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A cinematographic study was made of three female advanced archers to examine selected mechanical factors of the draw, anchor, release, and follow-through. Two cameras - one 25 feet directly in front of the archer, and one 20 feet above the ground directly over the archer's head - were used to record the archer's movements. Two of the archers drew using the back muscles as well as the arm and shoulder joint muscles, and one archer used the arm pull.

The length of the hold at the anchor position was the only factor examined that seemed to be related to the method of drawing the bow, with the two who drew using their back muscles holding longer than the archer using the arm pull. This did not seem to be influenced by the draw weight of the bow used. The angle of the forearm of the drawing arm to the shaft of the arrow did not seem to be related to the method of drawing the bow, but rather to the length of the third (ring) finger of the archer's drawing hand.

Bow movement in the horizontal plane after release was influenced by the alignment of the bow limbs to the arrow shaft prior to release as well as by string hand action at release. One of the archers dropped the bow arm after release, and was found to have started dropping it before the arrow had cleared the bow on one of the seven shots photographed. The action of the bow after release (vertical plane) was also examined.

A CINEMATOGRAPHICAL ANALYSIS OF TWO SELECTED METHODS OF DRAWING THE BOW

by

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APPROVAL PAGE

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CHAPTER I

INTRODUCTION

The mechanics of the archer, as well as the mechanics of the bow and arrow, affect the flight of the arrow. There are many mechanical steps from the moment the draw is begun until the completion of the follow-through that the archer must perform correctly in order to be successful.

Archery is an individual sport. The archer's bow arm position and draw will be based on his body build, strength, and other individual factors. Each individual develops his own style which is comfortable and successful for him. Even though there may be great variation in styles, there are certain mechanical principles that cannot be violated.

One factor which influences many of the mechanical steps of the archer is the method used to draw the bow. An archer usually draws using one of two methods, the method being based on the muscles used. One method utilizes only the upper arm and shoulder joint muscles. The other method utilizes the shoulder girdle, or back muscles as they are often referred to, as well as the upper arm and shoulder joint muscles. The muscles used affect not only the draw, but the hold at the anchor point, and the release.

Most archers can draw to the anchor position, regardless of which method is used to draw the bow. Once the anchor point is reached, it needs to be held long enough for the archer to aim and to steady himself before releasing the arrow. It is at this point that the muscles used to draw are of critical importance, since these are also the muscles used to hold unless the archer makes a "last minute" correction. The archer must be able to hold until the sight is on the aiming point on the target and stationary. The release is affected by the muscles used to draw due to their influence on tension in the string hand and the angle of the fingers to the string. For these reasons, the muscles used in drawing should be of primary concern to the archery teacher or coach.

Another factor which may influence arrow flight is bow arm position. An archer may bring his bow arm up into shooting position as he starts to draw, or he may position the bow and draw without moving the bow arm after the draw has started. The most important factor in the positioning of the bow arm is that the position be constant from the time the bow is aimed until the follow-through is completed.

Movement after aiming will obviously change the flight of the arrow. If the bow arm moves at release, it will affect the flight of the arrow if the movement takes place before the arrow has cleared the bow. Movement on the follow-through may be a continuation of movement that began at release, and should be regarded as a possible indication of technique error. To insure against any movement that could adversely affect arrow flight, the archer should concentrate on keeping the bow arm steady until completing the follow-through.

While the bow arm should remain steady, the bow should not be gripped tightly so as to inhibit its natural reaction. The natural movement of the bow in the hand upon release will not adversely affect arrow flight, but gripping the bow so as to inhibit this reaction may.

Using the muscles of the shoulder girdle, or back, to draw, keeping the bow arm steady until the follow-through has been completed, and keeping the bow hand relaxed are recommended by most authorities. Many do not give a reason for doing these things except that it is "good form." If a reason is given, it usually does not go below the surface of the mechanics involved. An understanding of the mechanical principles is needed to provide a scientific basis for what is taught. Such a scientific basis cannot be obtained by merely observing successful performers and adopting the form used. An understanding of the mechanical factors involved will not only give support to what is being taught, but will aid the teacher in analyzing and modifying the student's form so that he may attain a higher degree of success.

Cinematography has proven to be an effective tool in the scientific analysis of sports skills. It involves the scientific filming and analyzing of slow motion pictures. The films provide an accurate reproduction of the skill which can be analyzed frame by frame to study the parts of the movement in relation to the total performance. Many details that would be extremely difficult to analyze while the skill is being performed can be analyzed successfully using cinematography. Cinematography was found to be effective in allowing scientific analysis of the draw, anchor, release, and follow-through in archery.

Purpose of the Study

The purpose of this study was to examine selected mechanical factors of the draw, anchor, and release, and to determine if these factors were influenced by the method used to draw the bow.

Definition of Terms

The following definitions will be used in this paper:

Advanced archers: Archers with competitive experience who have shot at least a 500 on a Columbia Round.

Anchor position: The point under the chin at which the hand comes to rest when the bowstring has reached full draw. It is also referred to as the anchor point.

Arm muscles: The muscles of the upper arm which are used in flexion at the elbow. The primary movers in this group are the biceps, brachialis, and brachioradialis.

Arm pull: Drawing the bow using only the muscles of the upper arm and shoulder joint.

Back muscles: To avoid confusion with the shoulder joint muscles, the muscles of the shoulder girdle used for adduction of the scapula will be referred to as back muscles. The primary movers in this group are the rhomboids and the middle trapezius, part III.

Bow torque: The movement, or twisting, of the bow around its vertical axis.

Draw: The pulling back of the bowstring to the anchor position in preparation for shooting an arrow.

Draw using the back muscles: Drawing the bow using the muscles referred to as the back muscles as well as the muscles of the arm and shoulder joint.

Hold: The pause at full draw where the arrow is steadied before release.

Shoulder joint muscles: The muscles used for horizontal extension of the arm at the shoulder joint. The primary movers in this group are the posterior deltoid, infraspinatus, and teres minor.

Assumptions Underlying the Research

1. Cinematography can be used effectively to analyze the draw, anchor, and release of the bowstring and gives an accurate representation of the performance.

2. Adduction of the scapula indicates use of the back muscles. (36:446)

Scope of the Study

This study was confined to the motion picture analysis of the bow arm position, and the drawing arm movements on the draw, anchor, release, and follow-through of three college women archers with competitive experience. One archer used the arm pull, and two drew the bow using the back muscles. Stability of the bow arm varied.

The subjects were filmed using two spring driven Revere 16 millimeter magazine load cameras, both with a frame speed of

48 frames per second, and one motor driver Beaulieu S2008 Super 8 millimeter camera with a frame speed of 50 frames per second.

The following were examined with respect to the method of drawing the bow: (1) the length of time of the hold at anchor position, and (2) the action of the string hand at release and its possible influence on the change in the angle of the bow to the line of the arrow. The angle of the forearm of the drawing arm to the arrow, and possible reasons for the angle were examined. The action of the bow at release was noted to determine whether the natural reaction was permitted or inhibited.

Significance of the Study

An understanding of the mechanical factors affected by the method used to draw the bow is not available in the published literature. This understanding can aid teachers and coaches by lending scientific support to methods being taught, and in analyzing and modifying performance. There are many mechanical factors in the draw, anchor, release, and follow-through that can affect arrow flight, and are often overlooked. It is no longer enough to simply decide that what is successful is "good form" and adopt it without knowing WHY it is successful.

CHAPTER II

REVIEW OF LITERATURE

The amount of mechanical detail explained in archery literature presenting shooting instructions varies. Many of the publications do not go below the surface of the mechanical factors included in their instructions, and explain why the way presented is thought to be the most efficient. There is some disagreement on how certain steps should be performed.

Three factors generally agreed upon in the literature reviewed that were examined in this study were: (1) the fingers of the bow hand should be relaxed--the bow should not be gripped; (2) the anchor should be held long enough for the archer to aim and to steady himself before releasing; and (3) the bow arm should remain steady until the completion of the follow-through. There was disagreement, however, on when the bow arm should be brought into shooting position. Gillelan (15:55), Klann (22:54-55), and Whiffen (31:25) recommended that the bow arm be positioned before the drawing arm begins its movement. Barrett recommended this for beginners " . . . before developing an individual draw style," but stated for experienced archers, "the draw may be initiated in a number of ways." (2:46) Starting to draw while moving the bow into shooting position was recommended by Edwards and Heath (8:76), Gordon (16:86), McKinney (25:21), and Reichart and Keasey (28:46).

