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

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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

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An Independent Study

Submitted to the Graduate Faculty of the

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This Independent Study, submitted by Jason W. Brodina 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.

Thomas Mohr

(Faculty Preceptor)

Thomas Mohr

(Graduate School Advisor)

Thomas Mohr

(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 Jason Brodina

Date 12-9-99

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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.

<u>Draw (Drawback):</u> The term used for pulling the bowstring back.

<u>Draw Length:</u> Measurement of the distance an archer draws the bow.

<u>Full Draw:</u> The maximum draw length of the bow, before the release of the arrow.

<u>Holding Weight:</u> The weight or poundage the archer holds at full draw.

Measured in pounds.

<u>Let-off:</u> 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

Archery is enjoyed by thousands of people across the world. Archery has even been used as a therapeutic technique in the rehabilitation of paraplegics[4]. Thus, it not only has a recreational value, it can also be used clinically.

As a sport, archery is associated with various kinds of injuries. Common archery injuries caused are: 1) repetition injuries of the neck; 2) overused injuries of the flexor muscles of the forearm; 3) rotator cuff impingement; 4) tendonitis of the biceps tendon, 5) supraspinatus, 6) infraspinatus, 7) teres minor, 8) subscapularis; 9) laceration injuries; 10) flexor digitorum tendonitis; 11) acromial and subacromial bursitis; 12) recurrent subluxation of the humeral head; and 13) forearm irritation[2,3]. Many of these injuries could be prevented with proper shooting techniques and an adequate exercise program designed specifically for the archer[2,3].

An archer can typically choose from two different types of bows. The modern style bow is the compound bow, illustrated in figure 1. The traditional bow, which is shown in figure 2, has two types: 1)recurve bow, 2)longbow. The shooting styles and techniques of the bows differ. The compound bow shooter uses a style in which the holding arm (arm holding and stabilizing the bow) stays relatively stationary at 90 degrees shoulder abduction with the elbow in a fully extended position. The other arm, which is called the drawing arm (the arm that draws back the string of the bow), begins with the shoulder at 90 degrees abduction and horizontally adducted to 135 degrees.

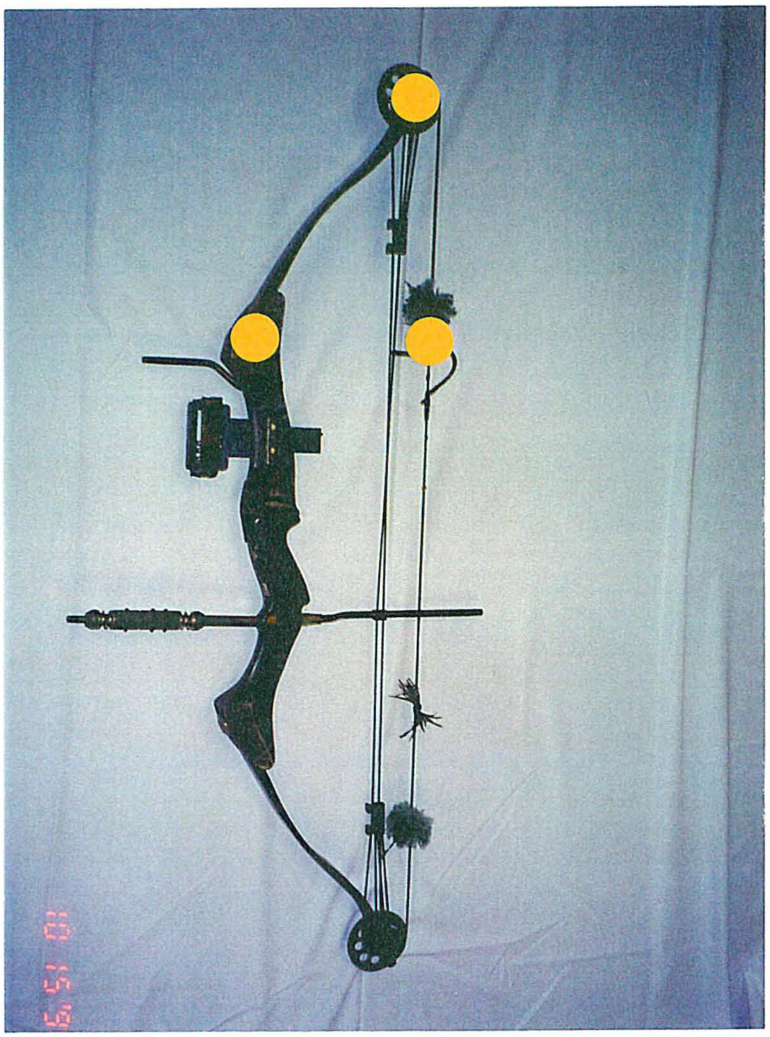


Figure 1. Compound bow. Circles indicate the placement of the reflective markers.

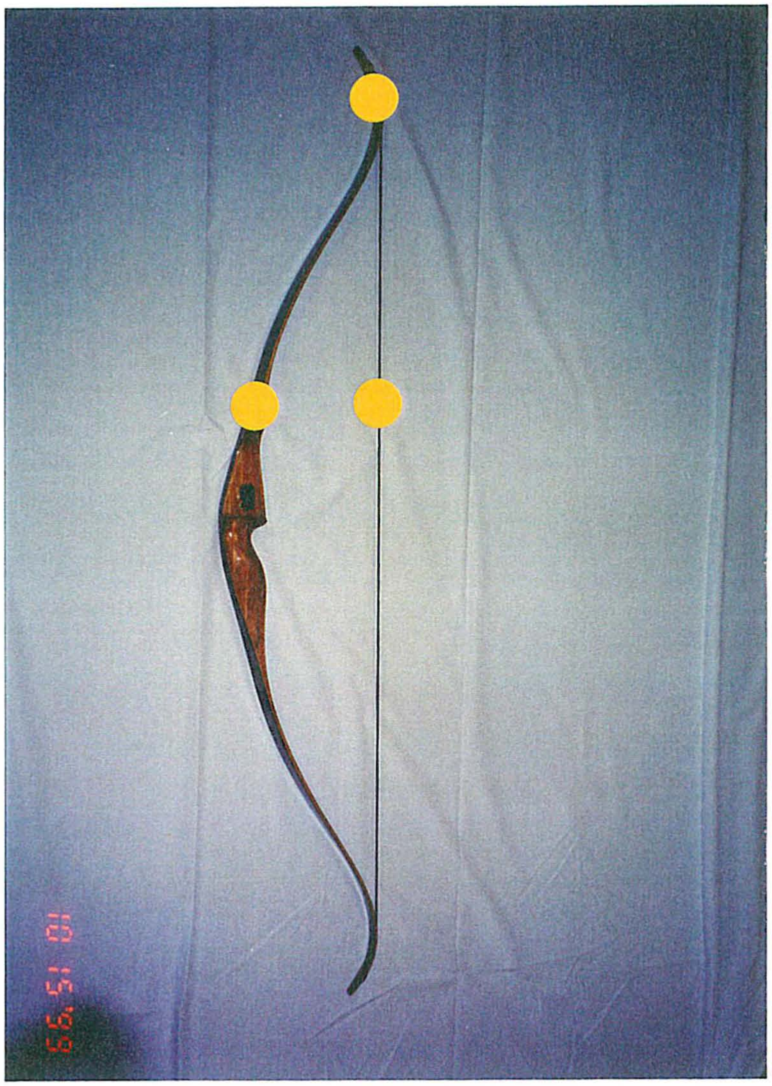


Figure 2. Traditional bow. Circles indicate the placement of the reflective markers.

Figure 3 shows the starting position of the drawback phase of the compound bow. The drawing motion consists of keeping the holding arm at its stationary abducted position throughout the motion while it utilizes a pushing force to stabilize the bow[5]. The drawing arm horizontally abducts across the body, using a pulling force to draw back the string of the bow, keeping the shoulder at 90 degrees abduction[6]. Some archers, during their drawing motion abduct the shoulder above 90 degrees. Also, some, once at full draw move their shoulder in the abduction/adduction plane, to settle their shoulder into their comfortable shooting position[2]. These last two motions can cause significant injuries in the glenohumeral complex[2]. The traditional bow has a different shooting style. It consists of a stance with the bow held in the front of the shooter's legs. Figure 4 shows the starting position for the drawback phase of a traditional bow. In one motion, the bow is brought into the final shooting position with the stabilizing arm applying a pushing force, having the arm fully extended at the elbow and the shoulder at 90 degrees abduction, and the drawing arm is using a pulling force with the arm in horizontal extension and shoulder at 90 degrees abduction[5,6]. Both the traditional and compound bow techniques end up in similar positions. Figure 5 displays the full draw position of both styles of bows. However, the drawing actions, which gets the shooter into the full draw position, are different. Thus, different muscles and different timing of muscle recruitment may take place between the bows.

