Performance archery shooting

by

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ABSTRACT

Bows and arrows can be traced all the way back to 65,000 BC and have evolved from a tool used for hunting, to a tool for war, and today used by hobbyists in competition. The evolution of this technology has progressed for the most part without an understanding of the effect it has on humans. The present study aims to connect how technology effects humans specifically looking at archery. The study measured the muscle activity in the bow arm of the archer and the vibration experienced on the bow arm of the archer during the shooting process. From those measurements, the presence of an impact to the human arm was established. It was also identified the archer was anticipating this impact with higher muscle activation in the bow arm upon releasing of the arrow. This resulted in focusing on research involving the back-tension release. The theory behind this release is it mitigates the anticipation of the impact by creating a surprise factor in shooting. This release reduced the ability of the human to brace in anticipation during the shot by taking away the knowledge of when the shot is going off. The results found in this study concluded the new technology did introduce a surprise factor, but it did not reduce the occurrences of preparatory muscle activation in the human's arm.

LIST OF TERMS

Compound Bow: A type of bow that has pulleys at the top and bottom of limbs.

Limbs: The top and bottom part of the bow which is used to create tension on the bow.

Cams: The pullies at the top and bottom of the bow which allow for the adjustable draw length and is what the bow string rolls on as the bow is being pulled back.

Whisker Biscuit: What is used to hold the arrow in place by the hand.

Knock: Is the location where the arrow is placed on the bowstring. Also, can be used as a verb to describe the process of placing an arrow onto the bowstring.

Draw Length: The distance at which the string on the bow is being pulled back. Calculated from the individual's wingspan in inches and divided by two and a half.

Example of an individual with a 72-inch wingspan. This individual will shoot with a 28-inch draw length. The draw length is then rounded down to the nearest inch.

$$\frac{72\ inches}{2.5} = 28.8\ inch\ draw\ length$$

Draw Weight: The amount of weight the individual will have to apply to the bowstring in the form of a pulling motion to completely draw back the bow. For the bow used in the study, it will be held a constant at 42.5 pounds +/- 2.5 pounds.

Let off: The percentage of weight that is taken off the bowstring once fully drawn back due to the mechanical advantage; the bow creates with pullies. The bow used in the present study will have 50% at full draw, and this weight will be 20 pounds.

Bow Arm: The arm the archer is holding the bow in. For the present study, it will always be the left arm due to only having a righthanded bow.

Draw Arm/Release Hand: The arm that is holding the release and pulling back the bowstring.

INTRODUCTION

Bows and arrows can be traced back to 65,000 BCE where they were found in Southern Africa (Lombard, 2011). Bows and arrows were primarily used for hunting for food in the beginning and evolved to a tool for protection. Through the years, humans have perfected the bow from a long bow to a recurve bow, to today's compound bow. In today's society, the bow and arrow have become more of a sport, at which one can compete at the highest levels, the Summer Olympics.

How have the technological improvements of the bow and arrow effect how humans use them? As technology evolves, it has become more effective at accomplishing the tasks it is used for, but what impact does the evolution of technology have on humans? Much of the previous research in this area concerned itself with the usefulness and usability of the technology (Thuring, Mahike, & Thuering, 2007). Rather than the impact, the technology has on the humans who use it. Specifically, research on the biomechanical activity of the muscles in the bow arm and how the interaction can affect an archer during the shooting process. Research is needed to understand better the interaction archery has on humans to bring about better product design of the equipment.

Through the ages, the way the bow is shot has evolved, yet the understanding of the effects it has on the human has not been identified. Stone (2007) looked at the biomechanical strain of poor form and how it can reduce accuracy when shooting. Stone (2007) did not investigate the biomechanical interaction of the human releasing the arrow from the bow. With archery being "a skill which involves high concentration and precisions while involving strength and endurance of the upper body to produce a consistent shot," the biomechanical ability of a human is important (Ertan, Kental, Korkusuz, Tümer, 2003). Archery has a few key aspects needed to produce high-quality shots and any small deviation from these aspects by the archer can cause an undesired outcome, such as where the placement of the arrow lands stated by Hwang and Lin (2005). To become a highly effective archer, the process of drawing, holding, aiming, and releasing of the arrow from the bow needs to be highly reproducible to have precision arrow placement. This requires an archer to have a large amount of cognitive and physical concentration to be highly successful.

In recent years, a way to release the bowstring from the bow has developed through the use of the back-tension release. How the back-tension release increases performance is by taking away the ability of the archer to know exactly when the arrow is going to be released. The use of a back-tension release has been argued and discussed by archery experts if it is taking away the tradition of archery because of the increase in performance (Brettingen, 2014). When talking with an archery expert it was stated, “While shooting, moments before the releasing of the arrow, the archer braces in anticipation,” (John Shappel, Archery Expert Tri-State Outdoors). Ideally, an archer wants to eliminate any last-minute movement or bracing when the arrow is being shot. This movement will then decrease the ability of the archer to place the arrow exactly where they want, archery expert Tom stated, “With a back-tension release an archer no longer is using their fingers to squeeze the trigger, rather, squeezing of the back muscles to release the arrow” (Tom Goldsmith, Competition Archery Expert Plum Creek).

This squeezing of the back muscles is supposed to eliminate any movement in two different ways: the arrow is now smoothly being released, and the archer no longer knows when the arrow is being shot, creating a surprise in the shooting. This surprise will not let the archer brace for the shot making the archer more precise of a shooter. For an archer, the muscle activity in the arms is extremely important to stay consistent. Ertan (2003) expressed, “The contraction and relaxation strategy in the forearm muscle during the release of the bowstring is critical for accurate and reproducible scoring," (Ertan et al., 2003). This point is strengthened with Schnieders, Stone, Oviatt, and Danford-Klein (2017) who found that small movements in the arm can lower the ability to be accurate. Sanes (1983) also made the statement, "the size of the movement is a critical variable in determining whether the central signal to muscle is adequate to specify the end point for the limb" (Sanes & Evarts, 1983). The amplitude of the muscle movement in the arm will cause an undesired placement while aiming the bow.

This preparatory muscle activation is caused by the idea Zaniewski (2010) purposes, "The sharp recoil of the handle after the bowstring has been released and the vibration of the bow after an arrow has been launched from its knock point…" is something archers attempt to avoid (Zaniewski, 2010). The bow will be used as the tool that compromises arm stability to see the effects caused upon the arm while under a static hold while also an identification if the surprise factor of a back-tension release can reduce the preparatory response time of the archer (Krutky, Ravichandran, Trumbower, & Perreault, 2009).

This muscle activation will be measured, and the timing of it looked at in comparison to when the arrow is being shot. The muscle activation will be measured through the use of electromyography and the time recorded with a video camera during the shooting trial. The use of the Facial Action Coding System (FACS) with Ekman's six basic emotions will be used to measure the element of surprise on the archer's face from the video recording (Ekman, 1992).