Gannon stated that " . . . every person has his own method of doing it--that which feels best to him . . . ." (13:101)

Most authors (Athletic Institute, 1:25; Baier, 33:32; Barrett, 2:47; Burke, 5:73; Campbell, 6:59; Edwards and Heath, 8:76; Elmer, 10:409; Forbes, 12:30; Gannon, 13:107; Gillelan, 15:56; Jaeger, 20:73; Klann, 22:57; Miller, 34:6; Neimeyer, 26:27; Reichart and Keasey, 28:46) recommended the use of the back, or shoulder girdle, muscles as well as the upper arm and shoulder joint muscles to draw the bow. Others failed to mention the muscles that should be used to draw. Of those that did recommend using the back muscles, few gave a reason for it. Elmer (10:409) and Gannon (13:107) both stated that the muscles of the back were more powerful than the arm muscles and should be used. Campbell (6:59) stated a reason that was not found anywhere else in the literature reviewed. He stated that "the shoulder blades simply change position to allow maximum range of motion for the arm." (6:59) Strength was also given as a reason for using the back muscles by Campbell (6:59). "At full draw your shoulder blades are pulled together. This enables the larger back muscles to play a major role in holding the position." (6:59)

Kinesiologically, the explanation of more available strength is logical. There are more muscles contributing to the movement. Campbell's "maximum range of motion" needs further explanation as to why it is needed when the arrow will be drawn to the anchor point and held regardless of the muscles used. What advantage does the extended range of motion have?

The literature disagreed on the position of the drawing arm elbow at full draw. Barrett stated,

> The idea of a perfectly straight line extending from the tip of the arrow, down its shaft, along the back of the hand and lower arm to the elbow, seems to be firmly established in literature on shooting technique. (2:47)

She goes on to state that "observation shows that this straight line does not usually exist. If the proper muscles are used, the tip of the drawing elbow will be slightly above the arrow." (2:47) Haugen and Metcalf maintained that in most cases the elbow should be in line with the arrow, but that some archers who shoot with their elbow higher than this " . . . get by with this variation from correct form by virtue of the fact that they generally have unusually long ring (third) fingers." (17:15-16) McKinney stated that

> . . . expert archers hold the elbow of the drawing arm slightly above the arrow shaft and arrow point. This elbow position is necessary to maintain a good arrow-finger relationship for the subsequent release. (25:24)

Elbow position is worthy of investigation. Many coaches regard a high elbow as an indication of technique error, and try to modify the archer's form so that the elbow will be in line with the arrow. In reality, there may be no fault in the archer's form, and modification may actually add a mechanical error instead of eliminating one.

Concerning the release, it is generally accepted that the fingers serve as hooks on the string and relax at release allowing the string to slide off. Most authors agree that the drawing hand should move backwards somewhat as a reaction to the release of the tension of the bowstring. Elmer (10:409), Hodgkin (18:150), and Neimeyer (26:31) maintain that the string hand should not be moved from the anchor point at release, and therefore recommend a "dead" release. Coaches today generally regard a "dead" release as an indication that the back muscles are not being used, and so this needs further consideration.

The follow-through was acknowledged as an important part of archery technique in all the literature reviewed. Most authors seemed to agree with Haugen and Metcalf who stated its importance as follows:

> Without the use of the afterhold, an archer may well have wasted all the time, precision, and care spent in properly executing all of the previous six fundamentals and their various steps. All six previous fundamentals may have been performed perfectly, and still that effort will have been wasted by dropping the bow arm and/or snapping away the string hand and arm at the instant after release (17:31)

It is clear that there is some disagreement in the archery literature regarding efficient technique. Teachers and coaches need a scientific basis to support what is being taught, and to aid them in analyzing and modifying the students' form.

Cinematography has been used for a number of years to study athletic performance. No previous cinematographical studies in archery could be found, although most of the archery literature contained pictures of what the author considered "correct form" for the various steps described in his presentation. Many referred to motion pictures that had been taken, but the results of an analysis of the films was not presented.

Williams and Lissner (32:103-104) presented an analysis of joint and muscle forces present in the anchor position, using a photograph to record the position for analysis. No details of archery form were presented, however, as it was merely included as an illustration for computing force in various positions.

CHAPTER III

PROCEDURES USED FOR THE CINEMATOGRAPHICAL ANALYSIS

In order to effectively study the draw, anchor, release, and follow-through, it was necessary to slow the action down so complete analysis was possible. Cinematography was the method used to implement the analysis procedure. High speed film was viewed one frame at a time so each step could be studied in detail.

Selection of the Subjects

In order to study the mechanical factors that affect the flight of the arrow, subjects who were relatively consistent in their individual form and had attained an above average level of skill were selected. Members of the Longwood College Varsity Archery Team agreed to participate as subjects in the study. Three of the archers, each with their individual shooting style, but each relatively successful, were filmed on their home range on May 4, 1972.

Subject number 1 had been shooting for 5 years, and was in her second year of competitive archery. She had shot above a 525 for a Columbia Round during the season, with her scores usually between 470 and 510. She drew using her back muscles.

Subject number 2 was in her first year of competitive archery. She had shot above 525 for a Columbia Round during the season with her scores usually between 430 and 480. She drew using her back muscles.

Subject number 3 was in her second year of competitive archery. She had shot above 510 for a Columbia Round during the season, with her scores usually between 430 and 480. She used the arm pull, with her back muscles contributing little to the draw and hold.

Photography

Two spring driven Revere 16 millimeter magazine load cameras and 1 motor driven Beaulieu S2008 Super 8 millimeter camera were used for this study. Both of the Revere cameras were set to operate at a speed of 48 frames per second. The Beaulieu camera was set to operate at 50 frames per second.

One Revere camera was positioned on a tripod 25 feet directly in front of the subject at shoulder height. This camera had a 1 inch lens. The exposure was set at f/11, as the filming was done in the bright sun. This camera was operated by the archery coach of the college who had been instructed in the operational procedure by the investigator.

The other Revere camera was positioned on a wooden frame at a 65^{o} angle to the ground, which was approximately a 25^{o} angle to the subject's body, focusing on the anchor position. This camera had a ½ inch wide angle lens. The exposure setting was adjusted to f/8, as both the camera and the subject were in the shade of the backdrop. This camera was operated by the investigator, using an air release.

The Beaulieu camera was positioned 20 feet above the ground directly over the subject's head. Twenty feet of 2 inch aluminum pipe with a 3 foot extension arm at the top extended the camera over the subject. The pipe was held in position by a flange bolted to a 4' x 2' sheet of diamond plate. The camera was attached to the pipe by a ¼ inch machine bolt through a flange at the end of the 3 foot extension arm. The lens was set for a wide angle exposure, since the camera could not be focused from above after it was positioned. The line of the air release was used as a plumb line to align the subject under the camera. The camera was equipped with an electric eye that automatically adjusted itself to the light available. This camera was operated by the investigator using an air release.

Kodak Kodachrome II movie film, daylight type, was used in all 3 cameras. Color film was used because the contrast between the bow and the background was vague on black and white film previously used by the investigator, and movement of the bow could not be clearly distinguished. On the color film, the contrasts were clearly distinguishable between the subject and the background, and the bow and the background.

The subjects all wore bathing suit tops so their arms and shoulders were exposed. Black tape was used to mark the subjects' shoulder joints, elbows, and wrists for later analysis of body segment movement. The length of the forearm of each subject, between the tape at the elbow and the tape at the wrist, was recorded for later calculation of the conversion factor.

A clock marked in 1/100 second, making 1 revolution per second, was filmed with each camera for later calculation of frame time. The clock was not visible in the picture when the subjects were filmed.

Filming Site

The motion pictures for this study were taken on the archery range at Longwood College, Farmville, Virginia on the afternoon of May 4, 1972. An 8' x 8' wooden frame held a 6' x 8' dark green tarpaulin to serve as a background behind the subject. A plumb line was dropped from the top of the frame so a true vertical reference line would be visible in the pictures.

While being filmed, the subject stood on a 6' x 8' dark green tarpaulin which provided a contrasting background for the overhead camera. The number of each subject was attached to each tarpaulin in view of the respective cameras when the subject was photographed.