Another distinct aspect between the two bows is the let-off in a compound bow. This type of bow has cammed wheels on both ends of the bow. These wheels allow for the weight at full draw to be a small percentage of the draw weight of the bow. Thus, once these cammed wheels turn over, the bow draw weight decreases (let-off) making it

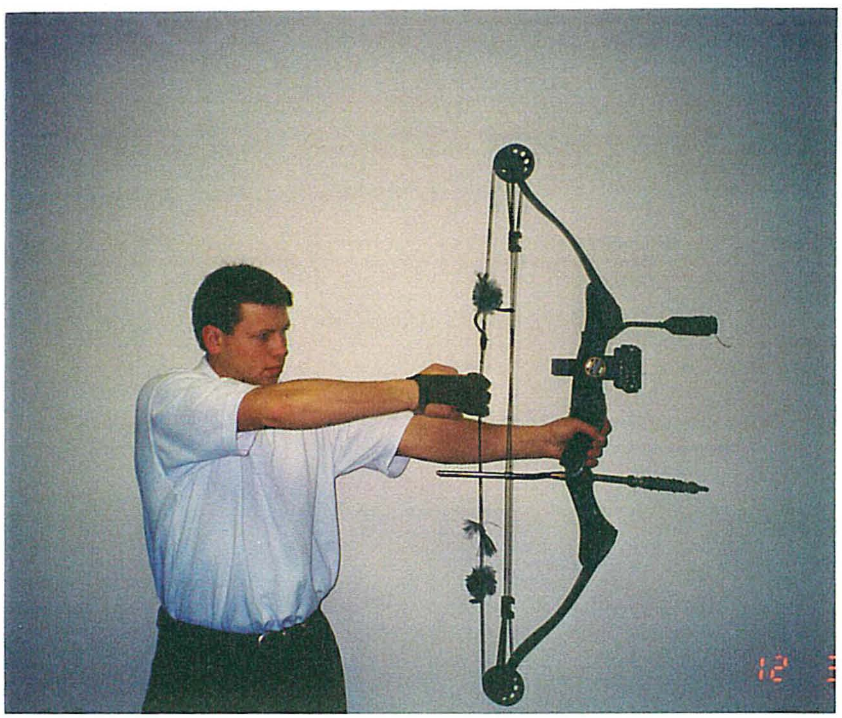


Figure 3. Beginning of the draw phase of the compound bow.

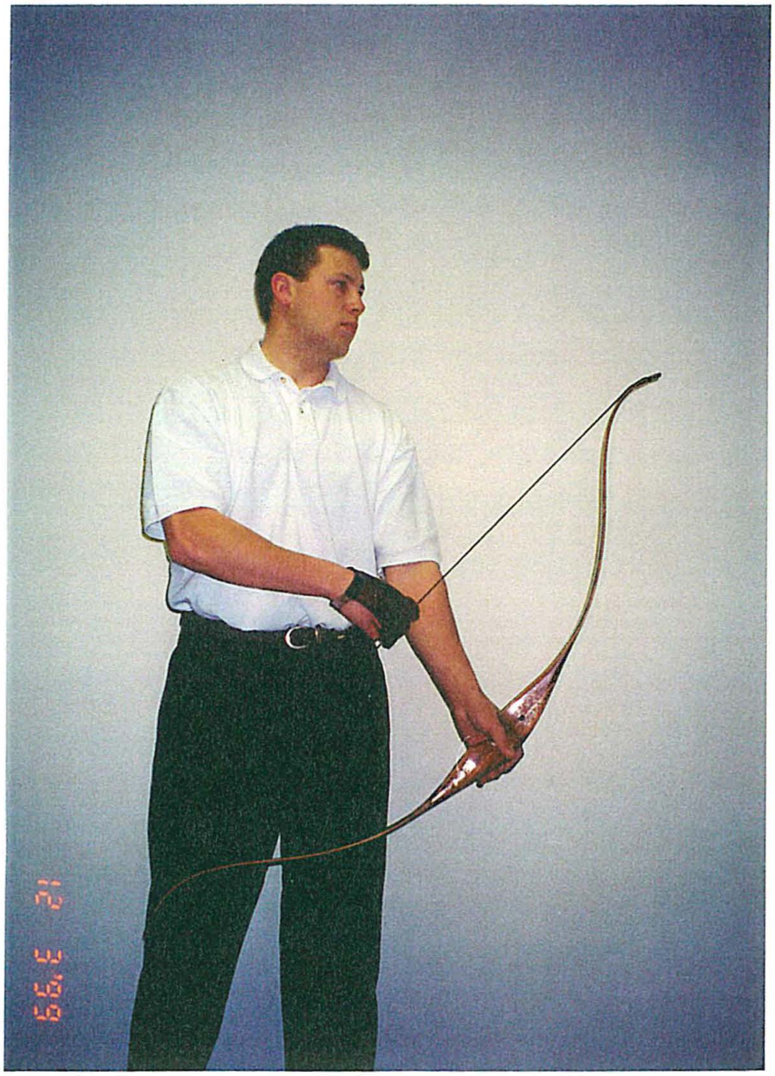


Figure 4. Beginning of the draw phase of the traditional bow.

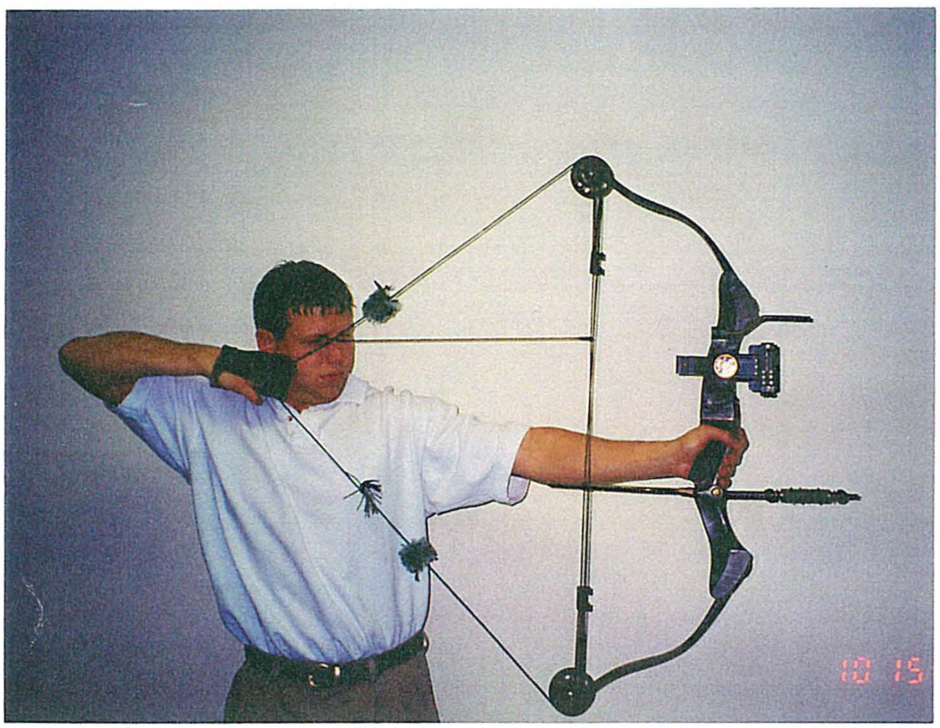


Figure 5. The end of the draw phase; full draw (compound bow shown).

easier to hold the compound bow at full draw. The percentage let-off in compound bows varies anywhere from 50 percent to 80 percent. However, the traditional bow increases its draw weight throughout the drawback. It does not allow for any let-off at any point of the drawback or hold phases of shooting the bow.

Due to the position of the upper extremities during the drawing action of these shooting styles of bows, some muscles are in a position to be prone to injuries. At the beginning of the motion, the drawing arm is in horizontal adduction, causing the tendons of the subscapularis and the long head of the biceps tendon to be pushed up against the coracoacromial arch[2]. During the drawing motion, the supraspinatus and the long head of the biceps tendon of the drawing arm are rubbed along the bottom surface of the coracoacromial arch. The infraspinatus and teres minor of the drawing arm also have tremendous amounts of strain placed upon them. Another muscle group affected during this motion are the forearm flexor muscles which are holding onto the string[3]. At full horizontal extension, the supraspinatus tendon of the drawing arm is impinged upon by the coracoacromial arch[2]. Some archers move their drawing arm elbow up and down, causing further injury to the supraspinatus tendon underneath the coracoacromial arch[2]. Mann and Littke[2] found that one-third of all archers participating in their study experienced tenderness over the infraspinatus/teres minor insertion area. They also reported that most of the archery injuries were observed in women. Because these muscles are put under a great deal of strain and are at a higher risk for injury, it is crucial that archers use a training program designed specifically to target these muscles. A strengthening program will also help with stabilization of the humeral head, which will help decrease impingement problems.

There are other chronic and acute injuries related specifically to archery. Acute injuries include lacerations, forearm contusions, and compression of the digital nerves[3]. Chronic injuries are medial epicondylitis, carpal tunnel syndrome, and De Quervain's tenosynovitis[3].

Another aspect of the drawing action which could cause injury is the holding of the bowstring. Typically, traditional bow archers use a three finger grip underneath the arrow to hold the string. The three fingers are in a position of finger mid-flexion, with the string resting in the creases of the distal interphalangeal joints. This place great strain on the finger flexors, which leaves them prone for injury[3]. Also, the median nerve can become compressed beneath the flexor digitorum superficialis muscle[3]. With the compound bow, a release aid is typically used. The purpose of the release aid is to increase the consistency of the release of the arrow and to decrease the strain on the finger flexors of the drawing arm.

As one can see, archery can involve many muscular injuries to the upper extremities. To lessen the chances of injury, a training program specifically designed for the archer is crucial. However, before a training regimen can be designed, the muscles recruited and the timing of these muscles needs to be described. A study performed by J.P. Claryls, et al[7] tried to identify these muscles through electromyographic analysis. The results of this study showed that the trapezius muscle in both shoulders initiated the muscular activity of the drawing motion. The brachioradialis muscle of the stabilizing arm contributed to the drawing action. Other muscles found to significantly contribute were the triceps brachii in the stabilizing arm and the biceps brachii, flexor digitorum superficialis, and deltoid muscles of the drawing arm. They concluded that although electromyographic muscle patterns stayed consistent, there were differences in muscular activity. Another aspect of this study depicted the differences between experienced and inexperienced archers. They found that the muscles having the greatest variability between the two groups were the trapezius during initiation of the drawing phase, the biceps brachii during the phase of full draw, and the extensor digitorum during release. However, the pattern of the muscle recruitment in the drawing arm between the two groups stayed consistent.

Other studies have also been performed to try to identify the musculature used in archery. A study performed by Zipp[8] stressed the deltoid and trapezius muscles as being the two most important for archery. Clarys et al[7] and Leroyer, Van Hoecke, Helal[5] also stressed the deltoid as being a primary muscle in archery. Another study by Mountford and Ainsley[4] tried to depict the musculature used during all phases of shooting a bow. However, the study used manual muscle testing and observation as a basis for identifying the recruited muscles. Tables 1and 2 outline the findings of the studies performed by Clarys et al, Zipp, and Mountford and Ainsley. Also included in this table are the results of a pilot study by the current researchers.