The hypothesis is when the archer is shooting with the traditional trigger release there will be more occurrences of preparatory muscle activation during shooting than with the back-tension release. It will be determined if a presence of vibration in the archer's bow arm occurs, and the magnitude of the vibration will be measured. The final hypothesis is the element of surprise will occur more often on the archer's face when shooting with the back-tension release rather than the trigger release.

METHODS

Equipment:

With the approval of the Institutional Review Board for the study, which can be seen in the Appendix. The study used a compound hunting bow (*Figure 1)*. It allowed for adjustability of the draw length; the range of the adjustability of the draw length was 22 inches to 30 inches. This allowed for the ideal draw length to be set for each archer. The bow was kept at a constant draw weight of 42.5 pounds +/- 2.5 pounds. The bow had a let-off weight of 50% when fully drawn back. To draw back the bow, the archer, used two different types of hand releases. A standard trigger release was used, and a new style back-tension release was used. Each type of release can be seen below in *Figure 2 & 3*. Practice arrows with practice target tips were used by the archers to shoot at a block target from five yards away. The target was set at a close distance to reduce the likelihood of arrows being missed by novice archers. A hand-held trainer (*Figure 4*) was used for practice which had a pull weight of 29 pounds and no let off at full draw. A hand-held trainer was used to teach novice and expert archers the proper technique to pull back and release the bowstring.

Figure 1. Compound Bow

Figure 2. Trigger Release.

Figure 3. Back-Tension Release.

Data Collection Equipment:

BioGraph Infiniti ProComp encoder was used to collect surface Electromyography (EMG) data from the participants. Also, four Pro Sensors and two Flex Sensors were used to measure muscle activity. The Svantek Vibration sensor was used to record vibrations given off from the bow and experienced on the hand of the archer. A GoPro was used to record the shooting sessions for further video analysis.

Participants:

A range of participants was used for the collection of data. This study had 15 participants. Due to some technical problems during the running of the study, only 12 participants data was used in the study. Three participants data was excluded from the study due to incomplete data gathering from all three data collection devices. All data from the 15 participants could be analyzed but was not always included in the comparison due to missing data and interference during the collection process. All participants were novices' archers when it came to the back-tension release (*Figure 3)*. Only two participants stated any prior knowledge of the workings of a back-tension release. About half of the participants had prior experience shooting archery, and a quarter had said they shot a compound bow like the one used in the study. Of the 15 participants, there was 14 male subjects and one female subject. The participants ranged in age from 18 years old to 51 years old. The range of draw length used by the participants was between 26 inches up to the maximum draw length by the bow 30 inches. All participants took somewhere between 45 minutes and an hour and a half to complete the study.

Experimental Procedure:

A subject performed one session of shooting. Upon arrival, the subject was provided a consent form to fill out and a ten-question survey. Once the appropriate paperwork was completed, the participant was instructed on the proper use of bow and each type of release. The instructions included the proper handling of the bow, how to knock an arrow, how to hold the bow, and how to draw the bow back and aim safely. The participant was trained and able to practice on a hand-held trainer (*Figure 4)* which will mimic the actions of the bow in a safe manner. The participant could practice with both types of releases until the participant felt confident to continue with the bow. The use of the trainer is to assist in safety while also reducing muscle fatigue upon the participants during practice.

Figure 4. Trigger Trainer

Before shooting the compound bow, the participant had surface EMG sensors placed on their muscles. The locations of the sensors were the trapezius muscle, deltoid, triceps, bicep, extensor digitorum, and flexor carpi radialis for a total of six surface EMG sensors.

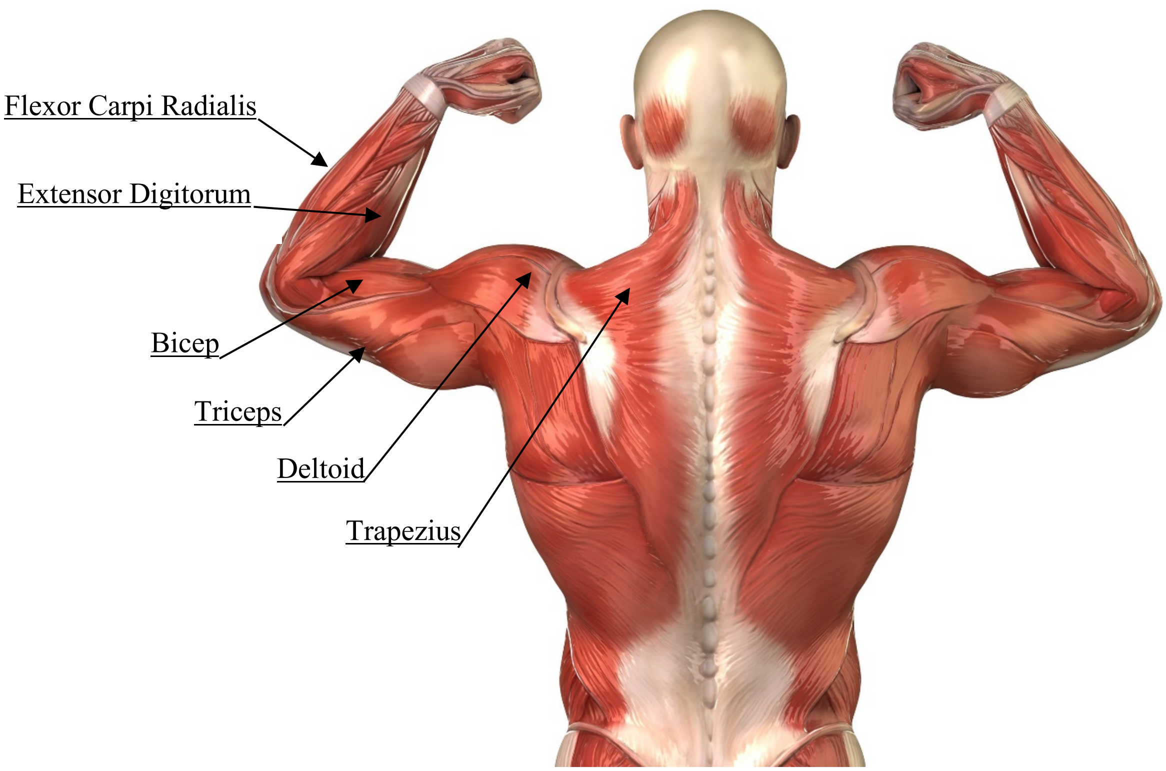


Figure 5. Human Musculature

The placement of all the sensors was on the bow arm of the participant, which for the present study was the participants left arm. The sensors were placed on the left arm due to the bow used in the study was a right-handed bow. With the placement of the sensors finished, maximum voluntary contractions (MVC) were taken from the individuals. The MVC was found through a range of static muscle movements which isolate the specified muscle. After each movement, the participant was given adequate rest time to regain strength. The number of times participants rested varied due to each participant need. With the completion of the MVC, the participant had one more sensor placed, the vibration sensor. The vibration sensor was positioned in the palm of the participants' bow hand. The vibration sensor would be in contact with the bow and the participant. With all sensors placed, the participant was handed the bow and allowed to shoot ten arrows at their own pace while being recorded. In *Figure. 6 & 7* it can be seen how the participant shoots each release with the sensors placed on their arms.