Each subject shot an arrow which had been marked off by inches by the investigator to provide a check on draw length. Each subject's bow was weighed at selected increments using a linear spring type scale so that the resistance force of the bow could be determined at the draw length shown in the film. (See Figure 1)

Method of Filming

Each archer was filmed shooting one end (six arrows) with her own arrows which were matched to her bow, plus one additional

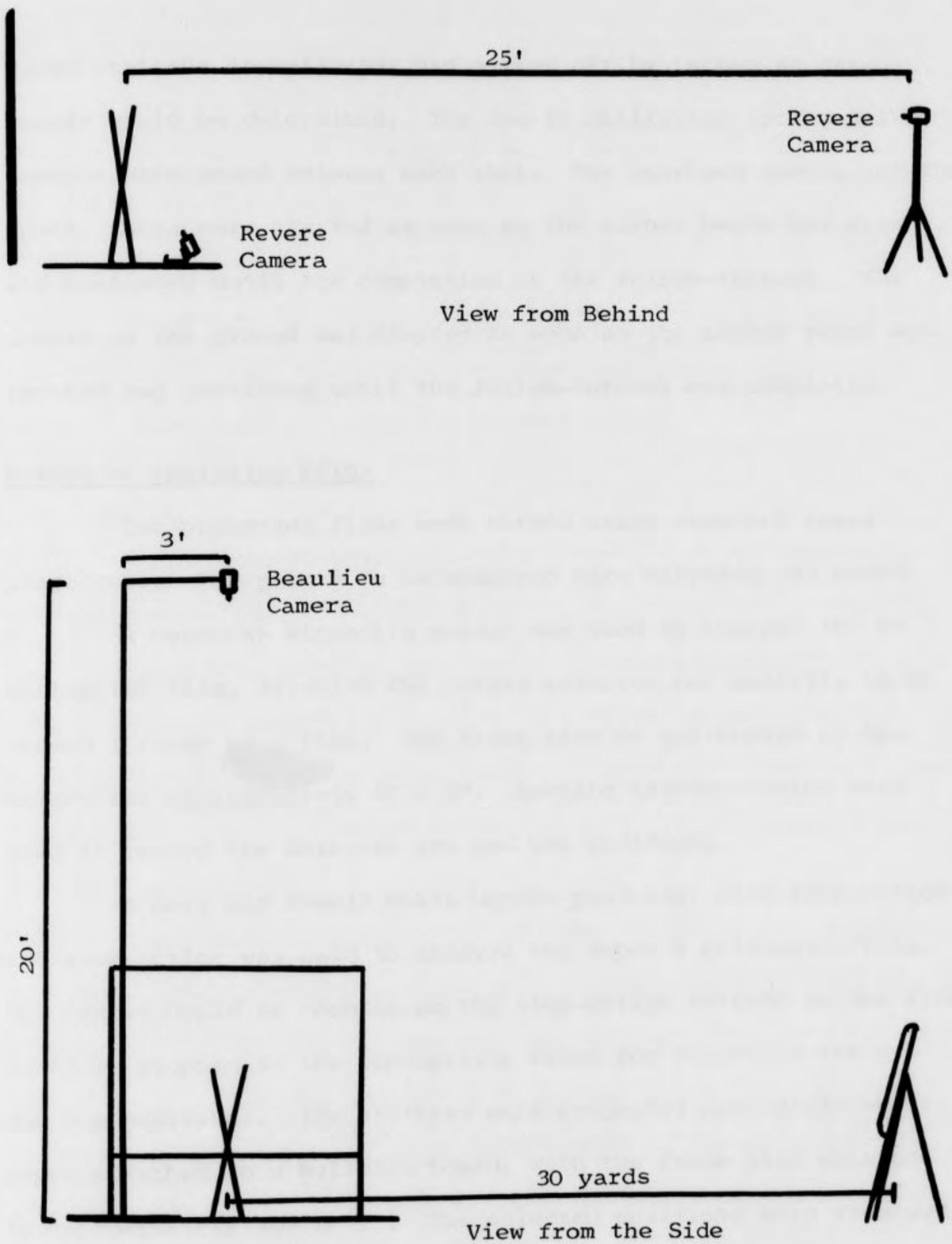


FIGURE 1

FILMING SITE

arrow that the investigator had marked off by inches so draw length could be determined. The two 16 millimeter spring driven cameras were wound between each shot. The overhead camera and the front camera were started as soon as the archer began her draw and continued until the completion of the follow-through. The camera on the ground was started as soon as the anchor point was reached and continued until the follow-through was completed.

Method of Analyzing Films

The processed films were viewed using standard speed projectors. The points to be analyzed were selected and noted.

A Recordak microfilm reader was used to analyze the 16 millimeter film, allowing the points selected for analysis to be viewed 1 frame at a time. The frame size on the screen of the reader was approximately 6" x 9". Acetate transparencies were used to record the selected arm and bow positions.

A Bell and Howell Multi Motion projector with step-action and stop-action was used to analyze the Super 8 millimeter film. The frames could be counted on the step-action setting so the film could be stopped at the appropriate frame for recording the arm and bow positions. The pictures were projected onto plain white paper attached to a bulletin board, with the frame size enlarged to approximately 10" x 12". The selected positions were recorded on the paper, which was attached so that after a position had been recorded, that sheet could be turned up and the next position recorded on an underlying sheet.

CHAPTER IV

FILM ANALYSIS

Cinematography was used to record the archers' movements for analysis. High speed film was viewed frame by frame and selected positions recorded for further study.

Front View

The 16 millimeter film of the front view of the subject was analyzed using a Recordak microfilm reader. Camera speed was determined by counting the number of frames necessary to film 1 revolution of the clock, or 1 second. The camera speed was found to be 40 frames per second, even though the camera had been set for 48 frames per second while filming. Frame time was computed to be .025 second.

The point after reaching full draw at which the anchor position appeared stabilized was determined. The number of frames between this point and release was counted to determine the length of the hold. This was converted to seconds by multiplying the number of frames by frame time. The length of the hold for each arrow was determined, and the mean of the length of the hold of each archer compared between the archers.

The shot of each archer made with the arrow which had been marked off by inches was viewed at the anchor position and the draw length noted.

It was observed when examining the length of the hold of each arrow that the camera speed was not fast enough to get a clear picture of the exact moment of release. It was originally planned to compare the shots of each archer to determine consistency, but this was not possible with this camera speed. The arrow was not in the same position in the frame immediately following release for all of the shots of any one archer. In order to select the shot in which the most action could be observed before the arrow cleared the bow, the frames immediately before and after the moment of release were examined for all of the shots. The film of the shot selected for analysis of each archer contained a frame in which the arrow was just beginning to move forward, with the arrow still visible in the following frame.

Tracings of the outline of the subject's body and the bow were made on acetate transparencies for the selected shot. The tracings were made at the anchor point, release, the 2 frames immediately following release, at two-frame intervals from this point until 12 frames (.3 second) after release, and at the completion of the follow-through. The wrists, elbows, and shoulder joints, which had been marked with tape when the subject was filmed, were recorded by marking a line on the transparency corresponding to the tape. The images from the transparencies were later traced on tracing paper for further study.

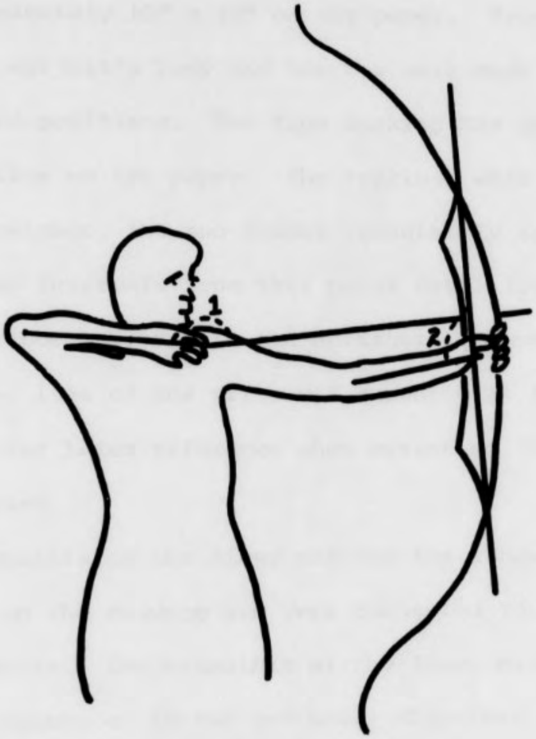
The angle of the forearm to the arrow at the anchor point, and the angle of the bow to the forearm were measured using a protractor. In order to measure these angles, the line of the forearm was determined by connecting the midpoints of the lines marking the elbow and wrist of each arm. The angle of the arrow to the forearm of the drawing arm was obtained by extending the line of the forearm and the line of the arrow and measuring the angle where the lines intersected. The angle of the bow to the forearm of the bow arm was determined by drawing a line between the points where the limbs join the handle riser section of the bow, and measuring the angle of this line to the line of the forearm. Figure 2 shows the angles measured.