Present Study

Scientific research on the drawback and hold phases of a bow is limited. Even less research has been done comparing the traditional and compound bows. The intent of this study is to scientifically identify the recruitment and timing of muscles utilized in the two styles of bows. Comparison of the two bow types regarding variances in timing will follow. I expect to see little differences in muscles recruited between the two bows. However, muscle timing and intensity I foresee to be distinct for each type of bow. This will help archers in the rehabilitation and prevention of injuries, and therapists in designing an exercise program specific for the style of bow an archer is using.

Table 1. Previous findings in literature of muscles utilized in stabilizing (left) arm.

	Middle Trapezius	Lower Trapezius	Serratus Anterior	Anterior Deltoid	Pectoralis Major	Middle Deltoid	Posterior Deltoid	Teres Minor	Infra-spinatus	Triceps Brachii	Brachio-radialis
Mountsford S, Ainsley J.[4]	X	X	X	X	X	X	X	X	X	X	NT
Clarys et al.[7]	NT	X	NT	NT	NT	NT	NT	NT	NT	X	X
Zipp[8]	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Pilot Study (Compound Bow)	X	NT	Y	Y	NT	X	X	NT	NT	X	0
Pilot Study (Traditional Bow)	X	Y	Y	0	NT	X	X	NT	NT	X	0

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.

	Middle Trapezius	Lower Trapezius	Serratus Anterior	Anterior Deltoid	Middle Deltoid	Posterior Deltoid	Triceps Brachii	Brachioradialis	Teres Major	Biceps Brachii
Mountford S. Ainsley J.[4]	X	X	X	X	X	X	0	X	X	X
Clarys et al.[7]	X	X	NT	X	X	X	NT	X	NT	X
Zipp[8]	X	X	NT	NT	X	X	NT	NT	NT	NT
Pilot Study (Compound Bow)	X	Y	NT	Y	X	X	0	X	X	X
Pilot Study (Traditional Bow)	X	Y	NT	0	X	X	Y	X	X	X

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, Elmood 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[9], 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).

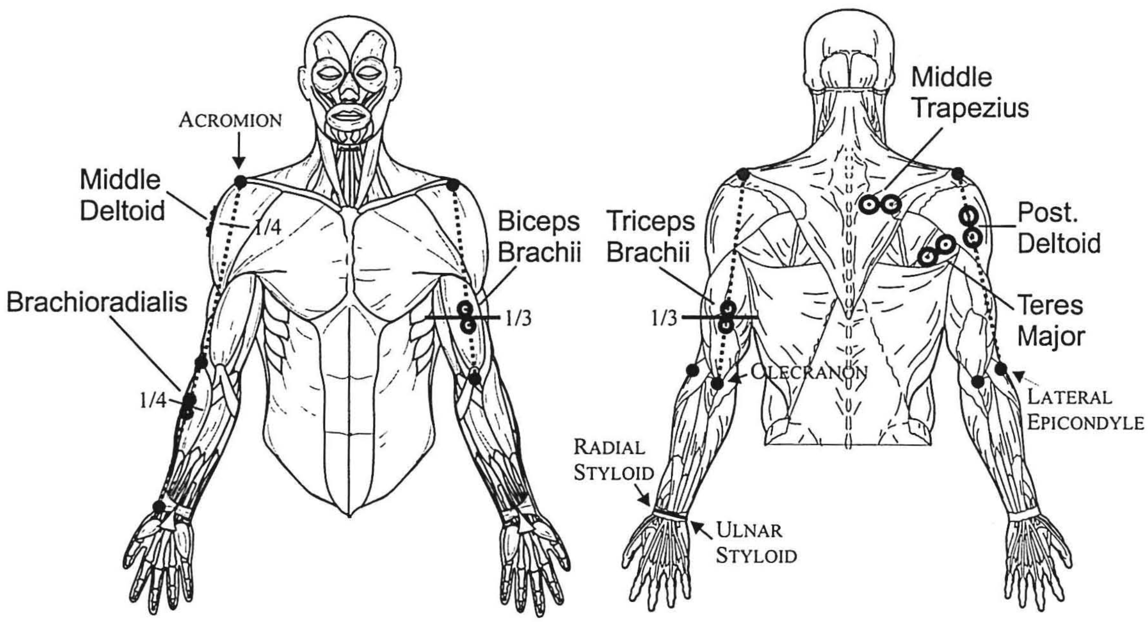
After recording all the trials, the subjects' movements were digitized using the Peak Motus Software package. The tapes were played back on a Sanyo Model GVR-S955 (Sanyo, 1200 W. Artesia Boulevard, Campton, CA 90220) video cassette recorder for the purpose of digitization.

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 draw-backs 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 (uV), 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

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.

Muscles	Compound Bow	Traditional Bow
Right Posterior Deltoid	10-39%	65-98.5%
Right Biceps Brachii	5-17.5%	None
Right Triceps Brachii	4-24.5%	None
Right Brachioradialis	6.5-24.5%	22-97.5%
Right Teres Major	9-33%	51.5-99%
Right Middle Deltoid	8-36%	43-100%
Left Brachioradialis	None	None
Right Middle Trapezius	12.5-53%	43-98.5%
Left Middle Trapezius	5.5-28%	53-99%
Left Triceps Brachii	2.5-23.5%	41-99.5%
Left Posterior Deltoid	9-26%	64-99%
Left Middle Deltoid	12.5-30.5%	27-98.5%

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.

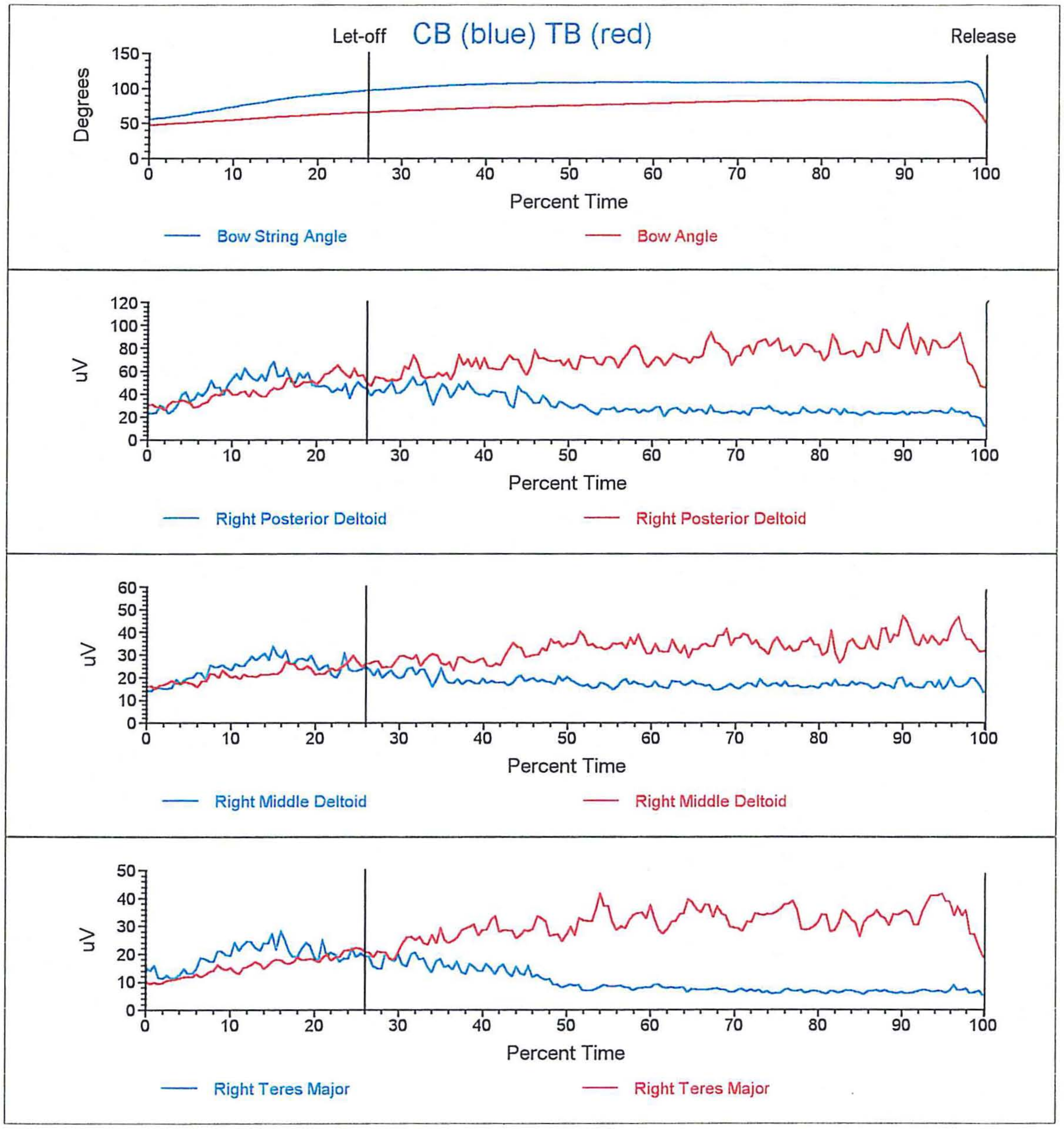


Figure 7. Ensemble averaged kinematic and electromyographic data from start to release of the drawing and hold phases; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and release of both bows.