Figure 6. Shooting with the Trigger Release

Figure 7. Shooting with the Back-Tension Release

When finished shooting, the ten arrows the participant rested. The amount of rest each participant had was equivalent to the amount of time the researcher needed to reset for the next release and ten arrows. This time was a minimum of five minutes and the researcher offered the participant more time if the participant needed. After the rest time, the participants were asked if they would like to practice with the trainer for the next release before starting the next shooting session. If the participant did practice another two minutes of rest was given before the study continued. When the study continued, the participant again shot ten arrows with the remaining release, again shooting at their own pace. Upon completion of the shooting, the sensors were removed, and a post-survey was administered, and any remaining questions were answered. The participants were free to leave upon completion. The participant was advised to contact the researcher if any muscle fatigue or soreness occurred after the session.

Dependent Variable

- Time each participant releases an arrow
- The draw length of the bow

Independent Variable

- Back-Tension Release (experimental release)
- Trigger Release (control release)
- The Compound Bow
- The draw weight of the bow (42.5 lbs. +/- 2.5 lbs.)

For the study, the rotation of which release being used first by participants was rotated every two participants. This was to reduce the chances of fatigue skewing the results. Within-subject variability was used for the present study. This allowed for each subject to perform all the variables in the study. Because of diverse draw lengths by each participant, a different amount of vibration was experienced upon the bow arm.

RESULTS

Vibration Results

From the 15 participants who participated in the study the recording of the amount of vibration being experienced upon the arm was recorded. Each participant peak vibration was recorded for each type of release. It was found participants experienced 0.016 m/s^2 to 0.064 m/s^2 of force exerted upon there forearm during each shot. The likely reason for a range of vibration between 0.016 m/s^2 and 0.064 m/s^2 is due to the different draw length for each participant. Each participant had a draw length set specific to them with some participants having longer draw lengths and others having shorter. A small trend was noticed; the longer draw lengths have a slightly higher vibration. Participant 17 and Participant 18 vibration data were excluded due to the interference of collection due to improper contact with the participant and bow causing large vibration outliers.

FACS

Facial Action Coding System (FACS) is an analysis tool to see what emotions are occurring on an individual's face. Each participant's video recording was looked at for emotional responses while shooting using the FACS system. A certified individual in the FACS system analyzed the video for the emotions. Ekman six basic emotions were identified in the videos of the participants. In *Table 1* an X signifies if the emotion was found on the participant during the shooting session. The emotion of surprise was most often found during the shooting trials. The emotion of surprise was found 16 times in total for all of the participants. The emotion of surprise makes up about two-thirds of the emotions found in FACS. For the other one-third of the participants, emotion was not able to be identified. For one participant the emotion of surprise turned into disgust. Of the 16 times, surprise was present on the face of the participant

11 occurred while the participants were shooting with the back-tension release. Two-thirds of the time surprise is presence on the archer's face, they were shooting with the back-tension release.

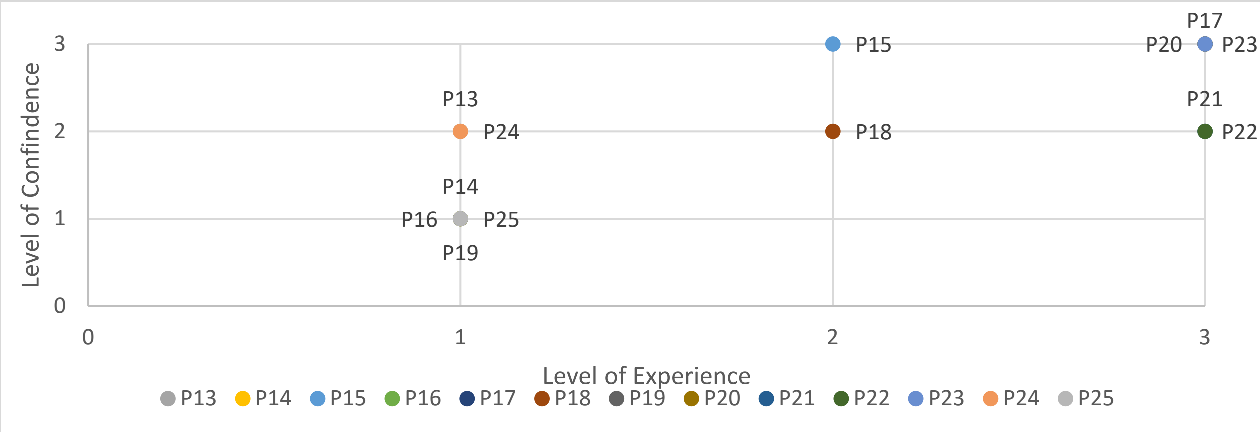
Table 1. FACS Scoring

	SCORE	Ekman Six Basic Emotions		
Participants	Surprise	Disgust	Sadness	Fear
P13 T				
P13 B	X	X		
P14 T				
P14 B	X			
P15 T	X			
P15 B	X			
P16 T	X			
P16 B	X			
P17 T	X			
P17 B	X			
P18 T				
P18 B	X			
P19 T	X			
P19 B				
P20 T				
P20 B	X			
P21 T				
P21 B	X			
P22 T	X			
P22 B	X			
P23 T				
P23 B	X			
P24 T				
P24 B	X			

Survey Results & Comments

All participants filled out a survey before and after the shooting session. The survey was given to gain information on how the individuals perceived they had performed during each shooting session and focused on the level of confidence the individual had compared to the amount of experience the individual had. This can be seen in *Table 2.*

Table 2. Perceived Confidence to Experience



Level of Confidence Scale	
Little	1
Moderate	2
High	3

Level of Experience Scale	
Once	1
Once a Year	2
Often	3

From *Table 1* it can be seen the more experienced individuals in shooting archery stated to have more confidence in their ability at the conclusion of the study. This was expected even with the study using all novices with the back-tension release. The most thought-provoking data collected from the survey was which release the participant found to more comfortable with and perceived to be more accurate with if given more time to practice of the 15 participants, one third stated they would be able to become more accurate of a shooter if they had time to practice with the back-tension release then if they had time to practice with the trigger release. This was an interesting conclusion when 12 out of the 15 participants stated they had no prior knowledge of the back-tension release or how to even go about shooting the release. It was noted in the field notes by the researcher conducting the study that it was simpler to train individuals who had no prior knowledge of archery to use the back-tension release then individuals who have experience shooting archery.