Overhead View

The Super 8 millimeter film of the overhead view was analyzed using a Bell and Howell Multi Motion projector with step-action and stop-action settings. The step-action setting allowed the frames to be viewed slow enough so the frames could be counted and the frames selected for analysis stopped. The shot selected to be recorded for the front view was also recorded for the overhead view.

Camera speed was determined by counting the number of frames necessary to film one revolution of the clock, or one second. The camera speed was found to be 40 frames per second, even though the camera had been set for 50 frames per second while filming. Frame time was computed to be .025 second.

The pictures were projected onto plain white paper attached to a bulletin board so that after a position had been recorded, that sheet could be turned up and the next position recorded on



1. Angle of forearm to arrow.
2. Angle of bow to forearm.

FIGURE 2

ANGLES MEASURED IN THE FRONT VIEW

an underlying sheet. The projector was adjusted so the picture size was approximately 10" x 12" on the paper. Tracings of the outline of the subject's body and the bow were made on the paper for the selected positions. The tape marking the joints was marked with a line on the paper. The tracings were made at the anchor point, release, the two frames immediately following release, and at two-frame intervals from this point until the bow was tilted forward so that bow movement in the horizontal plane could not be determined. The line of the arrow was drawn in at the anchor point and used for later reference when measuring the movement of the bow at release.

The midpoints of the lines marking the elbow, wrist, and shoulder joint in the drawing arm were connected to form the lines of the arm segments. The midpoints of the lines marking the elbow and wrist were connected in the bow arm. Midpoints of the upper limb of the bow were marked and a line drawn bisecting the bow limb. This line and the line of the arrow, which had been traced from the drawing of the anchor point, were extended and the angle of intersection of these two lines was measured using a protractor. The angle of the elbow of the drawing arm was also recorded. The angles measured are shown in Figure 3.

<u>View from the Ground</u>

The 16 millimeter film taken with the camera on the ground looking up at the anchor point was viewed using the Recordak microfilm reader. The purpose of this view was to

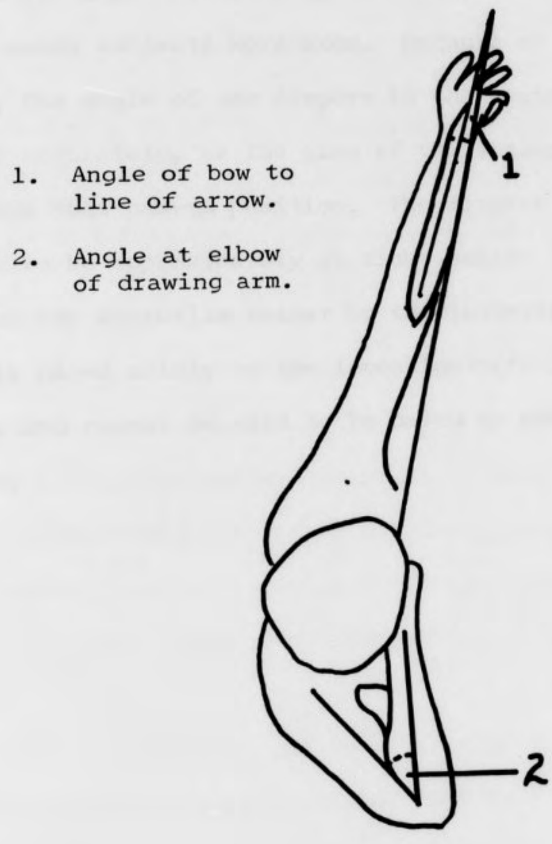


FIGURE 3

ANGLES MEASURED IN OVERHEAD VIEW

examine the angle of the fingers to the string, and the finger angle at release. The camera was positioned so it was at approximately a 25^{o} angle to the subject's body. This angle was necessary because women subjects were used. Because of this camera angle, however, the angle of the fingers to the string could not be recorded accurately, as the line of the string could not be determined from this camera position. The fingers of all the subjects appeared to be approximately at right angles to the string when viewed on the microfilm reader by the investigator. This observation is based solely on the investigator's judgement and perception, and cannot be said to be based on measurable scientific evidence.

CHAPTER V

ANALYSIS OF DATA

The purpose of this study was to examine selected mechanical factors of the draw, anchor, and release and to determine if these factors were influenced by the method used to draw the bow.

Length of Hold

The hold at the anchor position is an important step in the technique of the archer. Once the anchor point is reached, it needs to be held long enough for the archer to aim and to steady himself before releasing the arrow. The length of the hold at the anchor position was recorded for each shot of each subject. (Table 1)

Subject number 1, who drew using her back muscles, held the longest at the anchor position. The length of the hold ranged from 1.625 seconds to 2.775 seconds, with the mean being 2.1 seconds.

Subject number 2, who drew using her back muscles did not hold as long on 2 of her shots as the shortest hold of Subject number 1, and the mean of the length of time she held was not as long. The length of her hold ranged from 1.275 seconds to 2.525 seconds, with the mean being 1.8643 seconds.

Subject number 3, who used the arm pull, held the shortest amount of time at the anchor position. She held 3 arrows as long

TABLE 1

LENGTH OF HOLD AT THE ANCHOR POSITION

	Subject 1 (seconds)	Subject 2 (seconds)	Subject 3 (seconds)
Shot 1	2.775	1.775	.850
Shot 2	1.650	2.025	1.200
Shot 3	2.250	1.700	1.375
Shot 4	1.625	1.475	1.450
Shot 5	1.625	1.375	1.450
Shot 6	2.475	2.175	1.175
Shot 7	2.300	2.525	1.275
Mean	2.100	1.864	1.254

as the shortest hold of Subject number 2, but none as long as the shortest hold of Subject number 1. The length of her hold ranged from .85 second to 1.45 seconds, with the mean being 1.2536 seconds.

The length of the hold at the anchor position would appear to be related to the method of drawing the bow. The two subjects who drew using their back muscles both held longer than the subject using only her arm and shoulder joint muscles. The difference between the mean length of time the anchor position was held between Subject number 1 and Subject number 2, both of whom drew using the back muscles, was .2357 second. The difference between Subject number 2, whose mean length of hold was the shortest of the 2 who drew with their back muscles, and Subject Number 3, who used the arm pull, was .6107 second. The mean length of time that Subject number 1 held was .8464 second longer than the mean length of the hold of Subject number 3. The range of the length of the hold was greater for the 2 subjects who drew using their back muscles than for the subject who used the arm pull.

Length of Hold in Relation to Draw Weight

The draw weight of the bow at the subject's draw length was examined in relation to the length of time the anchor position was held. The draw weight of the bow at various increments had been recorded at the time of filming. Using this record, draw weight at the subjects' draw length could be determined by noting the draw length from the film of the shot of the arrow marked off by inches and reading the corresponding draw weight.

The mean length of time that Subject number 1 held at the anchor position was the longest of the 3 subjects. Her bow offered a resistance force of 25 pounds at her draw length.

Subject number 2 held the second longest at the anchor position. The draw weight of her bow at her draw length was 29 pounds. This was the heaviest bow, in terms of draw weight, used by any of the subjects.

Subject number 3, whose hold at the anchor position was the shortest, pulled the lightest bow. The draw weight of her bow at her draw length was 22 pounds.

There did not seem to be a relationship between the length of time the anchor position was held and the weight of the bow except between Subjects 1 and 2, both of whom drew using the back muscles. It was interesting that Subject number 3, who drew the lightest bow and also held the shortest length of time at the anchor position, used the arm pull. However, since the strength of the subjects was not measured to determine whether this could have influenced the draw weight used, and the length of the hold, no definite conclusions can be drawn.