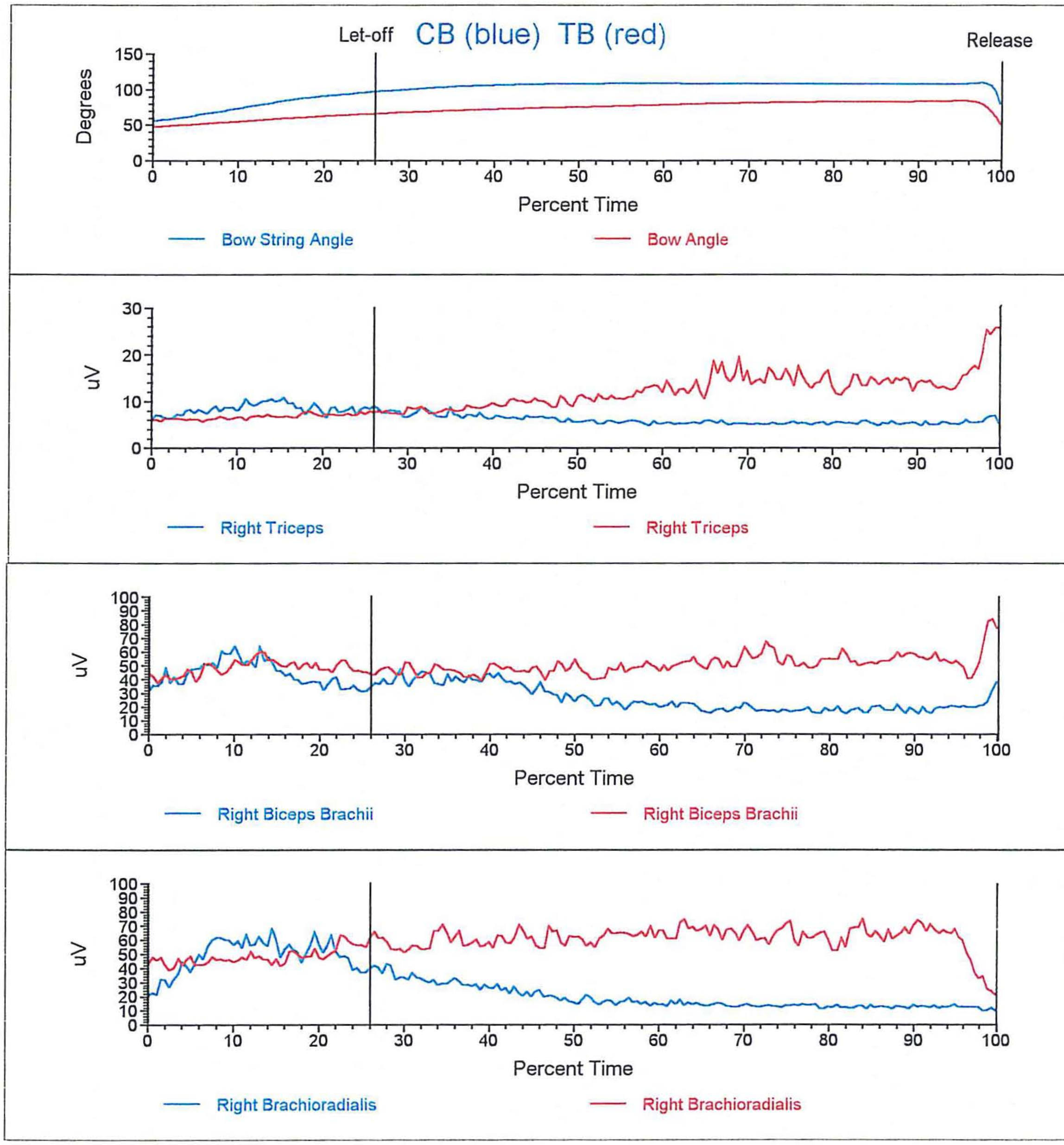


Figure 8. Ensemble averaged kinematic and electromyographic data from start to release of the drawing and hold phases; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and release of both bows.

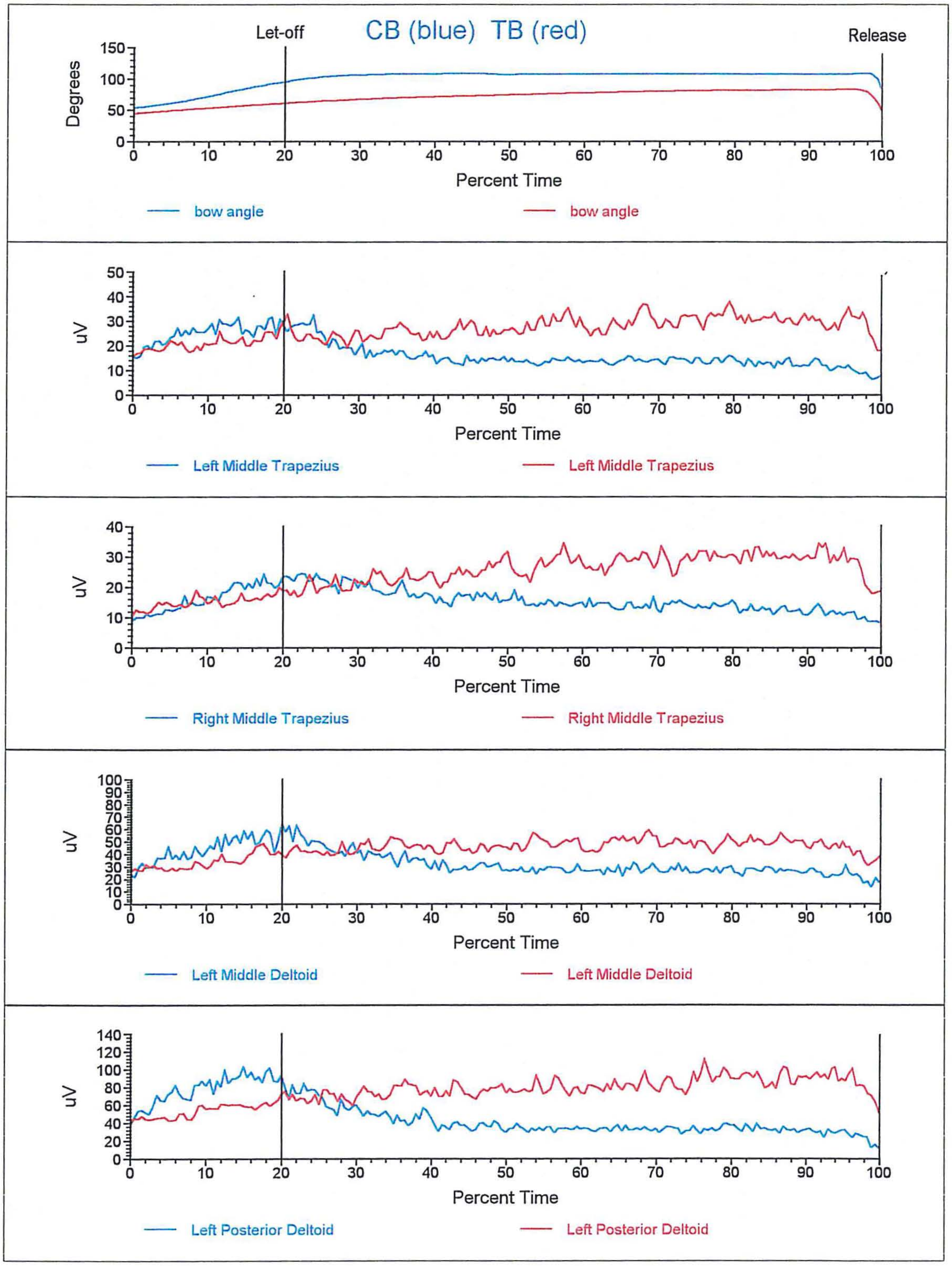


Figure 9. Ensemble averaged kinematic and electromyographic data from start to release of the drawing and hold phases; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and release of both bows.

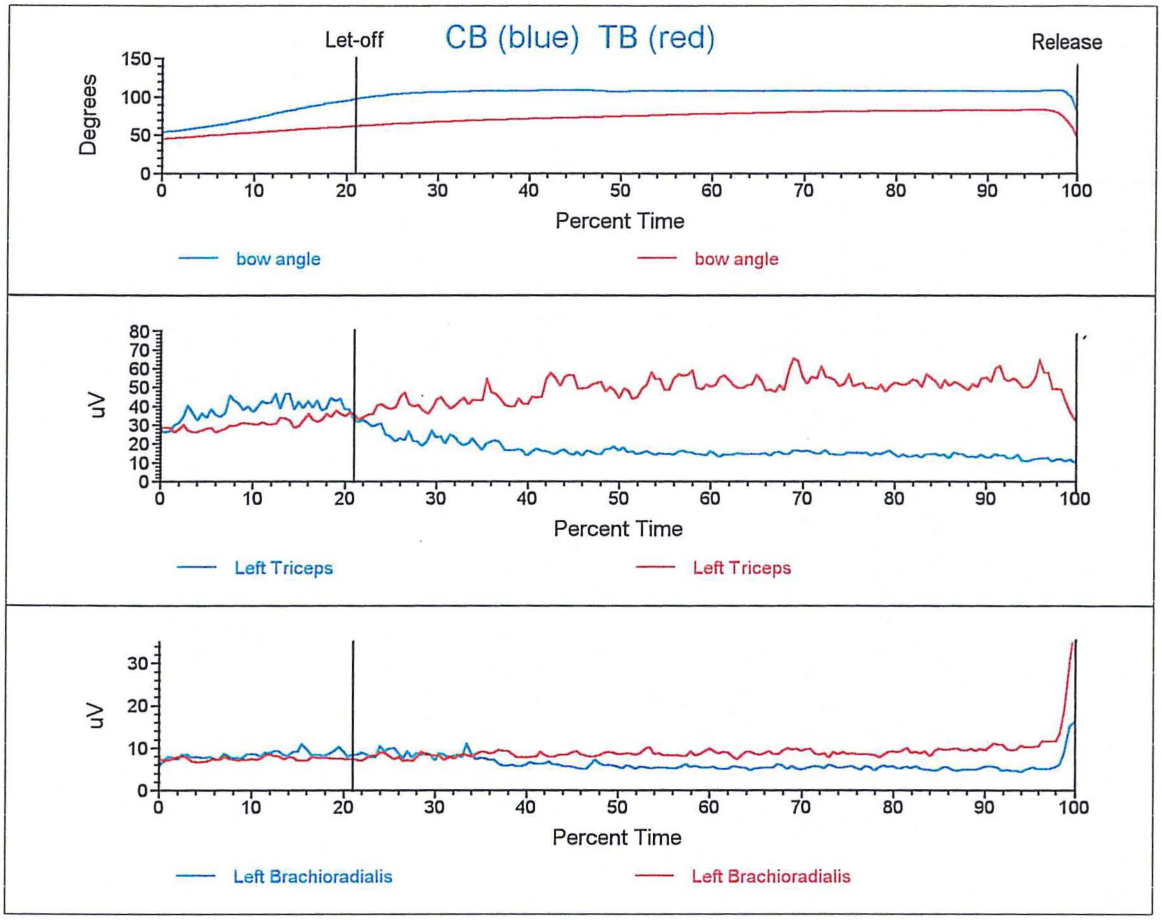


Figure 10. Ensemble averaged kinematic and electromyographic data from start to release of the drawing and hold phases; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and release of both bows.