The last aspect found from the surveys was if the participants noticed the auditable clicking sound created by the back-tension release before shooting. This clicking sound was a warning the arrow was about to be released. From the results of the survey, it was found that only six of the participants did not notice the clicking sound from the release. But from the nine individuals who said they noticed the clicking sound, only four of them were able to make the connection the arrow was about to be released or found the noise to be helpful. The other five individuals who heard the clicking sound stated they did not find it to be beneficial.

Video & Electromyography (EMG) Analysis

The video data was synchronized to the timeline of the EMG. This synchronization was done through a video analyzing software to line up the timeline of the start of the EMG to the timeline of the EMG sensor being started in the video. The accuracy of this synchronization was able to be broken down to a single frame +/- one frame during the video recording. The video was broken down in minutes, seconds, and frames; it took 30 frames for each second, and it took six frames to change a single frame rate. This allowed for sufficient enough accuracy since it was found to take up to six frames for the arrow to leave complete contact with the bow. This synchronization allowed for the comparison of when the participating archer shoots the arrow to the muscle spike recorded by the EMG sensors in each muscle. Example of the timelines being synchronized can be seen in *Table 3* under the column Time Adjustment. In *Table 3* the recording of the specific times of each shot by the participant was recorded along with the amount of adjustment time needed for synchronization. The yellow highlighted section was notes of pre-shots meaning the bow was not fully drawn back. The red highlighted sections are areas where sensors were seen to be knocked off during the shooting. From *Table 3* it can be seen the exact timing of the release of the ten arrows. These times were converted to seconds and then compared to the muscle activation spikes found from the EMG.

The muscle activation spikes from a participant can be seen in *Table 4,* along with the graphs that go with the muscle spikes found from the EMG code. The table and graphs for the EMG were created from the metric of data collected from the sensors on the participant. The data was run through two filters to smooth out the data and reduce the noise that was picked up during recording. The commonly used 450 hertz and 20 hertz Butterworth filters were used. Then the smoothed-out data was plotted in a table with the muscle activity being on the y-axis and the time being on the x-axis. From the table, the peaks were identified and recorded as a data point which was then compiled into a table. For each trial, 15 peaks were recorded and then analyzed to find the ten true peaks caused by muscle activation. *Table 4* is of the time points that occurred at each muscle activation spike. In *Table 4* the start and end refer to the time when the participant first released, and the end refers to when the arrow is no longer in contact with the bow and cannot be affected by the participant. From the results of the video timing of the arrow, it was also found the amount of time it takes for the arrow to come completely of the bow. It was found that for the arrow to no longer to be in contact with the bow to be around six frames after the releasing of the arrow by the archer. This comes out to be about 0.022 seconds +/- 0.005 seconds.

In *Figure. 8* the muscle activity can be seen for the participant while the participant was shooting with the back-tension release. *Figure. 9* is the same but when the participant was shooting with the trigger release. In both *Figure. 8 & 9* there are six graphs each graph is correlated to the muscle activity of the muscle during each shooting trial. On each graph, it can be seen ten spikes of data the peaks of these spikes of data were recorded for the data points of the timing of the muscle activation. The data points then are compared to the timing that was found from the video analysis.

To compare the two times a simple if statement was used to create a binary structured table. This if statement simply stated if the occurrence of the muscle spike was picked up by the EMG sensor on the muscle occurred before or after the recorded time of the shot in the video.

Table 5 shows the statistical test results for a preparatory muscle activation occurring more often when shooting a trigger release rather than a back-tension release. A single sample t-test was used to compare the number of occurrences of a preparatory muscle activation before the releasing of the arrow within one participant shooting ten arrows at a time with each styles of releases. The number of times a muscle activation time stamp occurred before the time stamp, found from the video, of the participant releasing the arrow was counted. Then the total number of occurrences counted from the trigger release was compared to the total number of occurrences found with the back-tension release. The difference of the total trigger release occurrence to the back-tension release occurrence was taken for each participant. Then the mean of the differences was found for all the participants for each of the six muscle groups.

Table 3. Time Recoding of the first three shots of all the Participants

Participant #	Time adjustment	Shot 1		Shot 2		Shot 3		Shot 4		Shot 5	
		Start	End	Start	End	Start	End	Start	End	Start	End
P11 T	0.14.28	0.39.24		0.56.10		1.10.18		1.25.16		1.39.11	
P11 B	0.1.07	1.02.25	1.02.26	1.29.00	1.29.01	2.04.26	2.04.27	2.26.23	2.26.24	2.52.23	2.52.24
P12 T											
P12 B											
P13 T	0.6.23	0.45.00	0.45.01	1.02.05	1.02.06	1.18.01	1.18.02	1.43.00	1.43.01	2.01.19	2.01.20
P13 B	6.18.14	6.56.08	6.56.09	7.20.02	7.20.03	7.40.17	7.40.18	8.03.13	8.03.14	8.24.06	8.24.07
P14 T	0.12.16	0.34.15	0.34.16	0.49.16	0.49.17	1.01.18	1.01.19	1.17.07	1.17.08	1.31.22	1.31.23
P14 B	5.29.15	5.55.01	5.55.02	6.26.28	6.26.29	6.47.03	6.47.04	7.05.24	7.05.25	7.26.04	7.26.06
P15 T	0.08.12	0.22.19	0.22.21	0.33.48	0.33.50	0.45.27	0.45.29	0.57.26	0.57.28	1.09.58	1.10.00
P15 B	0.07.22	0.34.57	0.34.58	0.51.57	0.51.58	1.11.50	1.11.51	1.30.27	1.30.29	1.51.42	1.51.44
P16 T	0.08.25	0.28.27	0.28.29	0.44.50	0.44.52	1.23.37	1.23.38	1.44.24	1.44.26	2.04.45	2.04.46
P16 B	0.09.57	0.42.18	0.42.20	1.02.40	1.02.42	1.19.43	1.19.45	2.33.24	2.33.26	2.51.37	2.51.39
P17 T	0.08.16	0.21.35	0.21.37	0.50.01	0.50.03	1.12.17	1.12.19	1.36.31	1.36.33	1.58.27	1.58.29
P17 B	0.04.38	0.45.36	0.45.38	1.28.08	1.28.10	2.04.06	2.04.08	2.27.21	2.27.23	2.47.37	2.47.39
P18 T	0.14.05	0.28.25		0.52.09		1.08.06		1.23.15		1.42.17	
P18 B	0.07.09	0.20.04		0.36.20		0.55.04		1.13.00		1.45.17	
P19 T	0.15.12	0.43.18		1.09.18		1.30.20		1.47.04		2.04.20	
P19 B	5.58.08	6.07.15		6.26.25		6.47.18		7.07.12		7.26.13	
P20 T	0.37.05	2.03.22	2.03.23	2.25.07	2.025.07	2.53.19	2.53.20	3.11.26	3.11.27	3.43.18	3.43.19
P20 B	6.26.25	7.04.24	7.04.25	7.43.01	7.43.01	8.29.09	8.29.09	9.18.24	9.18.24	9.53.14	9.53.15
P21 T	0.02.20	0.25.00		0.42.23		0.59.15		1.13.06		1.27.24	
P21 B	0.16.08	0.41.29		1.22.06		1.50.08		2.12.29		2.34.25	
P22 T	0.07.04	0.22.15	0.22.16	0.41.09	0.41.10	1.00.08	1.00.09	1.13.08	1.013.09	1.29.07	1.29.08
P22 B	0.07.11	0.25.13	0.25.13	0.41.29	0.42.00	1.00.17	1.00.17	1.15.28	1.15.29	1.31.23	1.31.24
P23 T	1.18.00	1.40.19	1.40.19	1.57.29	1.58.00	2.14.23	2.14.24	2.32.03	2.32.03	2.46.04	2.46.05