<u>Forearm Angle to Arrow</u>

Many archery teachers and coaches teach that there should be a straight line from the tip of the arrow to the elbow of the drawing arm. When reviewing the literature on shooting technique, most authors agreed that there should be a straight line down the shaft of the arrow along the back of the hand and forearm to the elbow. Barrett stated that "observation shows that this straight line does not usually exist." (2:47) The elbows of all three subjects in this study were elevated to some degree.

Subject number 1 shot with the elbow extremely elevated. At anchor, her elbow was 17° above the line of the arrow, the shaft of the arrow and the line of her forearm intersecting at an angle of 163°. (Figure 4) Taking into consideration Haugen and Metcalf's (17:15-16) reasoning that some archers could get by with an elevated elbow because they have unusually long third (ring) fingers, the subject's hand was examined. Her third finger was noticeably longer in relation to her other fingers when compared with the hand of the investigator. It cannot be stated definitely that the long third finger is the cause of the extremely high elbow, but it is a factor which should be given further consideration.

Subject number 2 had the least elevated elbow of the three subjects photographed. Her elbow was 2° above the shaft of the arrow, the angle of intersection of the arrow and the line of the forearm being 178°. (Figure 5) The length of her third finger was not noted to be exceptionally long in comparison to her other fingers.

The elbow of Subject number 3 was noticeably elevated, but not to the extent of the elbow of Subject number 1. Her elbow was 10° above the line of the shaft of the arrow, the line of the arrow and the line of the forearm intersecting at an angle of 170°. (Figure 6) The length of her third finger in relation to her other fingers was longer when compared to the investigator's hand, but not as long in proportion when compared to the hand of Subject number 1.

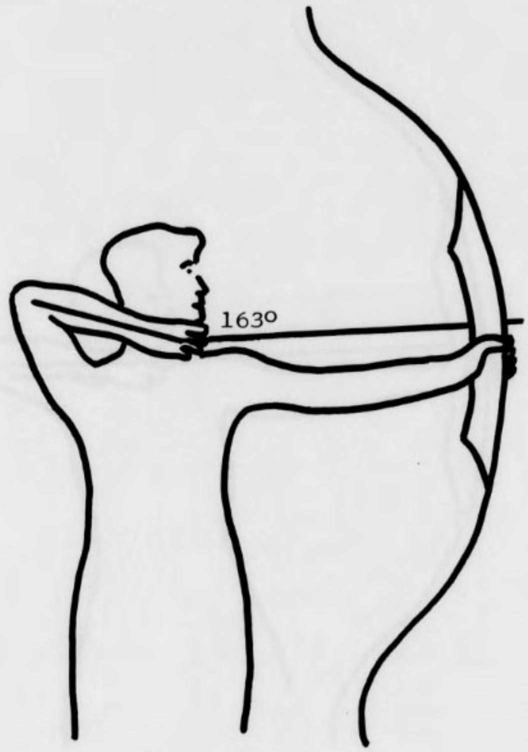


FIGURE 4

ELBOW ELEVATION OF SUBJECT NUMBER 1

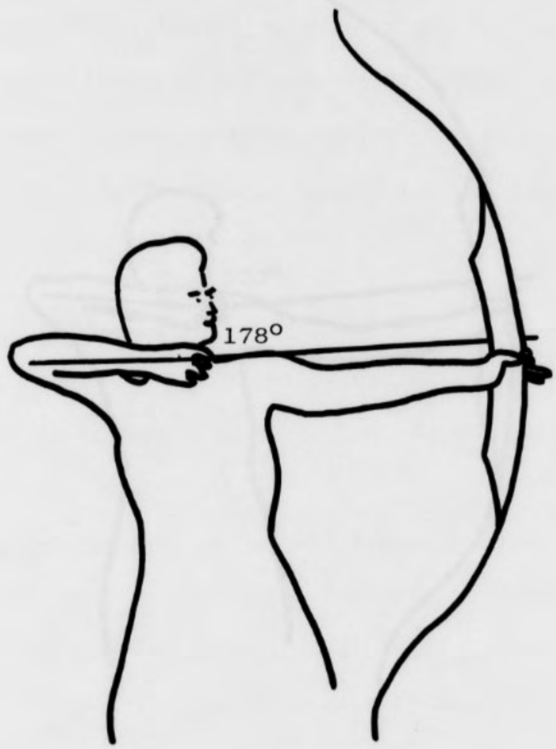


FIGURE 5

ELBOW ELEVATION OF SUBJECT NUMBER 2

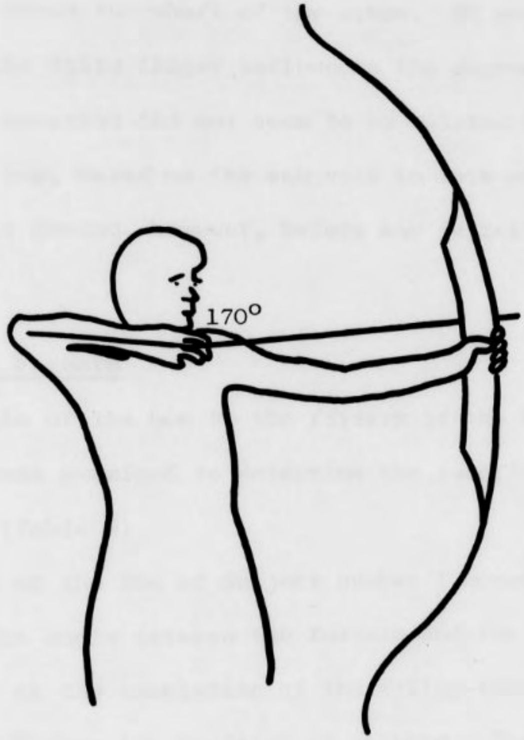


FIGURE 6

ELBOW ELEVATION OF SUBJECT NUMBER 3

The elbows of all the subjects in this study were elevated to some degree above the shaft of the arrow. It would appear that the length of the third finger influences the degree of elevation. The degree of elevation did not seem to be related to the method of drawing the bow, based on the subjects in this study. Further investigation is needed, however, before any definite conclusions can be reached.

Angle of Bow to Forearm

The angle of the bow to the forearm of the bow arm in the vertical plane was examined to determine the reaction of the bow after release. (Table 2)

The top of the bow of Subject number 1 moved forward after the release. The angle between the forearm and the bow steadily increased until at the completion of the follow-through, the angle had increased 23° from the position at release. The subject was noticed to wrap all of her fingers around the bow at release, having been relaxed and not gripping the bow prior to the release. Ulnar flexion at the wrist was also observed from release to the completion of the follow-through, which could have been partially responsible for the motion of the bow, or may simply indicate that the wrist was relaxed and moved with the bow.

The top of the bow of Subject number 2 moved backward until .1 second after release, the angle between the bow and the forearm decreasing, at which time it stabilized momentarily. At this point, the angle had decreased 6° from the release position. The angle

TABLE 2

ANGLE OF BOW TO FOREARM

Position	Subject 1 (Degree)	Subject 2 (Degree)	Subject 3 (Degree)
Anchor	94	93	94
Release	94	93	94
R+* .025 sec.	97	93	94
R+ .05 sec.	99	90	91
R+ .1 sec.	99	87	96
R+ .15 sec.	100	87	97
R+ .2 sec.	104	92	97
R+ .25 sec.	108	90	97
R+ .3 sec.	111	91	97
End of F-T**	117	108	97

* R = Release
** F-T = Follow-through

alternately increased and decreased until .3 second after release, at which time it began to increase. At the end of the follow-through, the angle had increased 15° from the angle at release, and 21° from the smallest point. Subject number 2 held the bow with her index finger, middle finger, and thumb against the bow. There was no way of determining how much pressure was exerted. The backward movement of the bow prior to the forward movement cannot be explained based on the evidence available. The backward movement could be the natural reaction of the bow, with the forward motion being forced by the archer, or it may be due to an error in the archer's technique at release.

The angle between the forearm and bow of Subject number 3 remained constant for .025 second after release. The angle had decreased .05 second after release, but began to increase after this point. The angle stabilized .3 second after release, having increased 3° from the angle at release. Subject number 3 had very little bow movement. All of her fingers were wrapped around the bow, but the tightness of her grip could not be determined. It can only be assumed that the bow action was inhibited by the grip.

Bow Arm Movement After Release (Vertical Plane)

Movement of the bow arm after release should not be ignored as it may be a continuation of movement that began before the arrow cleared the bow. If movement takes place before the arrow clears the bow, arrow flight may be adversely affected.