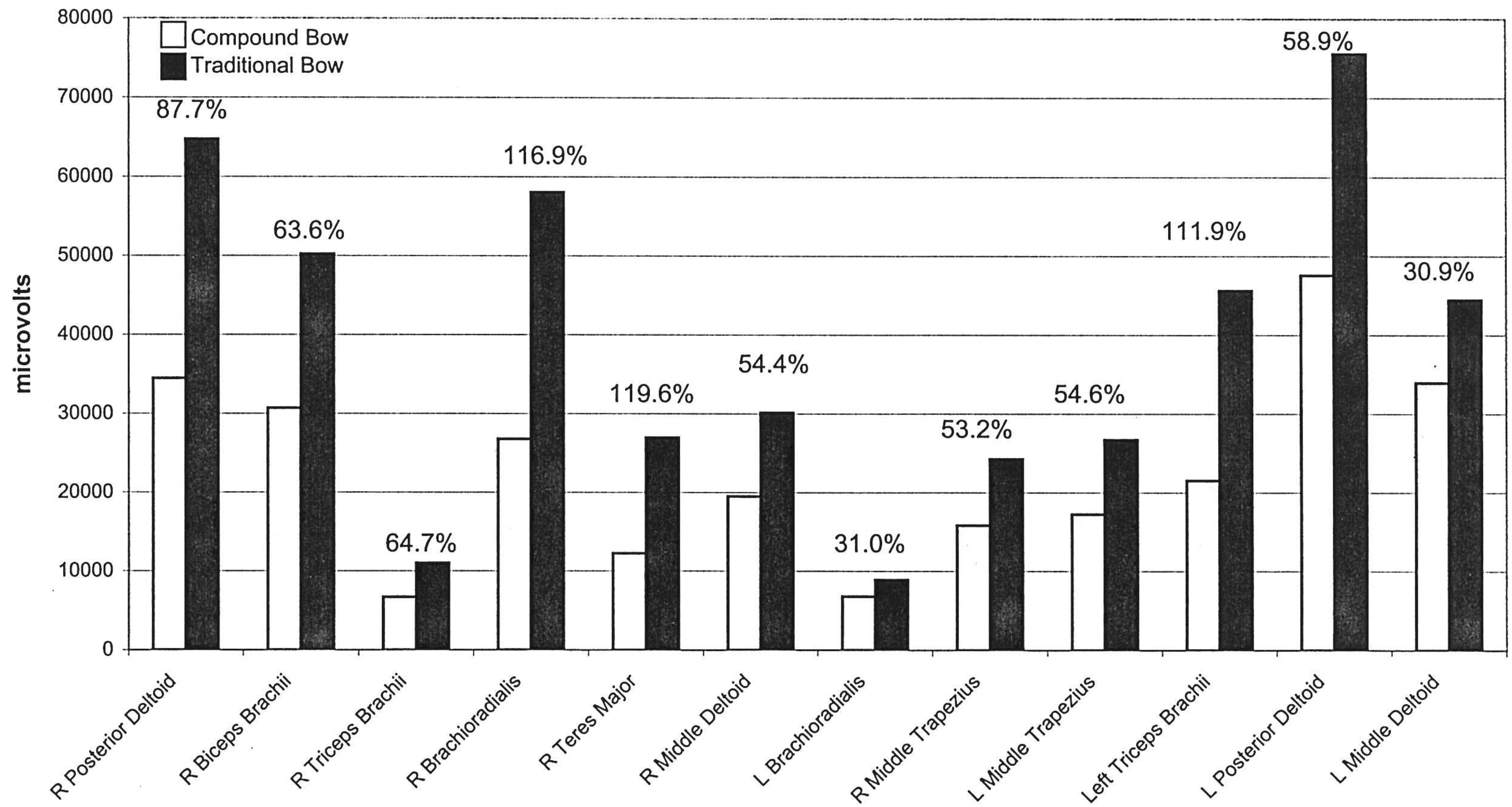


Figure 11. Average muscle activity from start to release of the compound and traditional bow. Percentages reflect the actitivty difference between the bows.

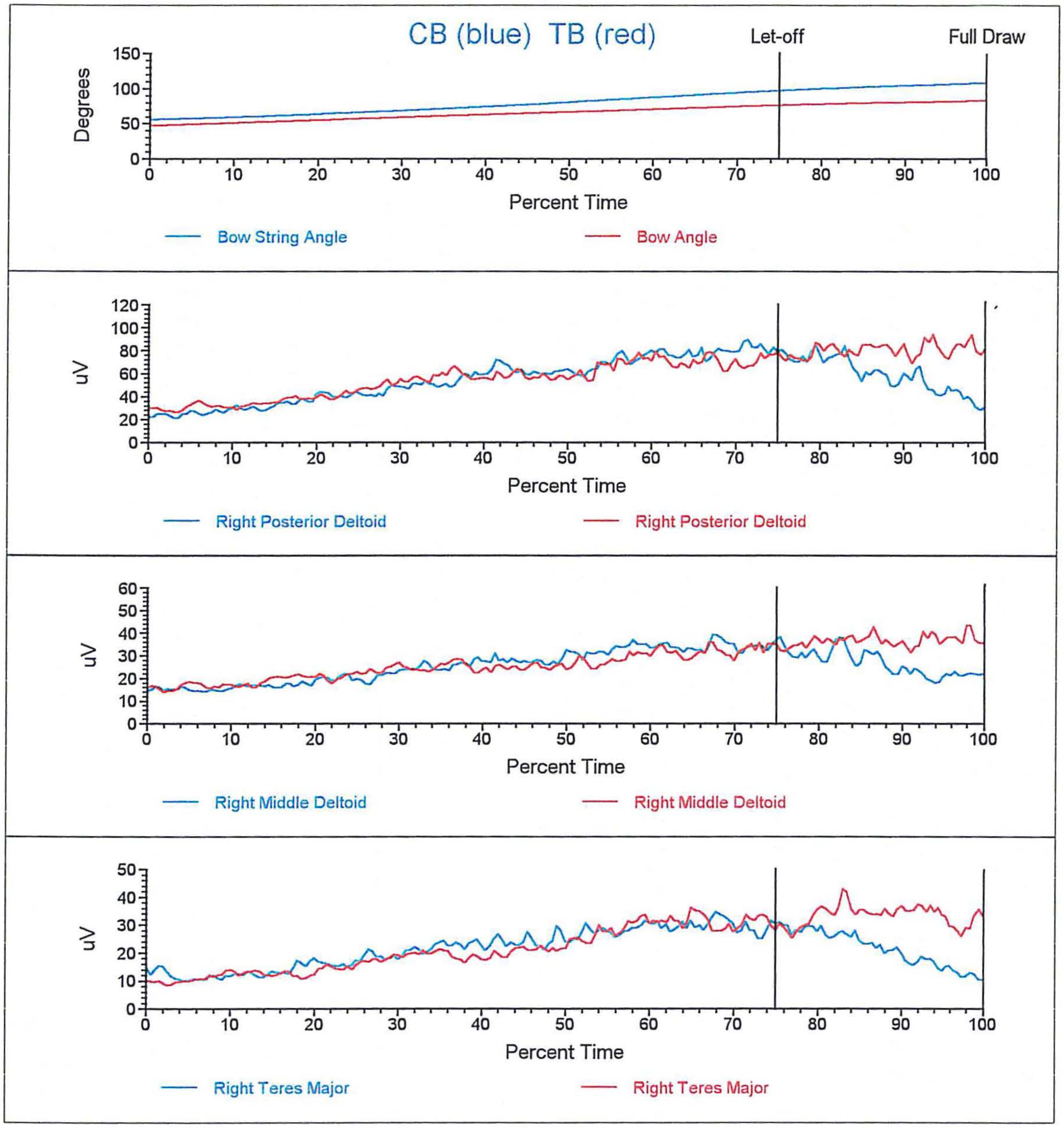


Figure 12. Ensemble averaged kinematic and electromyographic data from start to full draw of the drawing phase; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and full draw of both bows.