Table 3. Continued.

Participant #	Time adjustment	Shot 6		Shot 7		Shot 8		Shot 9		Shot 10	
		Start	End	Start	End	Start	End	Start	End	Start	End
P11 T	0.14.28	1.51.54		2.08.20		2.23.13		2.37.10		2.50.16	
P11 B	0.1.07	3.21.10	3.21.11	3.46.05	3.46.06	4.08.23	4.08.24	4.33.12	4.33.13	4.56.08	4.56.09
P12 T											
P12 B											
P13 T	0.6.23	2.13.19	2.13.20	2.27.02	2.27.03	2.39.22	2.39.23	2.50.21	2.50.22	3.07.05	3.07.06
P13 B	6.18.14	8.38.18	8.38.19								
P14 T	0.12.16	1.42.29	1.43.00	1.56.21	1.56.22	2.09.27	2.09.28	2.21.16	2.21.17	2.32.28	2.32.29
P14 B	5.29.15	7.42.16	7.42.17	7.59.09	7.59.10	8.13.01	8.13.02	8.28.00	8.28.01	8.41.09	8.41.10
P15 T	0.08.12	1.23.56	1.23.58	1.39.17	1.39.18	1.48.54	1.48.56	1.59.42	1.59.44	2.10.32	2.10.34
P15 B	0.07.22	2.06.41	2.06.43	2.21.30	2.21.31	2.44.19	2.44.20	3.06.14	3.06.15	3.26.22	3.26.23
P16 T	0.08.25	2.22.57	2.22.59	2.39.08	2.39.10	2.54.46	2.54.48	3.15.27	3.15.28	3.34.28	3.34.30
P16 B	0.09.57	3.10.40	3.10.41	3.31.33	3.31.35	3.51.07	3.51.08	4.08.24	4.08.26	4.22.42	4.22.44
P17 T	0.08.16	2.19.52	2.19.54	2.39.27	2.39.29	3.14.18	3.14.20	3.34.44	3.34.46	3.51.26	3.51.28
P17 B	0.04.38	3.02.17	3.02.19	3.20.15	3.20.17	3.37.51	3.37.53	3.57.26	3.57.28	4.11.51	4.11.53
P18 T	0.14.05	1.57.25		2.18.27		2.35.10		2.50.28		3.06.10	
P18 B	0.07.09	2.11.23		2.31.03		3.03.03		3.51.11		4.19.07	
P19 T	0.15.12	2.19.23		2.35.14		2.51.14		3.06.28		3.23.25	
P19 B	5.58.08	7.43.22		8.01.03		8.18.14		8.38.03		8.56.00	
P20 T	0.37.05	4.06.09	4.06.10	4.40.05	4.40.06	5.29.19	5.29.20	5.58.21	5.58.22	6.15.15	6.15.16
P20 B	6.26.25	10.54.19	10.54.20	11.38.19	11.38.20	12.38.14	12.34.15	13.11.14	13.11.15	13.51.11	13.51.12
P21 T	0.02.20	1.41.17		1.54.12		2.07.10		2.23.18		2.37.04	
P21 B	0.16.08	3.04.04		3.21.22		3.41.17		3.59.19		4.17.25	
P22 T	0.07.04	1.47.00	1.47.01	2.03.09	2.03.10	2.21.02	2.21.03	2.39.02	2.39.03	2.57.25	2.57.26
P22 B	0.07.11	1.50.29	1.51.00	2.07.11	2.07.12	2.23.23	2.23.24	2.38.16	2.38.17	2.55.00	2.55.01
P23 T	1.18.00	3.25.27	3.25.28	3.55.09	3.55.10	4.19.05	4.19.06	4.40.02	4.40.03	5.03.21	5.03.22

Table 4. Participant 11 Muscle Spikes

P11 B	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7	Shot 8	Shot 9	Shot 10
	48.31006	72.5918	107.8638	129.8877	155.833	184.4648	209.8677	232.9438	257.2192	280.2676
	46.15332	72.45508	108.0488	130.1348	155.5542	184.7676	209.208	232.7729	256.9004	281.7441
	45.08057	71.78662	107.8706	128.5239	155.9624	184.0708	210.0542	233.1162	257.4233	280.2124
	48.88428	75.06836	110.0205	132.2856	158.4722	186.8135	211.7881	234.165	258.8491	281.0215
	49.04248	75.11133	110.3008	132.2197	158.2905	186.8989	211.6377	234.1841	258.8423	282.6626
	48.28662	74.47314	110.3105	132.2168	158.2349	187.3101	211.6323	234.1812	258.8491	281.748
P11 T	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6	Shot 7	Shot 8	Shot 9	Shot 10
	21.71387	39.10889	53.14307	68.53467	82.85107	95.16211	111.2104	126.2593	140.792	153.9668
	21.57617	39.04248	52.94287	68.81592	82.59131	95.07813	111.8076	125.978	140.4829	153.9707
	21.63281	38.50195	53.0332	68.1084	82.53027	94.99121	111.6543	125.7915	140.6118	154.1396
	24.68848	41.70361	56.27881	71.42969	85.09131	97.25781	114.5542	126.8091	142.6377	154.4463
	25.23438	41.73145	55.92773	70.87207	84.771	97.16504	113.9692	123.8745	148.5913	158.7886
	25.18848	42.36084	52.41846	62.86328	75.47705	85.59033	115.1045	129.3438	143.3965	155.8784

