In Electromyographic Analysis of the Drawback and Hold of a Compound Bow 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 5-6-99  
Signature of Student Researcher

\^Consent 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."

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Date: 5-6-99

Signature of Student Researcher: [Signature]

---

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

An Electromyographic Analysis of the Drawback and Hold of a Compound Bow versus Traditional Bow in Experienced Archers.

Principal Investigators: Jason Brodina, Andrea Vagle, and Thomas 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 holding phases of archery. The purpose of this study is to determine which muscles are used and at what stages they are used during the drawback and hold of a bow. We hope that the results of this study will aid physical therapists in the rehabilitation and training of archers. We also hope to further educate those involved in the production of equipment to maximize archery success and minimize injury.

You were chosen because: 1) of your experience in archery (three archery tournaments over the past year), 2) you have greater than five years of archery involvement, 3) you are male, 4) you lack of history of major upper extremity injury in the past year, and 4) you are experienced with the equipment (compound bow with release aid and traditional/recurve bow).

As a subject for this study, you will be asked to report to the Physical Therapy Department at the University of North Dakota, located in the Medical Science North Building. Your age, height, and weight will be recorded. Following this, you will be asked to remove your shirt for application of electrodes and reflective markers. This may involve some clipping of excess hair and cleaning of the area with an alcohol swab. Two sets of four electrodes (8 in all) will be attached to the skin over the arm and shoulder area. The electrodes are attached to the surface of the skin with an adhesive material. We will also attach reflective markers at various points on your upper extremity. Your muscle activity will be monitored and two cameras will be filming your activity to measure the angles of your joints. You will be asked to go through approximately 2 draws with each bow (compound and traditional/recurve) The testing should take no longer than one hour.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that, because of your prior training, the risk of injury or discomfort is minimal. Minor muscle soreness may result following the repeated activity. However, to minimize this, you will be taken through a brief warm-up with your bow prior to the testing procedure.

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 to the investigators. The investigators 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.
health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department at the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigators involved are 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 asked by calling Dr. Thomas Mohr at (701) 777-2831. At your request, you will be given a copy of this form for future reference.

In the event that this research activity results in a physical injury, medical treatment will be as available as it is to a member of the general public in similar circumstances. You and your third party payer must provide payment for any such treatment.

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. I have read all of the above and willingly agree to participate in this study as it is explained to me by Andrea Vagle or Jason Brodina.

_________________________________________  _______________________
Subject's signature                        Date
REFERENCES