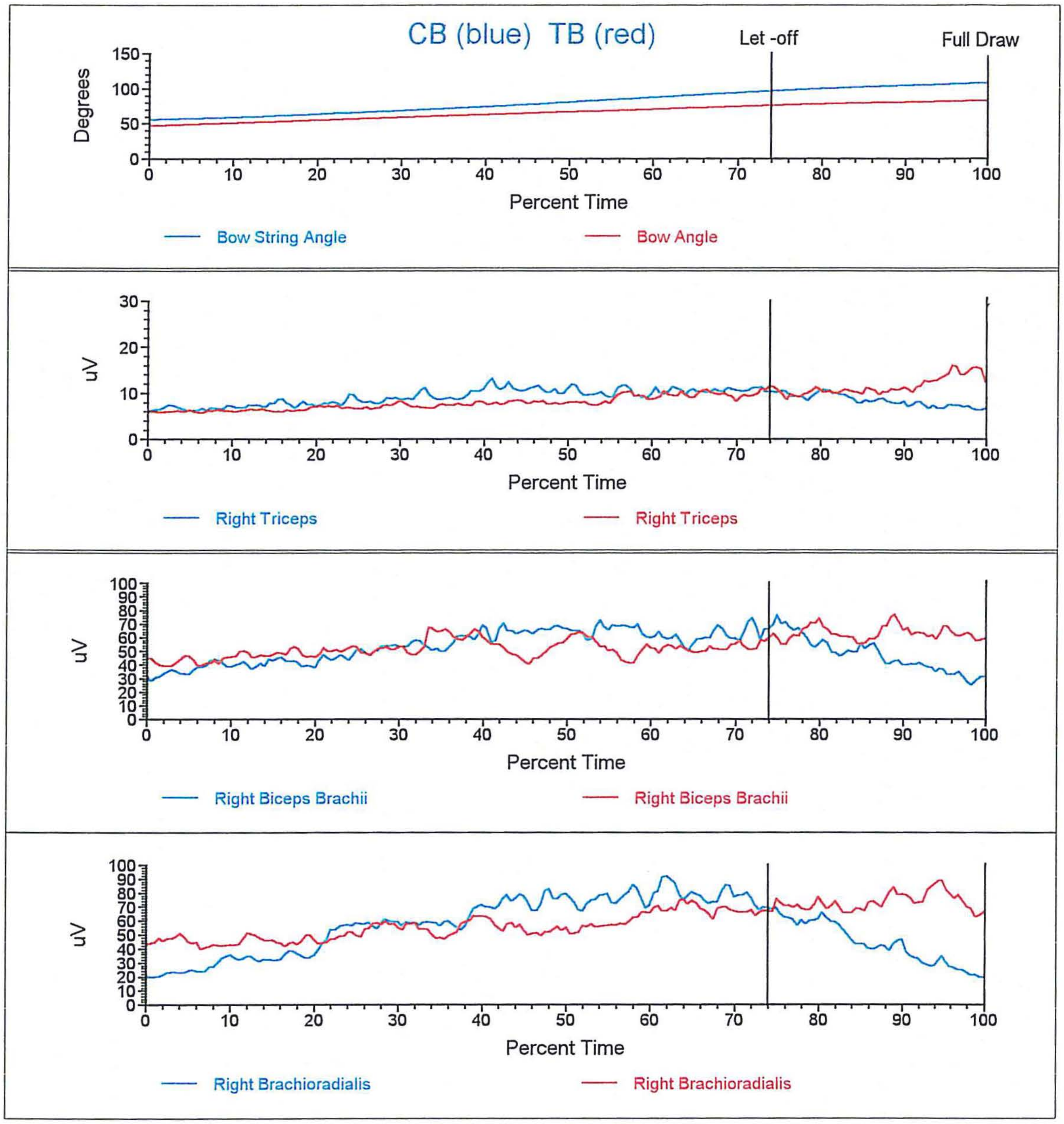


Figure 13. Ensemble averaged kinematic and electromyographic data from start to full draw of the drawing phase; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and full draw of both bows.

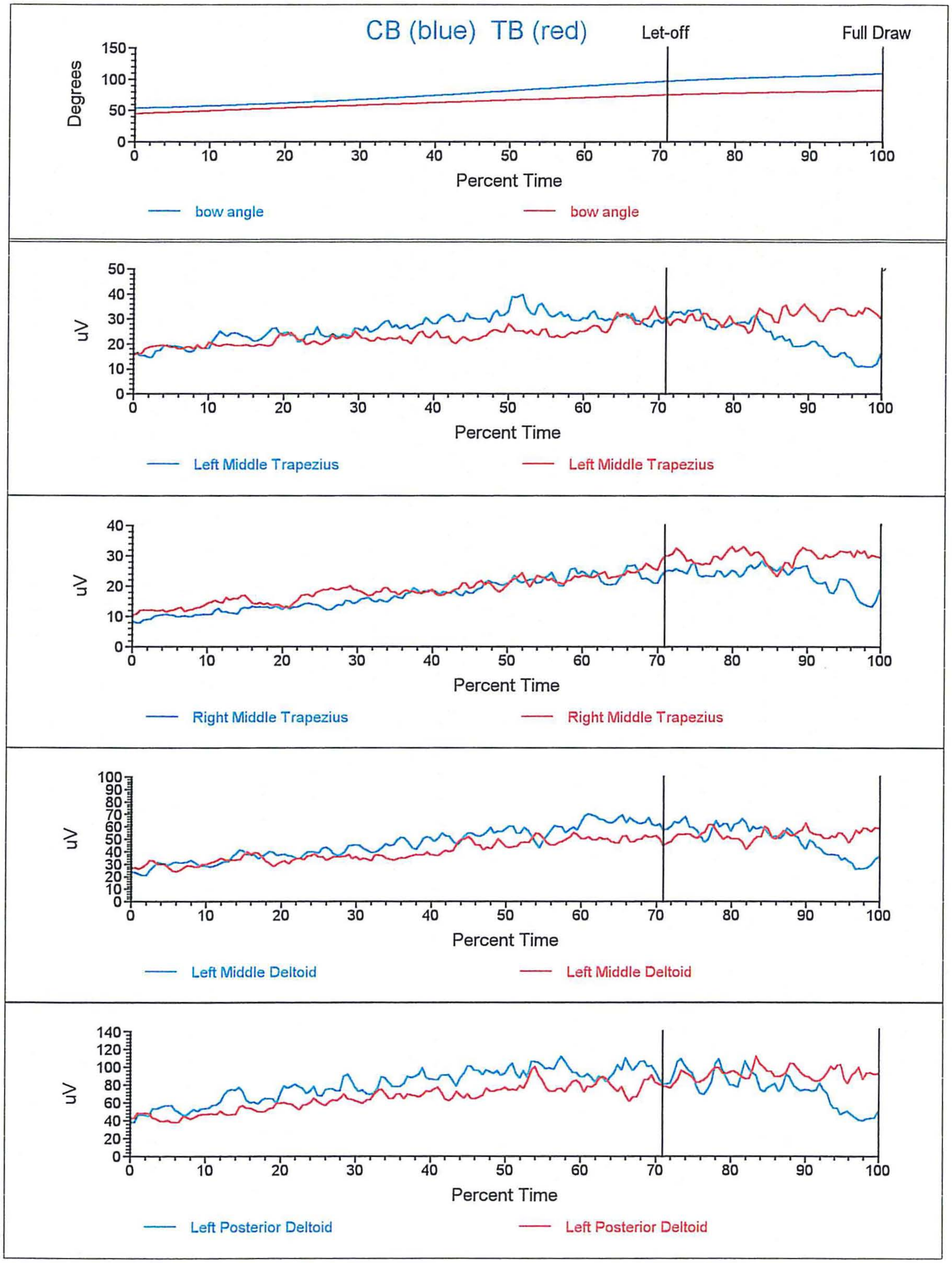


Figure 14. Ensemble averaged kinematic and electromyographic data from start to full draw of the drawing phase; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and full draw of both bows.

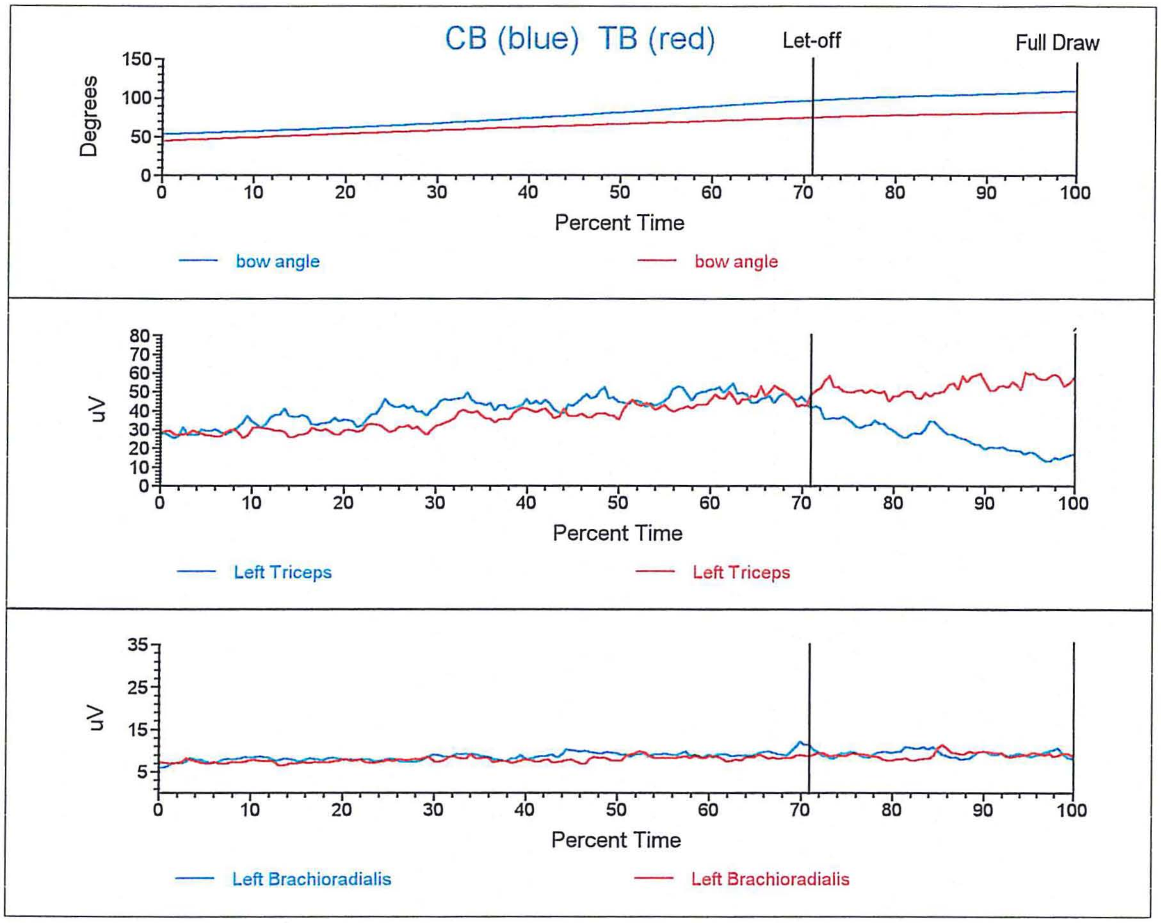


Figure 15. Ensemble averaged kinematic and electromyographic data from start to full draw of the drawing phase; compound bow (blue line) and traditional bow (red line). The vertical lines represent let-off of the compound bow and full draw of both bows.