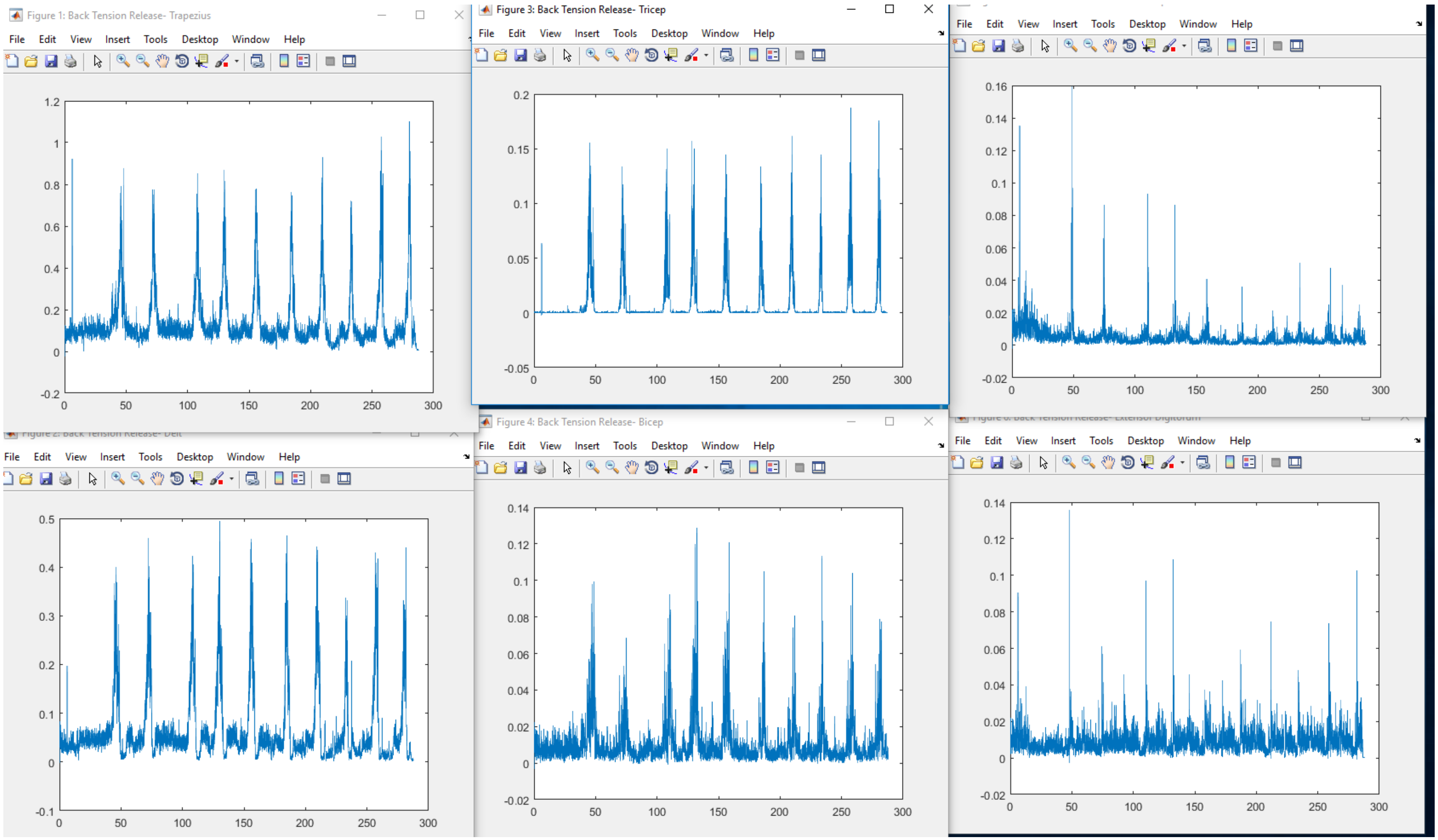


Figure 8. Back-Tension EMG Muscle Graph Spike

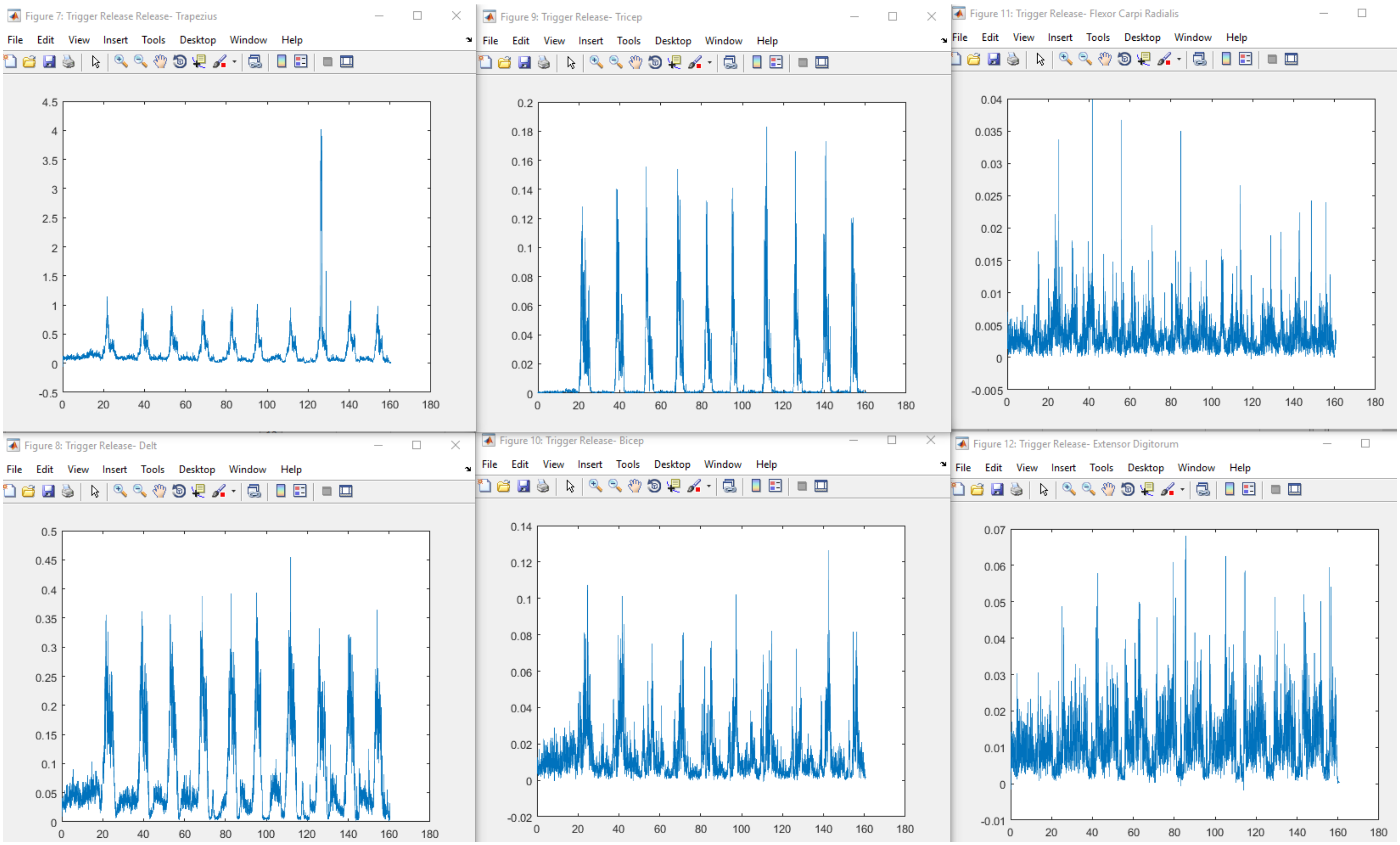


Figure 9. Trigger Release EMG Muscle Graph Spike

Table 5. Statistical Analysis of Significance of Preparatory bracing

Trapezius Muscle		**Deltoid Muscle**	
SD	1.66	SD	2.45
t	1.63	t	0.368
p	0.066	p	0.36
Mean of Difference of Occurrence	-0.818	Mean of Difference of Occurrence	0.727
Diffence between Trigger vs Back	+	Diffence between Trigger vs Back	-
Triceps Muscle		**Biceps Muscle**	
SD	2.44	SD	3.77
t	2.25	t	1.42
p	0.023	p	0.092
Mean of Difference of Occurrence	0.272	Mean of Difference of Occurrence	1.27
Difference between Trigger vs Back	-	Difference between Trigger vs Back	-
Flexor Muscle		**Extensor Muscle**	
SD	3.31	SD	4.1
t	3.12	t	2.82
p	0.005	p	0.008
Mean of Difference of Occurrence	-0.636	Mean of Difference of Occurrence	1.72
Difference between Trigger vs Back	+	Difference between Trigger vs Back	-

The sample standard deviation was found from the difference of the occurrence found within each participant for each of the muscle groups. With the sample standard deviation, the standard error was able to be calculated with the number of participants. It was assumed the difference between the two release would be zero, meaning there will be the same number of occurrences of preparatory muscle activation for both releases. With the Standard Deviation (SD) and Standard Error (SE), a t-value was able to be calculated. With the t-value found a single tailed t-test was able to be run on the t-value and the number of participants to find the p-value which identifies significances of the trigger release having more preparatory muscle occurrences than the back-tension release for the specific muscle. To know which way the muscle showed significances the direction of the mean difference of occurrences was recorded. If the direction is positive is stating, there were more occurrences of preparatory muscle activation in the trigger release than in the back-tension release.

The table shows the flexor carpi radius shows significances in a preparatory muscle activation only occurring in participants when shooting with the trigger release. The trapezius muscle also shows significance in a preparatory muscle activation occurring more often in the trigger release. The implication of the trapezius muscle being significant tells us the archer is using much of the trapezius muscles to hold and aim the bow and then with the insertion of a surprise factor the archer no longer can unintentionally brace up for the releasing of the arrow being fired. For the triceps and extensor muscle, preparator muscle activation is significant when the participant is shooting with the back-tension release. This is likely due to the participant recruiting those muscle to help shoot the release. If the extensor and trapezius muscle are being recruited, it means the archer is pulling the bow away and to the left to activate the back-tension release. This is likely to do with inexperience in being able to fire the back-tension release in proper form. The bicep can also be seen trending in the same direction with a 0.09 p-value. The deltoid muscle is the only muscle that showed no significance either way.

DISCUSSION

Results Analysis

The knowledge gained from this research is the presence of a preparatory muscle response when firing a bow due to an impact to the bow hand via vibrations given off during shooting. When shooting the bow, there is a vibration the bow gives off due to the tension the string is placing on the bow when firing. The vibration can be felt in the archer's arm at the moment of releasing the arrow which was found with the use of the vibration sensor. The archer will experience a magnitude of impact force on the bow arm while the bow arm is also trying to hold the bow static for aiming the shot. This means the bow arm muscles are already active and then trying to compensate for a vibration impact upon releasing of the arrow. This result leads us to look at the EMG and Video to see if the bow arm experiences a preparatory response due to the vibrations of shooting the bow.