The bow arm of Subject number 1 remained stable after the anchor position was established until the completion of the follow-through.

The bow arm of Subject number 2 dropped noticeably on the follow-through. To measure the drop in the arm, a line was drawn from the midpoint of the shoulder joint through the midpoint of the wrist. When the tracing of the release was compared with the tracing of the follow-through, there had been an 8° drop of the arm. (Figure 7)

After observing this drop, the investigator recorded the midpoints of the joints of the bow arm for all of the shots of Subject number 2 for the frame immediately before release, at release, and the following frame, or frames, until the arrow had cleared the bow to determine if the movement started before the arrow was clear. The plumb line used to establish a true vertical was used as a reference line in measuring movement. The arm was lowered on only one of the shots before the arrow left the bow. Even though the bow arm dropped before the arrow was clear in only one of the shots photographed, the arm should remain steady until the completion of the follow-through so the possibility of dropping it too early would be eliminated.

The bow arm of Subject number 3 remained stable until the top of the bow started forward, well after release. This movement was slight and was apparently related to the forward movement of the bow not affecting the flight of the arrow.

Bow Movement After Release (Horizontal Plane)

Change in the angle of the bow to the line of the arrow was studied in relation to the change in the elbow angle of the drawing arm at release. The angle of the bow limb to the line of

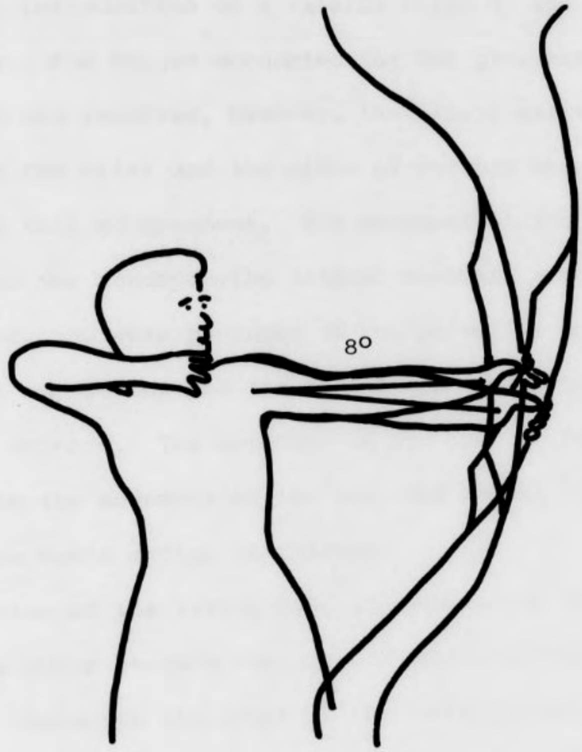


FIGURE 7

BOW ARM MOVEMENT OF
SUBJECT NUMBER 2

the arrow was thought to give an accurate representation of bow movement due to introduction of a lateral force by the string hand at release. Bow torque accounted for the greatest change in this angle. It was realized, however, that there was some change in the angle at the wrist and the elbow of the bow arm which may have influenced this measurement. The movement at the joints in the bow arm, and the accompanying lateral movement were slight and seemed to be, and were presumed to be, primarily a reaction to the movement of the bow and the relaxation of the tension in the bow arm at release. The movement in the bow arm was not thought to cause the movement of the bow, but rather to be initiated by the bow's action at release.

The action of the string hand at release was not visible from the camera above because the archers anchored under the chin. Therefore, the change in the angle at the elbow of the drawing arm was used as an indication of lateral movement of the string hand at release. (Table 3)

The angle of the drawing arm elbow of Subject Number 1 increased 4° from the anchor position at release. The angle of the bow to the line of the arrow changed 4° to the left during the same period of time. The bow swung back 6° to the right .025 second after release. In the next .025 second, the angle changed 13° to the left. The change in the angle of the bow to the line of the arrow after release seemed to be related to the change in the angle of the drawing arm elbow at release. This change in the angle at the elbow indicated that the hand exerted

TABLE 3

ANGLE OF DRAWING ARM ELBOW IN RELATION TO ANGLE OF BOW TO LINE OF ARROW

	Position	Angle of Elbow	Angle of Bow to Line of Arrow
		(Degree)	(Degree)
	Anchor	39	4 left
	Release	43	8 left
	R+* .025 sec.		2 left
	R+ .05 sec.		15 left
Subject 1	R+ .1 sec.		11 left
	R+ .15 sec.		9 left
	R+ .2 sec.		13½ left
	Anchor	36	3 right
	Release	35	5 left
	R+ .025 sec.		3 left
	R+ .05 sec.		5 right
Subject 2	R+ .1 sec.		8 right
	R+ .15 sec.		1 right
	R+ .2 sec.		5 right
	Anchor	40	Parallel
	Release	43	1 right
	R+ .025 sec.		2 right
	R+ .05 sec.		3 left
Subject 3	R+ .1 sec.		2 right
	R+ .15 sec.		3 right

*R = Release

The angle at the elbow at anchor and release only are given, as this is the time when the fingers are in contact with the string and influence torque.

lateral force at release, causing bow torque. The bow was 4^{o} left of the line of the arrow at the anchor position, indicating the bow would torque at release to some degree since it was out of alignment when the string was released. (Figure 8)

The angle of the drawing arm elbow of Subject number 2 decreased 1^{o} from the anchor position to release with a corresponding change of 8^{o} to the left in the bow angle. In the .025 second after release, the bow angle changed 2^{o} to the right and continued to the right 8^{o} in the next .025 second. The decrease in the angle of the elbow could indicate hyperextension of the wrist at release causing the fingers to leave the string at an angle, affecting bow movement. The bow was 3^{o} to the right of the line of the arrow at the anchor position, indicating the bow was out of alignment and would torque, to some extent, with a smooth release. (Figure 9)

The angle of the drawing arm elbow of Subject number 3 increased 3^{o} from the anchor position at release, with the bow moving 1^{o} to the right during this period. In the .025 second after release, the bow continued right 1^{o}. The bow angle changed 4.5^{o} left in the next .025 second. The increase in the angle of the elbow indicated that the hand exerted lateral force at release causing bow torque. The bow was parallel to the line of the arrow at the anchor, indicating the torque was due to hand action at release. Hand action is assumed to be the cause since a lateral force had to be introduced for torque to result. (Figure 10)

The change in the angle of the bow to the line of the arrow was greatest in Subjects 1 and 2. Both of these archers had the

FIGURE 8

ANGLE OF THE BOW OF SUBJECT NUMBER 1 TO THE LINE OF THE ARROW AT THE ANCHOR POSITION

FIGURE 9

ANGLE OF THE BOW OF SUBJECT NUMBER 2 TO THE LINE OF THE ARROW AT THE ANCHOR POSITION

FIGURE 10

ANGLE OF THE BOW OF SUBJECT NUMBER 3 TO THE LINE OF THE ARROW AT THE ANCHOR POSITION

bow aligned at an angle to the line of the arrow at the anchor position prior to release, indicating the bow would torque to some degree at release, even with a perfectly smooth release since the force would be exerted off center when the bow limbs began to straighten. Subjects 1 and 3 had the greatest increase in the angle at the elbow, which would seem to indicate lateral force being imparted to the string at release. The change in the angle of the bow to the line of the arrow was greatest in the bow of Subject number 1, who had a 3^{o} change in the elbow at release, and her bow out of alignment. The bow of Subject number 3 experienced the least torque. This bow was parallel to the line of the arrow prior to release, but the angle of the subject's elbow increased 3^{o} at release. Based on the subjects in this study, it appears that the alignment of the bow prior to release may have as much influence on bow torque as hand action, within reasonable limits. Figure 8, page 41, Figure 9, page 42, and Figure 10, page 43, show the bow alignment at the anchor position of the three subjects. Table 3, page 39, shows the angle at the archers' elbow and the angle of the bow to the line of the arrow.

Individual Characteristics of the Archers

There was some deviation from the "standard" form in the shooting style of all of the archers in this study. These differences were examined to see whether they were more a matter of individual style or performed some mechanical function.

There were several characteristics shared by the three archers. These will be noted first before describing individual differences. The archers were similar in that: (1) all three of the subjects used a square stance; (2) the bow was drawn as the bow arm was being positioned by all three archers; and (3) all three anchored under the chin.