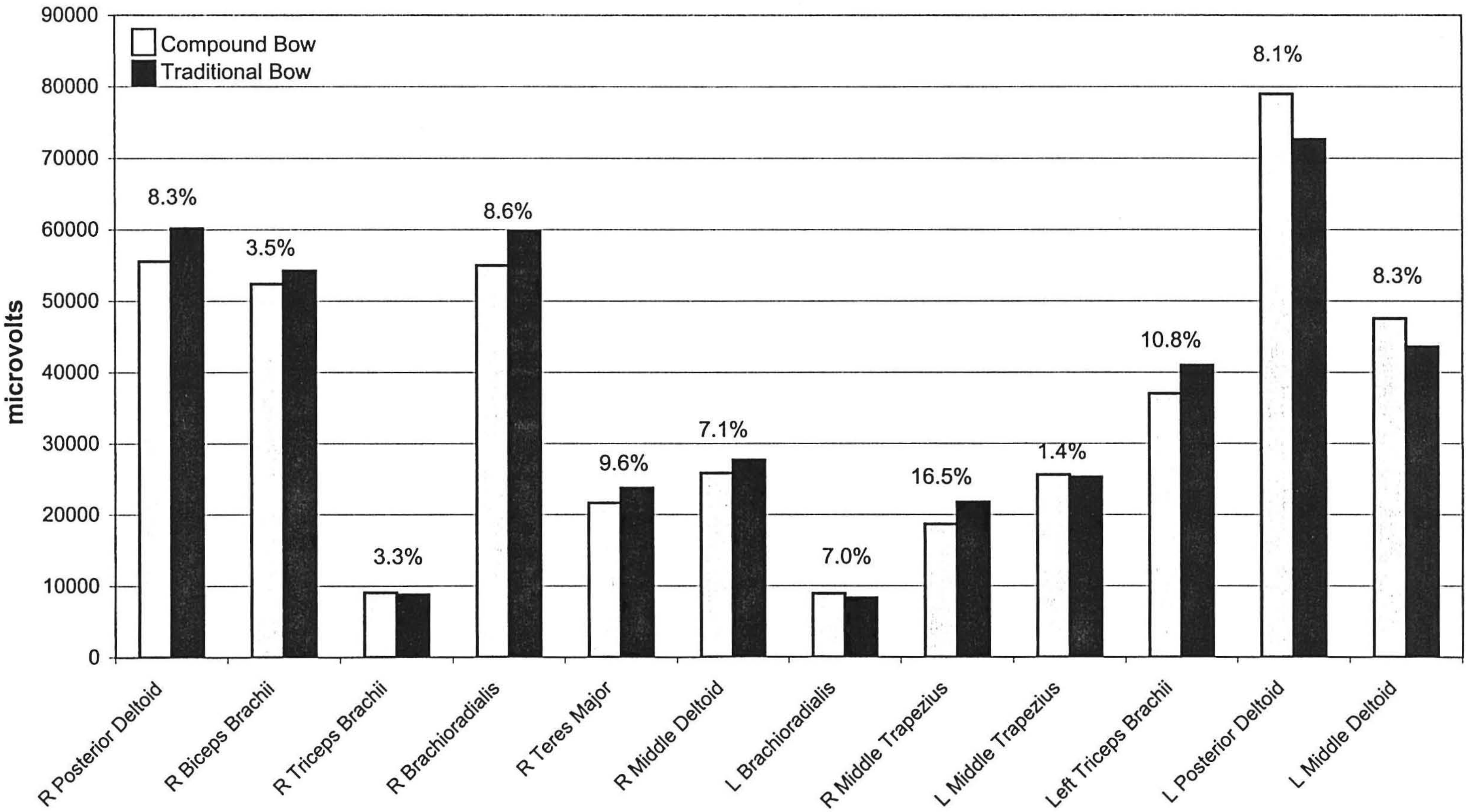


Figure 16. Average muscle activity from start to full draw of the compound and tradtional bow. Percentages reflect the difference in muscle activity between the bows.

CHAPTER V

DISCUSSION

The traditional bow and compound bow differ in their amount and timing of muscular activity. The traditional bow has an increase in muscle activity from start to release due to the peak draw weight being at full draw and during the hold phase. We hypothesize that during the hold phase, the muscles are going to continue to fire at the same intensity level because the bow's full draw weight is also its peak draw weight. Therefore, the traditional bow has its highest overall muscular activity during the full draw and hold phase. However, the compound bow has a drop-off in muscular activity at the point of let-off. This is due to the decreasing draw weight once let-off is achieved. Therefore, a compound bow's peak draw weight is just before let-off, which coincides with the compound bow's highest overall muscle activity. The muscle activity of the twelve muscles differ between the traditional bow and the compound bow.

Right Brachioradialis

We suggest that the right brachioradialis has a larger increase in initial muscle activity because of the differing drawing actions between the two styles of bows. The traditional bow's starting point for the drawing phase is with the forearm in neutral rotation (see figure 4). This allows the right brachioradialis to be more effectively recruited as an elbow flexor. However, with the compound bow the forearm is in slight supination at initiation of the drawing phase. This decreases the right brachioradialis's mechanical advantage as an elbow flexor, and requires the right biceps brachii to flex the elbow. Yet, the right brachioradialis has more muscle activity in the traditional bow. This can be attributed to the let-off of the compound bow and a decrease in the amount of muscle activity required by the elbow flexors.

Right Biceps Brachii

The right biceps brachii is similar in both bows from start to let-off of the drawing phase with a tapering of muscular activity in the compound bow thereafter. This is because the right biceps brachii is required to pull the bowstring back in both bows up to the let-off point. However, at let-off, less force is required to flex the elbow in the compound bow, whereas the traditional bow elbow flexion force continues to increase after the let-off point of the compound bow. Thus, we hypothesize that this decreased need for elbow flexion force in the compound bow causes a decrease in right biceps brachii muscle activity after let-off. The activity of this muscle in the compound bow is considerably less during the hold phase when compared to the draw phase. This is in disagreement with the literature, which states that the right biceps brachii is significant during the hold phase of shooting[7].

Right Middle Trapezius

The right middle trapezius had a large muscle activity difference between the two bows in the drawing phase. This is due to the traditional bow's peak weight being at full draw whereas the compound bow's peak weight is before let-off. The right middle trapezius's main job is to hold the scapula in retraction and to stabilize the scapula so the other muscles can achieve maximum effectiveness. The higher the draw weight of the bow, the more of a force is acting on the scapula to pull it forward at full draw. Therefore, the right middle trapezius has to increase its muscular activity in the traditional bow more than the compound bow towards the end of the drawing phase and continue this pattern into the hold phase.

Right Teres Major, Right Posterior Deltoid, Right Middle Deltoid

The right teres major, right posterior deltoid, and the right middle deltoid exhibit muscle activity differences between the two styles of bows. The activity of these muscles does not differ in both bows up to the let-off point of the compound bow. At this point, however, muscle activity of these three muscles decreases. The right teres major, right posterior deltoid, and right middle deltoid are major shoulder extensors. Therefore, a decrease in shoulder extensor force corresponds to the let-off of the compound bow. Yet, the shoulder extensor force of the traditional bow remains elevated, which should correlate to higher activity in these three muscles. This was evident in the results of our study

Left Brachioradialis

In the left brachioradialis, there is very little increase or difference in muscle activity from start to the point of release of the two bows. Up to the point of release, the vector force of the bow is superior to the left hand and in a direction towards the body of the archer, causing the resultant rotation into flexion of the elbow. This, we hypothesize, causes the left triceps brachii to increase its muscle activity to stabilize the bow. Therefore, the arm is in an extended position and the elbow flexors, including the left brachioradialis, would not be needed and may be inhibited by the elbow extensors due to the reciprocal inhibition theory. However, the left brachioradialis has a significant increase in muscle activity at the point of release. See figure 17 for further discussion of this hypothesis.