The findings from the EMG showed either before or after ever shot by ever participant; there was a spike in muscle activation. To find whether those muscle spikes occur specifically before or after the video was analyzed for time. The back-tension release makes a claim the archer no longer knows the exact timing when they are shooting the arrow, adding a surprise factor to archery. With this idea, the new release would release an arrow before a spike of muscle activity in the bow arm. This was not the case when comparing to the trigger release to the back-tension release. It was found only two muscles, the trapezius and flexor carpi radials had statistical significance in the occurrence of being activated after the releasing the arrow. The activation of the muscle after the shot with the back-tension release proves the back-tension release added enough element of surprise to move the preparatory bracing effect found when shooting the trigger release to after the releasing of the arrow with the back-tension release.

While in the triceps and extensor muscle show statistical significance of preparatory muscle activity with the back-tension release before releasing of the arrow. This likely has to do with the way an archer has to shoot the back-tension release without having much prior knowledge. This activation occurs because the archer is pushing the bow away with their triceps and extensor muscle to aid in the ability to gain the desired tension to shoot the release. While the triceps and extensor muscle are firing, it was also found the bicep muscle was trending towards activation before the release of the arrow. This makes sense in the case the bicep is applying an antagonist muscle motion to aid in the stabilization of the two-muscle moving in extension. For the deltoid muscle, it was found to be of no significant preparatory muscle activity for either type of release. This is likely to do with the arm being in an abducted state to hold the bow in place to aim while shooting. The conclusion from this is the use of a back-tension release with novice archers does not significantly mitigate the preparatory response in all of the muscle used to shoot archery.

The results of this FACS system allows for the connection of a physical stimulus the bow is creating on the human to be connected to a cognitive emotion. An interesting find was from the FACS analysis the experimental back-tension release did induce the emotion surprise. The occurrence of surprise is present in two-thirds of the emotions recorded and of those two-thirds of participant two-thirds again were shooting with the back-tension release supporting the claim the back-tension release did induce surprise into archery even when the muscle reading from the EMG and Video analysis showed no overall significant in all the muscle between the experimental back-tension release and the control trigger release.

Implications

The implication of this research will aid in the design of future products. This study has helped in gaining the knowledge of how new future technology can be built to improve the shooting ability in archery. With the understanding of a preparatory muscle activation upon releasing the arrow and the emotion of surprise being found through the FACS system, a new release can be designed to better aid in the surprise factor the current back-tension release is doing. A new product can be developed to more biomechanically aid physically and mentally in the performance of shooting archery by introducing the cognitive aspect of surprise with a device that physically takes away the ability to fire. This type of product would only be able to be applied in a competition or hobby setting, but it would likely improve upon the accuracy and precision of the archer.