Subject number 1 anchored with the string away from her face. The string did not touch either her chin or her nose. The index finger resting under the mandible served as her reference point. She was consistent in the anchor position, drawing to the same point each time. The mean length of her hold at the anchor position was the longest of the three subjects. The angle of the elbow of her drawing arm to the arrow was very noticeable. She had an extremely elevated elbow, 17^{o} above the line of the arrow. As noted previously, the high elbow could have been influenced by the length of her third finger, but the investigator is not satisfied that this was the only reason for the elbow being elevated to such an extreme. A more detailed study of the subject may reveal other factors contributing to the high elbow.

At release, the string hand of Subject number 1 pulled out to the right, rather than straight back. The right elbow had started to drop .05 second after release, and continued dropping until the completion of the follow-through. At the same time that the elbow was dropping, the hand was being brought around behind the head, so that at the completion of the follow-through, the right arm was in the position shown in Figure 11.

Subject number 1 shot a perfect end (6 golds) with her matched arrows while being filmed, so the basic mechanics of her

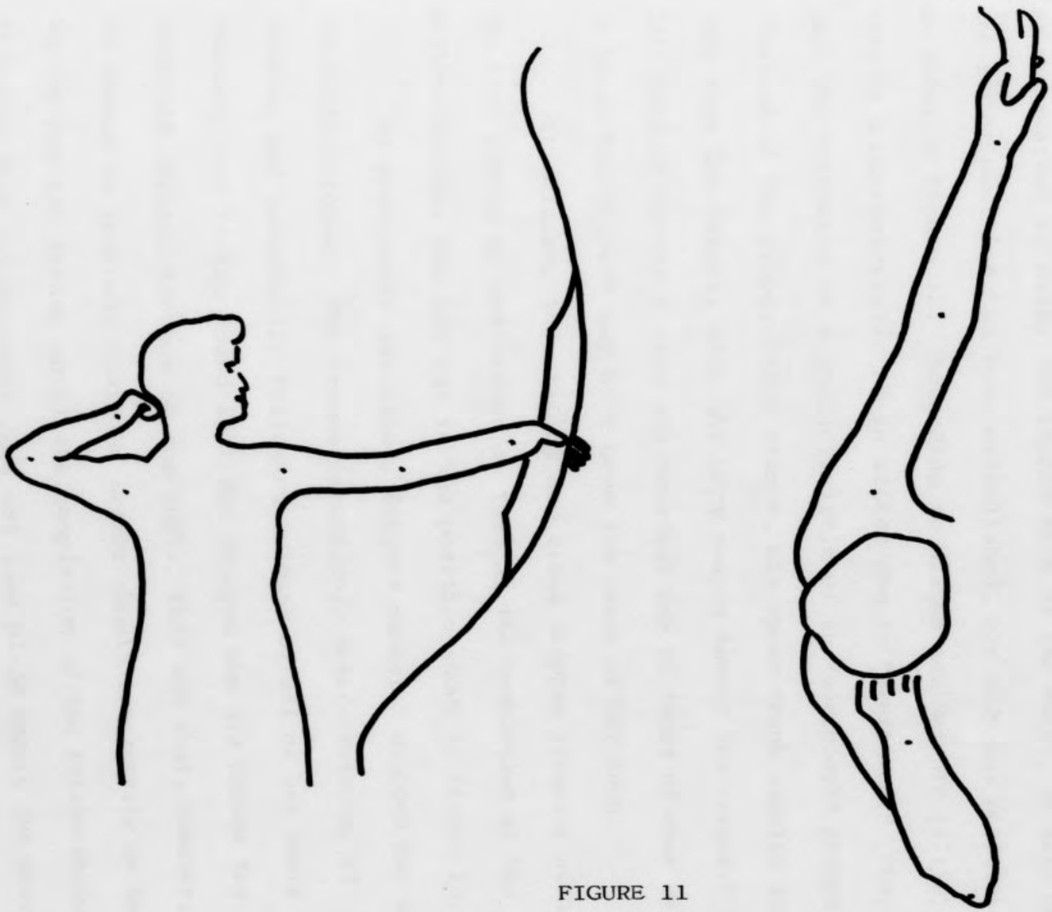


FIGURE 11

COMPLETION OF FOLLOW-THROUGH
OF SUBJECT NUMBER 1

style would seem to be sound and not adversely affected by the extraneous movements.

Subject number 2 anchored with the string pressing against her chin and nose, and the index finger resting under the mandible. As she started to draw, she leaned back at the waist, so that when the anchor position had been established, her body was positioned as shown in Figure 12. According to Haugen and Metcalf (17:12), this is a characteristic of an archer who is "overbowed." They gave the following as a characteristic of an "overbowed" archer: "Instead of the proper erect stance, his upper trunk usually leans away from the target, with the hips swayed toward the target." (17: 12) Subject number 2 used the heaviest bow in terms of draw weight so being "overbowed" may have been the cause of her lean.

At release, the drawing arm elbow dropped slightly with the hand coming up and around so that at the completion of the follow-through, the arm was in the position shown in Figure 13.

As previously described, Subject number 2 dropped her bow arm after release. The frames immediately before release, at release, and immediately following release of all of her shots were examined, and it was found that she dropped the arm before the arrow had cleared the bow on one shot. This one shot, however, was enough to indicate that the archer should concentrate on keeping the bow arm steady until the completion of the follow-through to insure that the movement does not take place before the arrow has cleared the bow. It was noted that five of the subject's six matched arrows were golds, but the order of shots was not known.