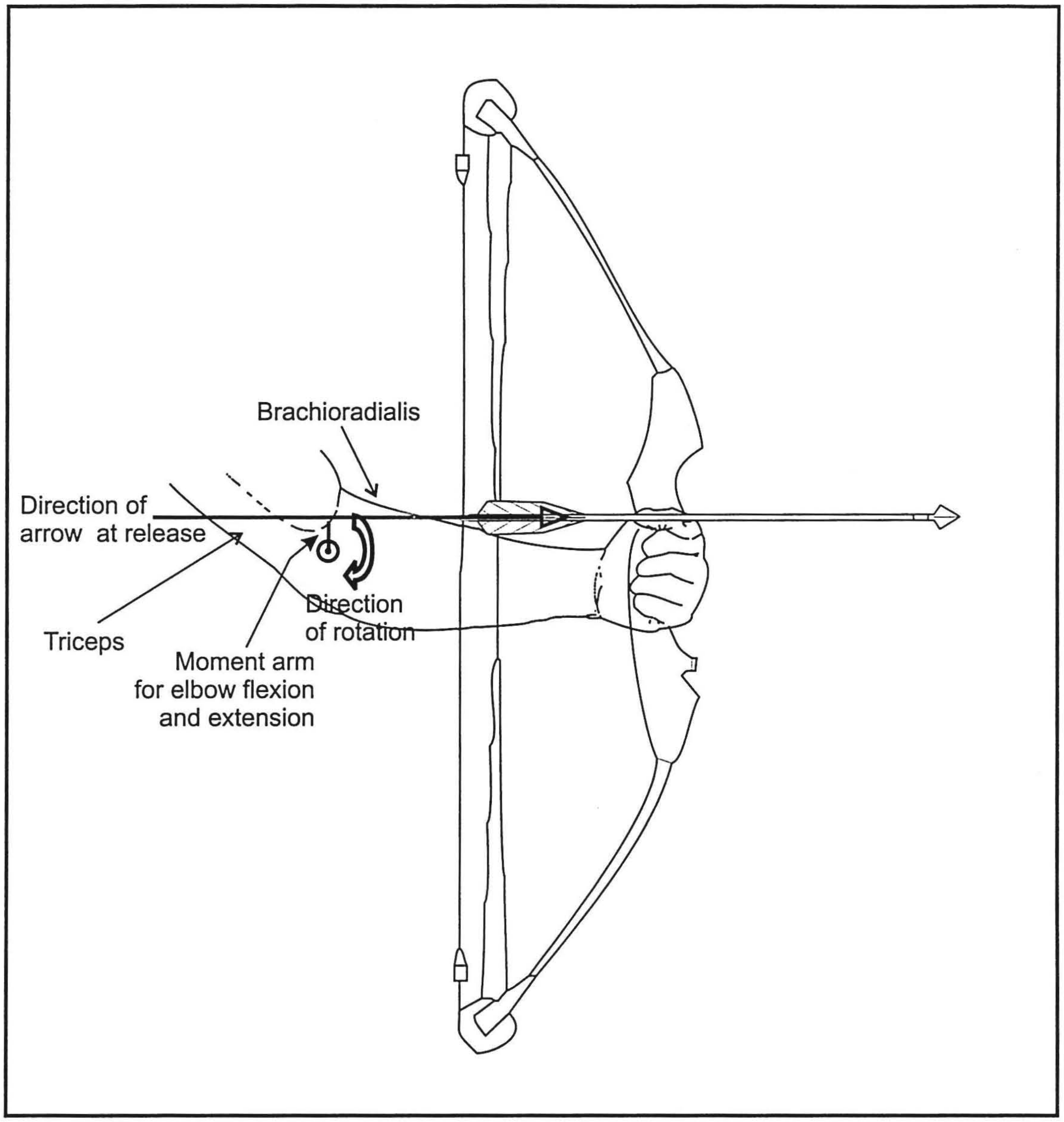


Figure 17. Model of left brachioradialis peak muscle activity at release. Two theories to explain this activity. 1) As the arrow is released, the resultant force and direction of rotation provided by the force from the arrow, causes a quick stretch to the elbow flexors, in this case, the left brachioradialis. 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.

Following the concept explained in figure 17, the traditional bow's left brachioradialis fires more than the compound bow's left brachioradialis at the point of release presumably by the increased energy produced by the flexible limbs of the traditional bow. Therefore, the limbs of the traditional bow recoil with more force than the compound bow. This places a higher degree of a quick stretch on the left brachioradialis, incorporating more of this muscle to keep the bow upright.

Left Triceps Brachii

The left triceps brachii is more active with the traditional bow due to the push-pull theory described by Leroyer, Van Hoecke, and Helal[5]. As the right arm draws the bowstring in horizontal abduction across the body, the left arm must exert an equal and opposite force to keep the bow stabilized. Thus, the left triceps brachii has to extend the arm to counteract the pulling of the right side. This push-pull effect is explained by Newton's second law, a force in one direction is equaled by a force in the opposite direction. Therefore, a decrease in draw weight in the compound bow should allow for a decrease in muscular activity of the left triceps brachii. This was shown to be true in our study.

Left Middle Deltoid, Left Posterior Deltoid

The left middle deltoid and left posterior deltoid showed less activity with the compound bow because of the let-off. Presumably, less shoulder stabilization is required with the compound bow and less overall torque is needed to draw the string, allowing for decreased muscle activity in the compound bow when compared to the traditional bow. However, of all the twelve muscles the left middle deltoid had the smallest percent difference (30.9%) of overall muscle activity between the two bows. This, we assume, is directly related to the left middle deltoid not being a main contributor in the push-pull theory explained by Leroyer, Van Hoecke, and Helal[5]. Therefore, this muscle would not be effected as much by the let-off of the compound bow.

Right Triceps Brachii, Left Brachioradialis, Left Middle Trapezius, Left Posterior Deltoid, Left Middle Deltoid

During the drawing phase, the right triceps brachii, left brachioradialis, left middle trapezius, left posterior deltoid, and left middle deltoid have a very slight increase in muscular activity in the compound bow compared to the traditional bow. Excluding the left brachioradialis, the four other muscles have a decrease in muscular activity in the compound bow from let-off to full draw. However, all four of those muscles elicit a higher muscular activity in the compound bow compared to the traditional bow from approximately 30% to let-off of the drawing phase. This may be due to the peak draw weight of the compound bow falling into the previously mentioned span of 30% to let-off of the drawing phase, causing higher muscular activity in those four muscles at that period of the drawing phase. This causes those muscles to report a slightly higher average muscle activity in the compound bow when the entire phase is used to report the muscular activity.

Limitations

This study had a number of limitations impacting the results. First, the study had a limited number of subjects. This may have allowed for a greater range in variability and an inadequate representation of all skilled archers of the compound and traditional bows. Second, the subjects' elbow and shoulder motions were not tested. This did not allow the result to show the exact point in the archer's motion in which the muscle activity took place. Third, a baseline of muscle activity was not recorded on each muscle of each subject. This impaired us from comparing the amount of activity each muscle required to draw back a bow. Therefore, a comparison between muscles could not be stated. A fourth limitation was the inability to place electrodes over the supraspinatus, rhomboid, and serratus anterior muscles for electromyographic testing due to the overlapping of the trapezius muscle and the electrical interference of the heart. The fifth limiting factor was the inability to compare these results with any other studies. Finally, each trial by each archer had variances in the amount of time from start to full draw and from start to release. This allows for an increase in variability when averaging together all the trials from each subject.

Conclusion

The compound bow has its greatest muscular activity during the middle of the drawing phase just prior to let-off. The traditional bow has its greatest muscular activity at full draw and hold phase just prior to release. Most muscles exhibit a considerable difference between the two bows during the hold phase. The left brachioradialis was minimally effected by the variations of the two styles of bows.

Clinical Implications

This study showed the muscular activity of the compound bow and the traditional bow. Considering the compound bow's peak activity is before full draw is achieved, a strengthening regimen would want to concentrate on the drawing motion at around the let-off point of the bow. This is where the archer will need the greatest amount of muscular activity.

In the traditional bow, the greatest activity is at full draw. A strengthening program for the traditional archer should focus on the end of the drawing phase. Isometric strengthening at full draw is recommended to improve the archer's strength during the hold phase of shooting a bow. If a traditional archer is strong at full draw and the hold phase, he/she will delay muscular fatigue for a longer period.

Training for the beginning and experienced archer should be a crucial aspect of their archery regimen to strengthen and prevent archery related injuries. This will allow the archer to have greater control of the bow and more accuracy while shooting.

APPENDIX

REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

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

NAME: Thomas Mohr; Andrea Vagle; 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. 4.
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

John P. [signature] 5-10-99

Signature of Designated IRB Member Date
UND's Institutional Review Board

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

(1/98)

_X_ EXPEDITED REVIEW REQUESTED UNDER ITEM _3_ (NUMBER[S]) OF HHS REGULATIONS
___ EXEMPT REVIEW REQUESTED UNDER ITEM ____ (NUMBER[S]) OF HHS REGULATIONS

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

PRINCIPAL INVESTIGATOR: Thomas Mohr, Andrea Vagle, Jason Brodina **TELEPHONE** (701) 777-2831 **DATE:** 4/22/99

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: P.O. Box 9037, Dept. of Physical Therapy, UND

SCHOOL/COLLEGE: Medicine **DEPARTMENT:** Physical Therapy **PROPOSED PROJECT DATES:** 5/01/99-5/01/00 (Month/Day/Year)

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

FUNDING AGENCIES (IF APPLICABLE): Not Applicable

TYPE OF PROJECT (Check ALL that apply):

_X_ NEW PROJECT ___ CONTINUATION ___ RENEWAL ___ DISSERTATION OR THESIS RESEARCH _X_ STUDENT RESEARCH PROJECT

___ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Thomas Mohr, Chairman of Physical Therapy Department

PROPOSED PROJECT: ___ INVOLVES NEW DRUGS (IND) ___ INVOLVES NON-APPROVED USE OF DRUG ___ INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

___ MINORS (<18 YEARS) ___ PREGNANT WOMEN ___ MENTALLY DISABLED ___ FETUSES ___ MENTALLY RETARDED

___ PRISONERS ___ ABORTUSES _X_ UND STUDENTS (>18 YEARS)

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

IF YOUR PROJECT HAS BEEN\WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S): ____

Status: ___ Submitted; Date ____ ___ Approved; Date ____ ___ Pending

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

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 psycho-logical, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

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:

Thomas Mohr   [signature] / Jason Brodina   5-6-99

Principal Investigator   Date

Thomas Mohr   5/6/99

Project Director or Student Adviser   Date

Training or Center Grant Director   Date

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[1]

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:

n 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.

5-6-99
Date

Andrea Vayle
Signature of Student Researcher

[1]Consent required by 20 U.S.C. 1232g.

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5-6-99
Date

Jason Brodina
Signature of Student Researcher

[1]Consent 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. 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

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