Along with improving the release mechanism of archery a new compound bow can be designed which absorbs more or displaces the impact vibrations experienced upon the archer during shooting. This improvement will make the bow more ergonomically friendly by being less strenuous upon the archer during the shooting process. If a bow is less strenuous to the archer, it would likely lower the probability of an archer bracing for the vibrations coming off the bow.

Some other implications are the knowledge and understanding of the capabilities of the human arm biomechanics, and the connection between a physical stimulus to the cognitive state due to the effect of the technology being used can be correlated to other tools. The compound bow is a perfect comparison tool to represent any device that needs the muscles in the arm to be held in static to aim. Then upon releasing, an impact was applied to the arm while the muscle was already activated. The understanding found in the research of how the muscles work when already under stress and more stimulus was applied can be tied to many other types of tools that require a static hold during aiming then firing or releasing which induce an impact to the arm.

In the present study, it was tested to see if the introduction of another technology for releasing or firing was introduced could mitigate the preparatory muscle activation the human experiences before the releasing or firing. The new technology added a surprise factor when aiming which was found to be present on participants faces but did not seem to have a major effect upon the preparatory muscle activation. This idea of adding another new technology to aid in existing technology can be incorporated into new product design. Rather than completely redesigning existing technology adding another device might be enough to mitigate the unwanted side effects being caused.

Future Work

In the future, the use of participants who are considered experts in archery with both types of releases would be tested. Also, in future research, three identical looking back-tension releases would be used with each set to go off at a different time. The three releases would then be randomly grabbed by the participants between each shot to reduce any learning of the timing of releasing the arrow. The specific amount of time that occurs between the muscle activity and the shot timing would be looked at to see if some significance was present. Other future work could look into the types of bows on the market to identify which one applies the smallest vibration upon the human's arm and how can those vibrations be reduced in the design of the bow.

REFERENCES:

Brettingen, B. (2014) A Case For Back Tension Release, In Depth Outdoors, Retrieved from https://www.in-depthoutdoors.com/magazine/october-magazine/case-back-tension-releases/

Callaway, A.J., & Mario Heller, M., & Wiedlack, J. (2017) Identification of temporal factors related to shot performance for indoor recurve archery, Journal of Sports Sciences, 35:12, 1142-1147, DOI: 10.1080/02640414.2016.1211730

Ekman, P. (1992). Are there basic emotions? *Psychological Review, 99*(3), 550-553. doi:10.1037/0033-295X.99.3.550

Ertan, H., & Kentel, B., & Korkusuz, F. & Tümer, S.T. (2003) Activation patterns in forearm muscles during archery shooting. Human Movement Science, 22.

Ertan, H., & Knicker, A.J., & Soylu, R.U., & Strüder, H.K. (2011) Individual Variation of Bowstring Release in High Level Archery: A comparative Case Study. Human Movement, 22(3), 273-276, DOI: 10.2478/v10038-011-0030-x

Ganter, N., & Matyschiok, K.C., & Partie, M., & Tesch, B., & Edelmann-Nusser, J. (2010) Comparing three methods for measuring the movement of the bow in the aiming phase of Olympic Archery. Procedia Engineering, 2, 3089-3094

HWANG, C.H., & Lin, K.B. (2005) Analysis of Correlation Between Aiming Adjustment Trajectory and Target. Journal of Mechanics in Medicine and Biology, 5(2), 253-259.

Igor Zaniewski. (2012). Recoil and Vibration in an Archery Bow Equipped with a Multi-Rod Stabilizer. *Shock and Vibration, 19*(2), 235-250.

Krutky, Matthew A, Vengateswaran J Ravichandran, Randy D Trumbower, and Eric J Perreault. (2010). "Interactions between Limb and Environmental Mechanics Influence Stretch Reflex Sensitivity in the Human Arm." *Journal of Neurophysiology* 103.1, 429-40. Web.

Lombard, M. (2011). Quartz-tipped arrows older than 60 ka: Further use-trace evidence from Sibudu, KwaZulu-Natal, South Africa. Journal of Archaeological Science, 38(8), 1918-1930.

Sanes, J. N., & Evarts, E. V. (1983). Effects of perturbations on accuracy of arm movements. Journal of Neuroscience, 3(5), 977-986.

Schnieders, Thomas, M. Stone, Richard Oviatt, and T. Danford-Klein. (2017). "ARCTiC LawE: An Upper-Body Exoskeleton for Firearm Training." Augmented Human Research 2.1, 1-10. Web.

Stone, R. T. (2007). The Biomechanical and Physiological link between Archery Techniques and Performance. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 51(18), 1227–1231. https://doi.org/10.1177/154193120705101837

Thuring, M., Mahike, S., & Thuering, M. (2007). Usability, aesthetics and emotions in human-technology interaction. International Journal Of Psychology, 42(4), 253-264.

Tinazci, C. (2011) Shooting Dynamics in Archery: A Multidimensional Analysis from Drawing to Releasing in Male Archers. Procedia Engineering, 13, 290-296

APPENDIX IRB APROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible
Research Vice President for
Research 2420 Lincoln Way,
Suite 202 Ames, Iowa 50014
515 294-4566

Date: 03/11/2019

To: Hunter Sabers   Richard T Stone

From: Office for Responsible Research

Title: **Archery Performance Shooting**

IRB ID: **18-490**

Submission Type: Initial Submission   **Review Type**: Full Committee

Approval Date: 03/11/2019   **Approval Expiration Date: 03/10/2022**

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, including the **recruitment materials and informed consent documents that have the IRB approval stamp**.
- Retain signed informed consent documents **for 3 years after the close of the study,** when documented consent is required**.**
- **Obtain IRB approval prior to implementing any changes** to the study or study materials.
- **Promptly inform the IRB of any addition of or change in federal funding for this study.** Approval of the protocol referenced above applies only to funding sources that are specifically identified in the corresponding IRB application.
- **Inform the IRB if the Principal Investigator and/or Supervising Investigator end their role or involvement with the project** with sufficient time to allow an alternate PI/Supervising Investigator

to assume oversight responsibility. Projects must have an eligible PI to remain open.

- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.

- IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g., student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

- Your research study may be subject to **post-approval monitoring by Iowa State University's Office for Responsible Research**. In some cases, it may also be subject to formal audit or inspection by federal agencies and study sponsors.

- Upon completion of the project, transfer of IRB oversight to another IRB, or departure of the PI and/or Supervising Investigator, please initiate a Project Closure to officially close the project. For information on instances when a study may be closed, please refer to the IRB Study Closure Policy.

If your study requires continuing review, indicated by a specific Approval Expiration Date above, you should:

- **Stop all human subjects research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Human subjects research activity can resume once IRB approval is re-established.

- **Submit an application for Continuing Review** at least three to four weeks prior to the **Approval Expiration Date** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.