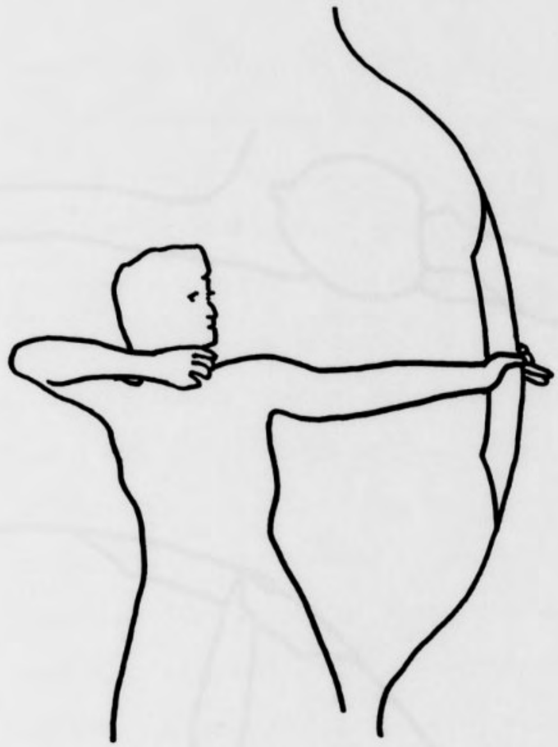


FIGURE 12

SUBJECT NUMBER 2 AT THE ANCHOR POSITION

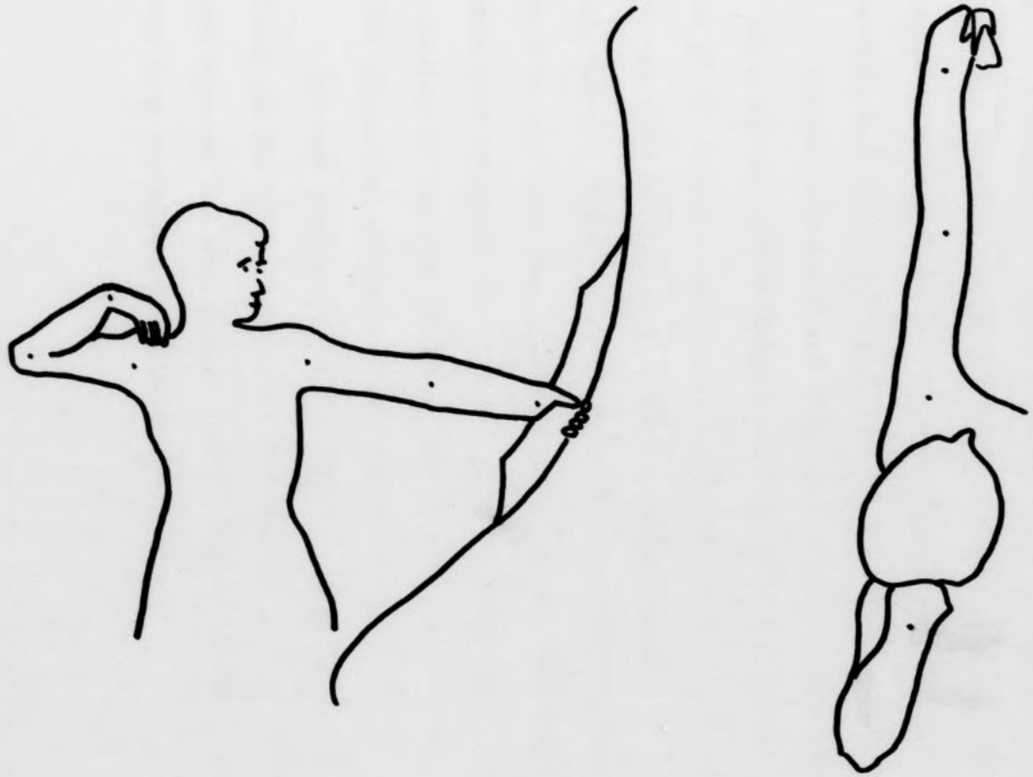


FIGURE 13

COMPLETION OF FOLLOW-THROUGH
OF SUBJECT NUMBER 2

It can only be speculated that the shot that missed the gold was the one on which the arm dropped before the arrow had cleared the bow.

The follow-through of both Subject number 1 and Subject number 2 involved much more movement than the natural reaction of the arm due to the release of tension of the bow string. This exaggerated movement after the natural reaction had no mechanical advantage, and was simply a matter of individual style.

Subject number 3 anchored with the bow string touching her chin, and her index finger resting under the mandible. The elbow of the drawing arm was elevated at the anchor position 10° above the line of the arrow. When viewing the film at regular speed, Subject number 3 appeared to have a "dead" release. However, when the film was viewed frame by frame, the hand was seen to move back slightly at release, as a reaction to the release of the tension of the bow string. The position of Subject number 3 at the completion of her follow-through is shown in Figure 14.

Subject number 3 had the shortest hold at the anchor position of the three subjects. She apparently had not taken enough time to aim and steady herself before release, because her arrows were scattered over the target face.

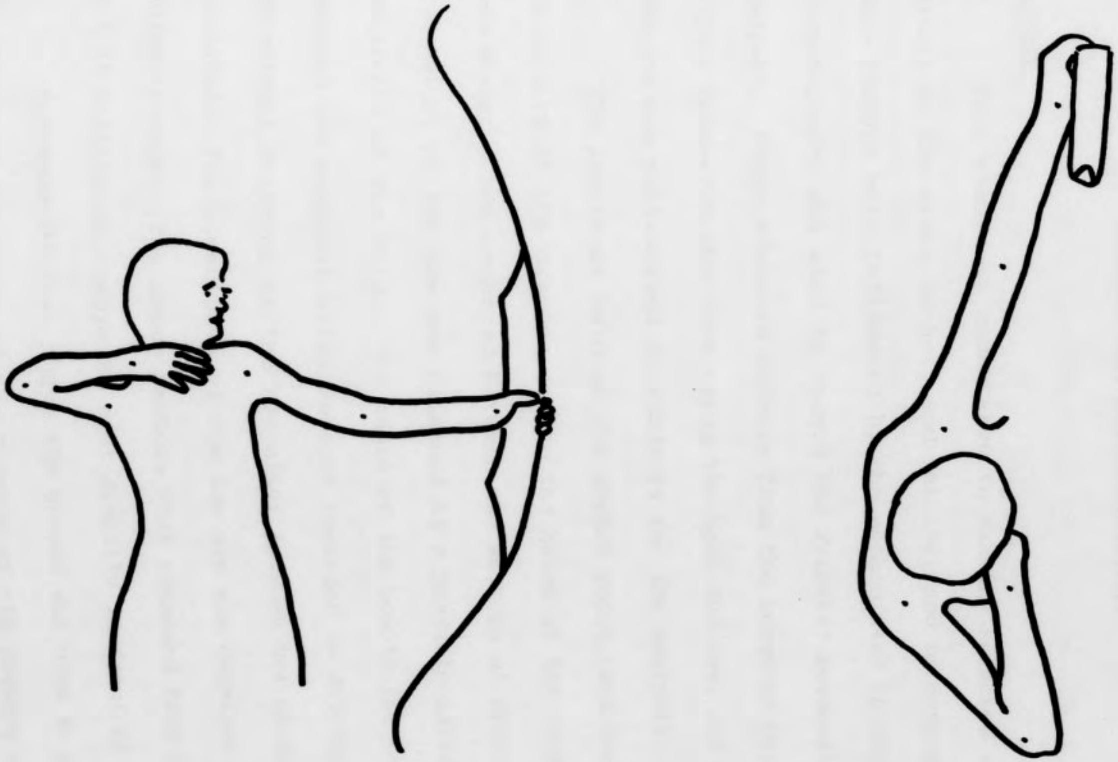


FIGURE 14

COMPLETION OF FOLLOW-THROUGH
OF SUBJECT NUMBER 3

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

Summary

This study was undertaken to examine selected mechanical factors of the draw, anchor, and release, and to determine if these factors were influenced by the method used to draw the bow. Cinematography was used to record the archers' movements for later analysis. Three advanced archers from the Longwood College Archery Team--two who drew using the back muscles, and one who used the arm pull-served as subjects for the analysis.

The length of hold at the anchor point, and the angle of the forearm of the drawing arm to the arrow at the anchor point were measured and compared between the methods of drawing the bow. Draw weight of the bow was examined as a possible influence on the length of the hold. The angle of the bow to the forearm was measured and movement after release recorded to determine whether the natural reaction of the bow after release was permitted or inhibited. The steadiness of the bow arm was examined on the follow-through. The above factors were examined from films taken by a 16 millimeter camera 25 feet directly in front of the subject.

A camera 20 feet above the ground was used to photograph the change in the angle of the forearm of the drawing arm at release, and its effect on bow torque. It was planned to examine finger angle to the string using a camera on the ground focusing upward on the anchor point. It was not possible to measure the angle of the fingers to the string, however, due to the angle of the camera necessary when filming female subjects.

The films were viewed frame by frame and the positions selected for analysis recorded. The length of the hold was determined by counting the frames from the point when the anchor position was established until the release, and multiplying this number by frame time.

Summary of Results

As a result of this cinematographical analysis, a number of things were determined regarding the mechanics of the archers, and the influence of the method of drawing the bow on selected mechanical factors.

A. Length of the Hold

1. The length of the hold at the anchor position appeared to be influenced by the method of drawing the bow.
2. The archers who draw using their back muscles held longer than the archer using the arm pull.
3. The length of the hold at the anchor position varied within each archer.

B. Forearm Angle to Arrow

1. The elbow was frequently elevated above the line of the shaft of the arrow.

2. The elevation of the elbow was not related to the method of drawing the bow.

3. There seemed to be a relationship between the degree of elbow elevation and the length of the third (ring) finger on the drawing hand.

C. Angle of Bow to Forearm

1. Even though the bow hand appeared relaxed prior to release, the archers seemed to grip the bow to some extent at release inhibiting the natural reaction of the bow.

2. There was an increase in the angle of the bow to the forearm when the follow-through was completed, regardless of the direction of the bow immediately after release.

D. Bow Arm Movement After Release (Vertical Plane)

The archer who dropped her bow arm after release was found to have started dropping it before the arrow had cleared the bow on one shot. This could have adversely affected arrow flight.

E. Bow Movement After Release (Horizontal Plane)

1. Bow movement after release was related to hand action at release, which was reflected in the change in the angle of the elbow of the drawing arm.

2. Bow movement was increased after release when the bow limbs were not in alignment with the line of the arrow prior to release.

Recommendations

On the basis of this study, it is recommended that:

1. more cinematographical studies be done of archery using more subjects, with a wider variety of skill level;
2. faster camera speed be used so the action at the moment of release can be recorded;
3. a way be devised to film the angle of the fingers to the string at the anchor position so the angle of the fingers at release can be studied;
4. the position of the elbow of the drawing arm be studied further, and the causes for its position be examined;
5. electromyography be combined with cinematography to study the archer's movements;
6. bow weight be studied in relation to the subject's strength, strength being measured in relation to the specific movement involved.

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